

Chapter 2

Background on Vegetation Classification Systems

Introduction

Vegetation is formed by plant species growing as the result of a long development process consistent with the places they inhabit and which constitutes a fundamental part of ecosystems. As a result, vegetation is understood as resulting from the effects of various environmental factors on sets of species which cohabit in a determined space and period (Velázquez and Romero 1999; FGDC 2005). Generally speaking, two major categories can be seen: cultural vegetation and natural vegetation. The former owes its development, permanence, and expression to processes regulated by the continuous activity of mankind, for example agricultural areas and planted forests, which are a relatively recent expression (to the order of decades and centuries). Natural vegetation, by contrast, is underlain by processes in the main determined by climatic, geomorphological, edaphic, and ecological components, which interact simultaneously and continuously over extended periods of time (to the order of hundreds to thousands of years). As the effects of human actions have become more evident, it has become increasingly difficult to determine the limits between natural and cultural vegetation, though international agreements exist which allow for the understanding of irrefutable predominance. Profound knowledge of vegetation in general, the directional forces determining its presence notwithstanding, is fundamental for multiple purposes as much locally as globally, particularly in terms of better vegetation management and conservation (Matteucci and Colma 1982; FGDC 2005).

This chapter serves as a brief description of the diversity and approaches fundamental to various vegetation classification systems employed at the global level and forming the backdrop against which the main expressions used in Mexico and the systems most highly regarded and employed in research and in the management of natural resources in the country are described. It should be mentioned that there exist different vegetation classification system proposals for Mexico, and the first

question is whether, in reality, it was necessary to write this chapter. The arguments for its inclusion in this present work are explained in the following paragraphs.

The abundant terminology existing in vegetation research materials reflects, in part, the physiognomic–structural–floristic complexity of vegetation communities found in Mexico. Moreover, there is interest in the need to recognize the heterogeneity of the vegetation and of its typification through the names characterizing it. In general, the prevalent initiatives have been those concerned with local demands, from which, when the need arises to extrapolate to the macroregional and national levels, conflict arises from the lack of compatibility in the criteria used in creating classifications and nomenclature. Equally, confusion is generated by a plethora of recurring synonyms. Faced with such circumstances, it is difficult or well-nigh impossible to use local information, as plentiful as it may be, to integrate data for analysis at the national level or even to make comparisons between regions sharing common characteristics (Huber and Riina 2003). The proposals covering the most territory and most commonly used among academics are not free of inconsistencies and synonyms, thus contributing to the prevailing entropy surrounding the Mexican vegetation classification system (González-Medrano 2003). Despite multiple efforts, there is still no generally accepted compatible, hierarchical standardized system in Mexico.

Research into plant species populations (autophytoecology) can dispense with relying on a single standardized, hierarchical system for vegetation in Mexico. On the contrary, for research on vegetation communities (synphytoecology), it is fundamental to identify the unit of research, and it is here where terms such as —vegetation type||, —plant community||, and —vegetation association|| are used time and again with different connotations and generally applied in different ways across various regions and between academics, resource managers, and local data collectors. Currently, with the boom in remote sensing sources and the availability of spatially explicit databases handling geographic information systems, synphytoecological studies have become even more complex. On the one hand, no clear unit of research applies from the purely vegetational point of view, where plant species aggregates are the —unit||, whereas from the purely spatially explicit point of view, land cover classes are solely recognized as the —unit|| (Velázquez et al. 2006). This ambiguity makes for difficulties when it comes to planning systemized research, natural resource management, or conservation strategic planning and work, in fact, ultimately, in taking any action within the scope of conserving environmental goods and services (Carabias and Landa 2006). Global, national and local policy-makers dealing with natural resource management need to be provided with sound, irrefutable units describing vegetation as a basis for policy-making.

Multiple examples illustrate the necessity of relying on a single classification system in Mexico, as in most countries worldwide and on its corresponding syntaxonomy and nomenclature. For the study of vegetation *sensu stricto*, it is fundamental to understand its spatial distribution and to derive conclusions from it, which conclusions can then be applied beyond the sample conditions. This task is currently impossible in Mexico given that the majority of vegetation studies, with very few exceptions, do not present complete floristic lists, whereas the remaining

show the preserve of taxonomic interest groups or are limited by the accessibility of the sampling area (Bojórquez-Tapia et al. 1995). For a greatly diverse country possessing such a geological heritage, it would be desirable to rely on databases which include, taxonomically speaking, a high proportion of all species within the country. Examples of systematic vegetation databases in general permit descriptions of habitat conditions and of entire continents such as Europe or complete countries of enormous territorial proportion and diversity such as Canada and Colombia, which prioritize their research needs based on —spaces|| or —types of vegetation|| not yet thoroughly researched (<http://europa.eu/scadplus/leg/nl/vb/128076.html>).

The best-known defenders of natural vegetation are mostly from the biological sciences guild (ecologists, agronomist, foresters, and geographers, among others). Mexico is no exception, and, in all cases, the ecosystemic vision predominates as the framework for sustainability. The great challenge lies in the lack of a single inventory of ecosystems in Mexico. Thus, vegetation tends to be fallen back on as a substitute. At the same time, the territorial expression of ecosystems is subordinated to plant cover. The vegetation as much as the land cover, however, lacks a rigorous inventory. For example, in the following table, a comparison is made over a 24-year period. The loss or gain value for a category of plant cover therefore depends on its definition and eventually on its territorial expression, a task in which a single classification system would be of enormous assistance in terms of reducing incongruence (Table 2.1).

Each block shows that there are different data and demonstrates the importance of relying on a vegetation classification system which permits losses and gains in each category to be measured (Velázquez et al. 2002).

In contrast to common practice across most of Europe, where the phytosociological classification system has been widely adopted in naming most plant communities, on the American continent the lack of consensus on establishing one or various vegetation classification systems is notable. Over a decade ago, a group of vegetation researchers set out to create an international classification of ecological communities for the terrestrial vegetation of Canada and the United States, and now, more than 10 years later, the creation of an international vegetation

Table 2.1 The area covered by a plant formation measured at two different times allows the rate of change and net loss per year to be calculated

Plant formation	t ¹ (1976) km ²	t ³ (2000) km ²	Rate r	Net (Ha/year)
Forest	352,117	327,810	−0.003	−40,708
Jungles	378,367	307,207	−0.009	−111,106
Shrubs	604,933	557,089	−0.003	−79,687
Forest and jungles	730,484	635,027	−0.006	−154,391
Woody vegetation	1,335,417	962,422	−0.014	−547,288

If plant formation aggregation changes, so it does the rate, hence precise definition on what to compare with what reveals critical for understanding vegetation trends (Source Velázquez et al. 2010a)

classification panel has been initiated on the continent of which Mexico forms part. The proposal put forward by this commission is not to create a unified vegetation classification system, but rather to propose systems which maintain a consensual platform with the aim of facilitating communication as well as research on the subject (FGDC 2008).

In Mexico, despite the information amassed on the characteristics and composition of different vegetation units from the local through regional levels, there is still not a hierarchical and standardized vegetation classification system, which is consistent with the criteria and levels seen in North America and in the rest of the world and which includes the benefits of previous proposals, such that it might become widely used both by academics and by those responsible for the management of natural resources. In this chapter, background on various classification systems and approaches to classification having affected Mexico are presented. In the following chapters, a proposal outlining the fundamentals of a better classification system for vegetation types in Mexico is developed in detail. It aims for the production of maps and legends detailing plant cover on different scales, for the deepening of knowledge on the plants of Mexico and the generation of information leading to the creation of botanical research strategies applied to the better management and conservation of natural resources.

Broad-Scope Vision Classification Systems

Throughout the centuries, the study of vegetation classification has been an ongoing activity. To speak of vegetation classification systems means describing as many classifications as there are authors on the subject. Arising from diverse contexts, many approaches and schools have sprung up, all working towards the same goal—the development of vegetation classification systems—and all born as a response to the problems presented by different regions of the planet (Whittaker 1962). In this context, Huber and Riina (2003), for example, cite 3,500 traditional phytoecological terms used in Mexico, Central America, and on the islands of the Caribbean, showing the breadth of the reference framework generated by the physiognomic–structural–floristic complexity of plant communities across the region.

Among the first plant community classifications is found Humboldt's —*Hauptformen*|| (1806) used by Grisebach 30 years later in the sense of —*Formations*|| to denote physiognomic characteristics in vegetation. Originally, these formations made reference to a uniformity in their dominant biological spectra and made it possible to make comparisons among distinct biogeographical regions. A century later, at the third International Botanical Congress held at Brussels in 1910, the concept of —plant formation|| was proposed as an expression of determined conditions for life (Table 2.2).

For their part, Holdridge et al. (1971) propose that —life zones|| on the planet can be classified through the analysis of vegetation and from some basic climatic data—that is to say that the physiographic conditions of the land, the complexities

Table 2.2 Correspondence between distinct climatic and bioclimatic criteria determining the principal plant formations globally

Plant group (De Candolle)	Postulated plant requirements	Formation	Köppen climate class
Megatherms	Continuous high temperature and abundant moisture	Tropical rain forest	A (tropical rainy climates)
Xerophiles	Drought and heat tolerant	Tropical desert	B (dry climates)
Mesotherms	Moderate temperature and moisture	Temperate deciduous forest	C (warm temperate climates)
Microtherms	Less heat and moisture, tolerate long cold winters	Boreal forest	D (snowy-forest climates)
Hekistotherms	Tolerant of conditions beyond the tree line	Tundra	E (polar climates)

Translated from Archibold (1995: 2)

of the soil and the plant communities together with the animal component are fundamentally subordinated to the macroclimate. This method divides the earth’s macroclimates into over 100 ecologically equivalent units, with each unit representing a sector of the climatic continuum and hosting a certain set of plant associations (Fig. 2.1).

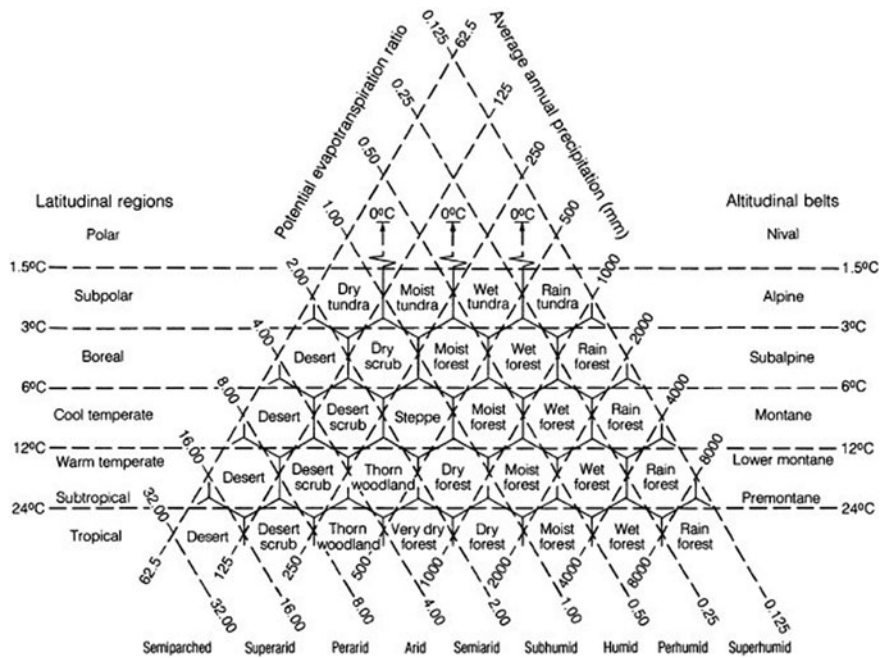


Fig. 2.1 Diagram of life-zone classifications or world plant formations according to Holdridge (1967) (taken from Archibold 1995: 3)

Table 2.3 General summary of the thermal limits of the principal types of climate in Mexico (García 2004)

Humid climates	Symbols	Mean annual temperature
Hot	A	Above 22 °C
Semi-warm	A(C); (A)C	Between 18 and 22 °C; above 18 °C
Temperate	Ca; Cb	Between 12 and 18 °C
Semi-cold	C(b') Cc	Between 5 and 12 °C
Cold	E(T) C	Between -2 and 5 °C
Very cold	EF	Below -2 °C
Arid climates	Symbols	Mean annual temperature
Hot	B(h')	Above 22 °C
Semi-warm	Bh'(h); Bh	Between 18 and 22 °C
Temperate	Bk; Bk'	Between 12 and 18 °C
Semi-cold	B(k'')	Between 5 and 12 °C

From the climatic perspective, García (2004) lays out for Mexico a series of modifications to Köppen's classification referring to temperature (Table 2.3), in which she identifies two large groups—humid and arid. The first group is divided into five thermal categories, with the second divided into four. The use of climatic information has been constant as much for defining plant formations as for their typification and nomenclature.

The first plant classifications from the floristic approaches applied at a global level were based on —floristic kingdoms||, taking into account the differences between the continents as per their particular formation. In this sense, Good (1953) defined six floristic empires or kingdoms in the following manner:

- (I) Boreal (North Temperate Zone)
- (II) Paleotropical (tropical zones in the Old World) subdivided into: (a) *African*, (b) *Indomalayan*, and (c) *Polynesian*
- (III) Neotropical (tropics in the Americas)
- (IV) Southern Africa (with the exception of the Cape region of South Africa, which is home to exceptional flora)
- (V) Australian (the most isolated)
- (VI) Antarctic (including the South African cape and islands such as those of New Zealand).

Riley and Young's classic work (1966) also defined from an ecogeographic perspective eight types of plant formations: (1) *deciduous forests*, (2) *coniferous forests*, (3) *rain forests*, (4) *grassland*, (5) *savannas*, (6) *arid zone vegetation*, (7) *tundra and alpine vegetation*, and (8) *coastal and freshwater vegetation*. Using the same approach, Takhtajan (1986) establishes floristic kingdoms, regions, provinces, sectors, districts, and tesserae. Later, Dinerstein et al. (1995) divided the world into five ecosystems and 200 ecoregions further divided into distinct ecodistricts and ecosections.

Table 2.4 Classes and leaf measurements from Raunkiaer (Raunkiaer’s modification 1934)

Class	Designation	Size (mm ²)	Measurement proposed for Mexico (mm ²)
1	Leptophyll	0–25	0–25
2	Nanophyll	25–225	25–125
3	Microphyll	225–2,025	125–625
4	Mesophyll	2025–18,225	625–3,125
5	Macrophyll	18,225–164,025	3,125–15,625
6	Megaphyll	>164,025	>15,625

Olson et al. (2001) proposed 867 terrestrial ecoregions, classified into 14 different biomes.

Physiognomic approaches to the classification of plant communities are developed by emphasizing the external appearance of the plants in their totality to indicate an adaptive connotation. A predecessor to many of these proposals was Raunkiaer’s —*Life forms*|| (1934), which was based on the bud position and established five main categories (phanerophytic, camephytic, hemicryptophytic, cryptophytic, and terophytic), which permitted comparisons of the plant composition differentials in the major ecosystems of the world, and which also, in an attempt to facilitate statistical research on the communities, established six classes of leaf size (Table 2.4), relating longitude and leaf area to the climate even where the structure of the floristic composition differed widely (see Granados and Tapia 1990).

The specialization processes seen throughout the nineteenth and twentieth centuries motivated the development of proposals, which, though more specialized, were based on data from particular regions and localities. This approach gave rise to a wide range of possibilities or approaches described herein below.

Approaches to Vegetation Classification

According to Fosberg (1961), vegetation is defined by its external appearance (physiognomic approach) and is the result of the Bioma structure (structural approach), the proportion of life forms (functional approach) and the coarse features of the floristic composition (floristic approach). There exists the eventual possibility of integrating these criteria to define holistic classification approaches from a landscape angle. In this way, according to Granados and Tapia (1990), the main approaches to vegetation classification prevalent in the world and, by consequence, in Mexico can be grouped as (a) physiognomic, (b) structural, (c) functional, (d) floristic, and (e) landscape.

Physiognomic

Physiognomic characteristics have formed the base for many vegetation classification systems, that is their physical characteristics and their external appearances (e.g. tall perennial forests, low deciduous jungle, shrublands), and have been widely used for both local and regional studies. They can refer both to growth forms of the dominant species and to leaf characteristics (seasonality, shape, phenology, duration, size, and texture). These attributes provide a quick and efficient mechanism for characterizing vegetation (González-Medrano 2003).

There exist as many vegetation classification systems as researchers and conditions, and, as an example, there is a refined school which includes measurements in a determined area as to the dominance detected through three elements: number, distribution, and biomass of the individual plants (Granados and Tapia 1990). Among methods for the physiognomic description of vegetation, those of Cain (1932) and Cain and Castro (1959) are widely used. They distinguish between two types of dominance: (1) physiological or ecological and (2) physiognomic. Küchler's system (1949) uses parameters such as easily observed life forms, measurements, and representation and, are, moreover, applicable to any region, making them useful in comparative studies. Dansereau's physiognomic system (1951) relates structure to function, also taking life form, height, cover, shape, size, and leaf texture into consideration. The system uses letters, numbers, and drawings as symbols in such a way that the community structure is expressed through a graphic synthesis (<http://www.glyndwr.ac.uk/bartlett/ecology/community.htm>). For Oosting (1956), it is evidently the uniformity of the vegetation in a climatic region that is manifested in relation to the life form of the dominant species, which are specifically a product of the climate. Shimwell's system (1971) proposed the representation of vegetation characteristics through the use of formulae giving a quick and complete description of the community.

The physiognomic approach is prevalent in earth science studies (e.g. agronomy, forestry, geography) and social sciences (e.g. anthropology and archaeology) as well as among a considerable number of biologists interested in the cartographic expression of vegetation. One example of the applications is the 1:1,000,000 map produced by the United Nations Educational and Scientific and Cultural Organization (UNESCO) in 1973 (Table 2.5) with the participation of many researchers and based on the classification system proposed by Mueller-Dombois and Ellenberg (1974). From the physiognomic approach, vegetation classification systems establish links between the dominant biological forms which stand out and are chiefly the product of the relationship between the vegetation and the climate, but which invariably incorporate the distribution, abundance, and density aspects of the individuals' plants, aspects germane to the structural approach to classification systems.

The UNESCO classification is based on a hierarchy distinguished by a key of letters and numbers (first column). In the second column, come the different categories with their associated nomenclature. In the third, nomenclature is presented

Table 2.5 Some characteristics of the UNESCO 1973 physiognomic proposal (Spurr and Barnes 1982)

Class	Levels	Attribute	Level I
I, II, III, IV, V, VI, etc.	Formation class	Physiognomic	I. Closed forest
			II. Woodland
			III. Shrub
			IV. Dwarf shrub and related communities
			V. Herbaceous vegetation
			VI. Deserts and other scarcely vegetated areas
			VII. Aquatic plant formations
A, B, C, D, F, G, etc.	Formation subclass	Xeromorphy and leaf fall	
1, 2, 3, etc.	Formation group	Climate	
a, b, c, etc.	Formation	1. Leaf characteristics	
		2. Presence of conifers	
		3. Presence of spines	
		4. Succulence	
		5. Leaf width	
		6. Vegetation height	
		7. Soil characteristics	
		8. Topography	
		9. Tree crown type	
		10. Presence of bamboo	
		11. Water characteristics	
		12. Presence of palms	
(1), (2), (3), etc.	Subformation	13. Sclerophyllous floor	
(a), (b), (c), etc.	Further subdivisions	14. Presence of calcium	

for the first level (formation class), and, in the fourth, come the attributes corresponding to the different levels—for the first physiognomy and for the second (subclass of formation), taking leaf fall and the xeromorphy into account. In the

third (formation groups), climate was considered, and criteria for determining formations, subformations, and other subdivisions were from 1 to 14, over and above the attributes of the preceding categories (González-Medrano 2003).

Structural

Structural classification does not generally exclude physiognomic attributes and is related to the distribution and spatial organization of the different components of the plant community. It is also largely a function of the life form of the same. The structural approach is particularly useful in areas where the flora is not well known and the structural data can be collected quickly even by inexperienced personnel (Spurr and Barnes 1982).

Lutz's phytograms (1930), for example, are polygonal figures used to characterize four factors of the physiognomic structure of species, and they allow for comparisons between the following: (1) *density*, (2) *frequency*, (3) *dominance*, and (4) *size-based classes*. The profile diagram was initially put forth by Davis and Richards (1934) and describes vegetation stratification through the use of semi-schematic —profile diagrams. It is applied mainly to tropical zones, though it can also be applied to temperate and boreal regions.

Larsen and Holm-Nielsen (1979) presented another structural system, which was developed for describing tropical vegetation with a view to military and counterinsurgent strategies. The descriptions are expressed through formulae obtained by assigning symbols divided into 12 groups: (1) *biological form*, (2) *predominance*, (3) *distribution*, (4) *stratification*, (5) *periodicity*, (6) *leaf characteristics*, (7) *height*, (8) *diameter*, (9) *spacing*, (10) *characteristics of the trunk and of the superficial roots*, (11) *elasticity*, and (12) *the nature of possible hindrances and dangers*.

Physiognomic-structural diagrams are, in general, stratification-cover-species-number outlines and result in a graphic representation of the horizontal strata of the vegetation. They can be used instead of profile diagrams (Table 2.6). The arrangement of a community can be schematized and described according to its physiognomy and structure, but its functional features can be another useful criterion in vegetation classification systems.

Functional

Fosberg's system is based on (1) *physiognomy (the vegetation's appearance)*, (2) *structure (the vegetation's distribution)*, and (3) *function (retention or fall of the foliage)*. This system is a diverse method widely used the world over, and it divides the vegetation successively into smaller units called **formations**. The method uses a key which first offers three alternatives leading to the first division corresponding to primary structural groups:

Table 2.6 Categories and criteria used in Dansereaugrams

Categories	Criteria
(A) Structure	1. Canopy type (open or closed)
	2. Tree spacing (uniform or irregular with distances between trees)
	3. Stratification (enumerated strata)
	4. Strata description (height and foliage)
	5. Observations on associations in strata
(B) Physiognomy	6. Height and distribution of lianas and epiphytes
	7. Trunk characteristics (e.g. buttress roots and stem succulence)
	8. Observations on special life forms (e.g. arborescent ferns, cicadofitas)
	9. Evergreen or deciduous trees with foliage (percentage)
	10. If deciduous, time with foliage and time of leaf fall
	11. Leaves (simple or complex)
	12. Leaf size (uses Raunkiaer's size classifications)
	13. Life forms (ground and soil strata field)
	14. Ground strata periodicity (e.g. seasonality)
	15. Seed production and method of dispersal (most important trees)
	16. Vegetative propagation (trees and bushes)
	17. Floristic composition (by stratum listed separately)
(C) Site	18. Name of the community (of dominants or characteristics)
	19. Common name (where applicable)
	20. Site location
	21. Size and type of sample (no less than half a hectare)
	22. Elevation, exposure, aspect, and slope.

Taken from Matteucci and Colma (1982)

Closed vegetation: crowns or touching stems or superimposition over 80–100 % of the cover.

Open vegetation: the plants are separated by a space at least twice their own diameter in 20–80 % of the cover.

Very open vegetation: the plants in the most complete stratum are separated by great distances and form less than 20 % of the cover.

Each primary structural group is divided into what constitutes a second tier of vegetation unit known as **classes of formation**, each of these being distinguished and receiving its name according to the dominant stratum (e.g. *dwarf shrub*). The following level is the **formation group**, in which each class of formation is divided according to function, that is to say whether the foliage is perennial or deciduous. Following on, the fourth division concerns itself with leaf texture, size, and shape in the dominant stratum, resulting in the **formations** being based on physical criteria and, sometimes, subdivided into **subformations**, which make up the fifth and last division.

This table (Richards et al., 1940) sums up the parameters considered in making a profile diagram of tropical vegetation—an example of a physiognomic–structural classification system.

As their popularity and relevance to the understanding of functional processes increased, criteria such as dispersal syndromes, establishment mechanisms, and pollination strategies, among others, began to be incorporated among the divisions, providing a very complex range of possibilities but having only limited applications, given that they require information, which, in the main, is non-existent. This functional approach is mainly suited to autophytoecological studies.

Floristic

Since the inception of Linnæus' binomial nomenclature system, information on floristic composition has been receiving greater attention. Initially, physiognomic–structural–functional classification systems gained strength using dominant species to name categories. At the beginning of the twentieth century in places where quasi-complete inventories were starting to become the norm, unlike in other less sampled regions, such as most of the tropics, there was set in motion the creation of a tool permitting not only the organization of data already gathered, but also of provision of direction and of a space for subsequent vegetation studies. The most important approach was the phytosociological, of which the principal exponent was Josias Braun-Blanquet, whose method for studying plant communities and their relationship with the terrestrial medium followed a trajectory similar to that developed for the classification and nomenclature of individual species. This system requires knowledge of the floristic composition in order to differentiate between and name the vegetation units, the basic unit being the association, a term used mainly by Humboldt (1805) and formalized by Flahault at the First International Botanical Congress held at Paris in 1900. At the sixth Congress (Amsterdam 1935), it was agreed that the term —association|| would only be used for units defined by the possession of characteristic and differential species as per the phytosociological approach or Zürich-Montpellier school or at least as per units of the same order of importance (González-Medrano 2003).

Vegetation researchers in North America, unlike their counterparts in Europe, followed a different course when it came to the conception and use of the term —association||. On the one hand, it can be explained through the term's being clearly identified with rigid European definitions, and, on the other, as being due to the Clementian sense used by the North Americans, which was only related to climax communities. For a time, the term fell into disuse in the English-speaking world, —community|| being used instead. That said, although this term is not restrictive in and of itself, it was coined with an eye to its popularity. It is currently recognized that the particular meaning of —community|| can be applied to all categories or levels of vegetation (e.g. holm–pine community, climax community—Spurr and Barnes 1982).

The phytosociological approach consists of a detailed description of the vegetation's structural morphology, its temporal dynamic, its spatial placement, its evolutionary history, and its denomination according to a well-established nomenclature for species associations (Werger 1974). The phytosociological approach, or Zürich-Montpellier school, has a solid scientific base and addresses the necessities of vegetation classification at an appropriate, efficient, and versatile level in relation to other approaches, leading to its gradual acceptance across Europe and in various regions of other continents (Africa, Asia, and in a goodly part of the Americas). In the same way, in the past decade, scientists in the English-speaking world with the partial exception of England and Australia (Schamineé et al. 1995; Jennings et al. 2002) have recognized the usefulness of the phytosociological approach in terms of the development of classification systems facilitating the characterization of vegetation cartography. In this sense, and for pragmatic reasons, it is recognized as important that phytosociology *sensu stricto* offers: (I) a minimum unit of the classification system (the association), (II) a sampling unit (the relevé), (III) a sampling method (stratifying the random), (IV) a single mechanism for categorical denomination (syntaxonomy), (V) a mechanism for territorial expression (synchorology), (VI) a dynamic vision of vegetation (syndynamics), (VII) likewise a method for describing structure (synmorphology), and (VIII) a temporal conception of vegetation (synchronology).

The phytosociological methodology consists of two steps: the first (analytical) involves carrying out the sampling phase, and the second (synthetic) is where the vegetation tables are derived through analogical comparison of the relevés. The sampling unit is the phytosociological relevé, and it is based on the selection of a minimum area delimited by its ecological homogeneity and uniformity in which each species' coverage is estimated as a function of the projected coverage by stratum of the whole of the individuals of the species. Moreover, in each relevé, a series of physiognomic and physiographic data taken during the sampling are linked (Werger 1974). The information obtained from these relevés is entered into a relational database matrix structure in which the information is weighted and the diagnostic species—those which determine the associations and their names are identified. This entire process is very elaborate and can be carried out by computational ordination methods and classification (Ter Braak and Prentice 1988; Velázquez 1994).

Among the data to be processed, a distinction is drawn between those of a physiognomic nature: (a) type of plant community, (b) height, (c) height by stratum, (d) dominant biotypes, (e) presence of bare soil and rock, the coverage by strata and by species expressed as a percentage; and those of a physiographic nature: (a) topography, (b) substratum, (c) elevation, (d) exposure, (e) slope, (f) coordinates, and (g) tree height. Over and above these data, the surface area of the land inventoried is estimated in the field, and all the different plant species found on the sampling site are collected for correct determination in the laboratory. Later, the series of delimited bioclimatic storeys are determined as a function of changes in temperature and precipitation (thermoclimatic and ombroclimatic). From these changes originate different vegetation storeys occurring from the basal zone through

to the mountain tops. This phytosociological approach is used increasingly, has affected the formation of what is known today as —vegetation science||, and is of great usefulness in addressing cartographic issues.

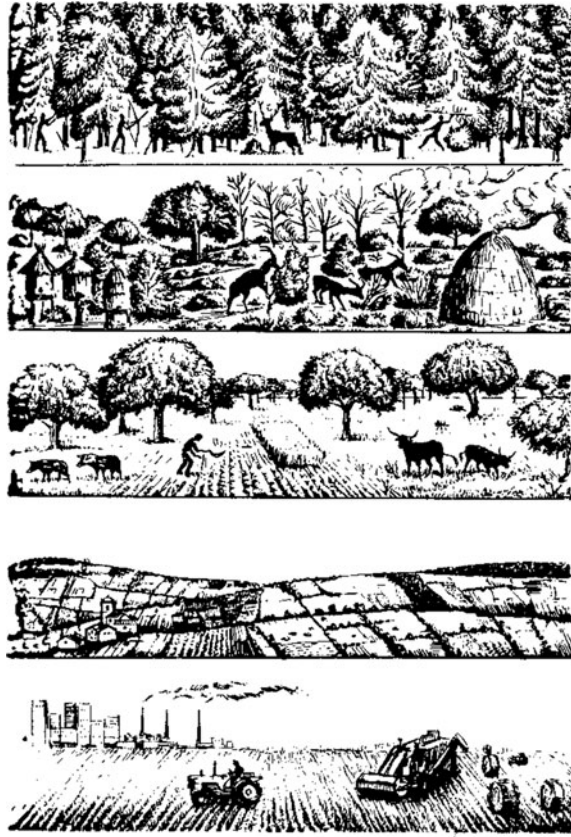
Landscape

Landscape is a conceptual framework derived from diverse disciplines and makes a holistic study of a territory. Within this framework, there exist different orientations, among which the most widely known are landscape ecology, geocology, and ecogeography. Vegetation is a central element or component for all these fields and thus it has been studied from various approaches. Granados and Tapia (1990) mention that the French phytogeographical school has devised a tridimensional method, called —block diagrams||, to represent plant communities.

The structure is a block to scale representing a mesoregion, establishing within the relief configuration, the topography, hydrological aspects, and, most importantly, the vertical and horizontal distribution of the life forms. It allows the coverage density to be observed. In the same way, succession stages in the vegetation dynamic can be considered. On the other hand, a clear representation of the distribution of vegetation types can be made for areas of lesser size in specific ways including, in many cases, urban areas (Fig. 2.2). Likewise, the soil profile, adding indicators related to drainage, salinity, stoniness et cetera, can be represented at the front of the diagram. The following are necessary features of a block diagram: aerial photography, the cartography of potential land use, and botanico-ecological knowledge of the zone in question. This information is entered into large qualitative and quantitative databases of information on plant species and the environmental factors associated with them. In general, three goals are pursued within this kind of approach: association classification plus cartographic and topological descriptions along with the identification and ordination of the factors best explaining the spatiotemporal patterns observed. Because of the associated complexity, multivariate analytical methods are used.

The development of increasingly efficient computational methods and of sophisticated statistical methods has led to an advance in the analysis and interpretation of large quantities of data through relatively few parameters—in this case, of multiple variables within ecosystems. There currently exists a great variety of methods, among them one being to characterize life forms using a multivariate approach to ordination and classification (CANOCO and TWINSpan), which works from the basis that organisms present similar morphological adaptations, which, theoretically, at least, respond functionally to the environmental pressures to which they are subjected. These methods are an alternative to the purely taxonomic in ecological descriptions, explanations, and preconditions of plant communities (Hill 1979; Ter Braak 1986; Kent and Coker 1992; Velázquez and Cleef 1993; Dallas 2000).

Fig. 2.2 Degree of anthropogenic influence across the landscape results in complex intermingling mosaic vegetation formations. These range from predominantly native plant species aggregates (where human actions are mostly subordinated to natural conditions) to predominantly man-made plant species aggregates (where human actions are the system's driving force) (Taken from Zonneveld I. 1979. Rural Ecology Course lecture notes, ITC-The Netherlands, unpublished notes)



According to Matteucci and Colma (1982), there exist two grand approaches to vegetation ordination. The first type deals with the use of mathematical tools for the reduction of the —dimensionality of the vegetational space, referred to as —**taxometric ordination**— and consisting of the ordination of the set of individuals recognized in the sampling exercises. In the second type, referred to as —**ecological ordination**—, the attempt is made to find relationships between variations in the vegetation (structural descriptors of the community) and the environmental gradients. In these approaches, the authors recommend —sacrificing mathematical exactitude in favour of ecologically interpretable results—.

Another plant community classification technique is that put forth in the theory of fuzzy sets, which allows for the inclusion of certain attributes not easily incorporated into conventional approaches to classification, namely because plant communities are not separated by precise limits, but, on the contrary, there is a blurring of the lines, rendering overlap and internal heterogeneity characteristic of ecological communities. The concepts of ecosystem as well as those of community, association, and trophic level, et cetera, are all examples of fuzzy sets. The theory of

fuzzy sets is useful for description and analytical purposes in these circumstances and serves as an alternative conceptual base for the most satisfactory representation of ecological communities (Equihua 1991; Pérez-Vega et al. 2010).

Predominant Approaches in Mexico

The Physiognomic–Structural–Floristic Approach

In the Mexican context, the first attempts at vegetation classification were based on physiognomic features (Sanders 1921; Shelford 1926 and Smith and Johnston 1945, cited in Rzedowski 1978). Even so, said works also tend to use bioclimatic or geomorphological criteria and lay out features of the floristic composition in their characterization. Leopold (1950) outlines a table distinguishing between 12 types of vegetation and indicates their distribution on a map originally published on a scale of 1:20,000,000. Miranda and Hernández-X (1963) recognize 32 types of vegetation. The work lacks a map but includes data on geographic distribution, principal relationships with environmental factors, photographs, and a succinct description of the floristic composition of each type of vegetation included. Flores-Mata et al. (1971) prepared an excellent cartographic reference in which 25 categories were recognized including as many vegetation types as land uses. That said, the document does not explain many of the criteria selected in denominating the various categories.

Rzedowski (1978) relates his proposal with other classification systems, amply justifies the categories created, provides an outline distribution map, and describes in great detail the most outstanding features of the climate and of the floristic composition differential of his proposed categories in differing regions and entities of the country as well as the general difficulty arising from the lack of information and/or exploration or deterioration accelerated by human activity. This book also includes vegetation research material and classification diagrams for the country as a whole and by individual region within his proposed categories and dedicates ample discourse to climate, physiography, and possible floristic relationships, making this indubitably the most complete contribution on Mexican vegetation.

The soil and vegetation classification system designed and used by the Instituto Nacional de Estadísticas y Geografía (INEGI 1999) separates the physiognomic and structural features of vegetation types from land use. Later, there appears the proposed —communities’ used in the Inventario Nacional Forestal (INF) of 2000 (Palacios-Prieto et al. 2000), in which are incorporated criteria related both to the classification of coverage types and to land use as different physiognomic–structural and compositional features of plant community typification.

The 2003 González-Medrano proposal for unified plant community classification criteria in Mexico also stands out, given that it makes clear that the criteria regulating the proposal up to the formation level are bioclimatic–

physiognomic/structural and that they correspond approximately with numerous categories of vegetation types used in aforementioned systems insofar as the criterion of floristic composition is incorporated in the proposal at the levels of association and consociation. Unfortunately, the work does not go as far as characterizing any particular area of Mexico at these levels.

The prevalent approach in Mexico is physiognomic–structural–floristic. Even so, the databases in general are descriptive in nature, and thus the categories used to define vegetation types are very different. It would be impossible to include a highly detailed description of the multiple proposals drawn up for the various regions of the country. In general, there are five to a greater or lesser degree prevalent and fundamental to the creation of adaptations of highly specific proposals where they are needed to resolve a particular situation. These proposals are described in Table 2.7, in which the attempt has been made to find the level and nomenclature corresponding to that of the various authors. It should be mentioned that this table was originally drawn up by Dr. J. Rzedowski, and, in this present work, only previously non-existent information has been added—for example, the term —Xerophile shrubland|| has its equivalent in various of Miranda and Hernández-X’s 1963 plant-classification units, indicating that they are not the same category.

The preceding table raises the general notion that each and every one of the different units described can be placed in a hierarchy of distinct levels. That said, different criteria are used from system to system and sometimes even within the same system, making it difficult to understand the hierarchy and structure derived from the proposals. A more precise example of levels and associated nomenclature originating from some case studies on particular regions is shown in Table 2.8.

It should also be mentioned that the contributions made on this subject by Mexican governmental institutions carrying out research on vegetation are fundamental source material, given the importance of the research derived from its national scope. The same can be said of research carried out by environmental protection organizations. Proposals originating with institutions seek, in the main, to create cartographic expressions of vegetation in contrast to earlier studies, the aim of which had been to study vegetation in its chorological expression. Outstanding among this research are the efforts of various bodies: the Secretaría de Programación y Presupuesto (SPP), which publishes its charts on land use and vegetation. It has about 80 terms it uses to describe different vegetation communities, many of which are taken from the works of various researchers, but the majority of them are adequate for the secretariat’s own purposes. The INEGI in its various publications, such as its 1:250,000-scale land use and vegetation charts, uses terminology consistent with Miranda and Hernández X’s 1963 proposal, all the while adapting it for the institute’s own purposes. The INEGI uses over 60 categories. Additionally, for the regional determination of Rangeland Coefficients, (COTECOCA), the Comisión Técnica Consultiva uses approximately 70 categories to describe units of vegetation. In its turn, the Instituto de Geografía at UNAM, in its bulletin —*Investigaciones Geográficas*||, 43 (Palacios-Prieto et al. 2000), recorded the terms —**formation**||, —**types of vegetation**||, —**communities**||, and —**subcommunities**||, terms which would later be used by the National Forest

Table 2.7 Approximate correspondence between nomenclatural terms in different vegetation classification systems in Mexico. Rzedowski (1978) was taken as the starting point

Rzedowski (1978)	Miranda y Hernández X. (1963)	Flores-Mata et al. (1971)	Palacios-Prieto et al. (2000)	González-Medrano (2003)
Evergreen tropical forest	High evergreen jungle, high or mid-height subevergreen jungle	High evergreen jungle	Evergreen jungle and subevergreen	Humid tropical forest (in part)
Subdeciduous tropical forest	High or mid-height subdeciduous jungle	Mid-height subevergreen jungle (in part)	Deciduous jungle and subdeciduous (in part)	Humid tropical forest (in part)
Deciduous tropical forest	Low-height deciduous jungle	Low-height deciduous jungle (in part)	Low deciduous jungle (in part)	Dry tropical forest (in part) Tropical mountain forest?
Spiny forest	Low subevergreen jungle (in part), Low spiny evergreen jungle, Low spiny deciduous jungle?	Low deciduous jungle (in part), low subevergreen jungle, Mezquital (in part)	Mezquital (in part)	Dry tropical forest
Grassland	Grassland, zacatonal, high paramos vegetation	Meadowland, zacatonal, savannah	Meadowland	Meadowland
Xerophile shrubland	Spiny shrub with lateral spines, cardonales, Neobuxbaumia tetetzo, etc., izotal, nopaleras, spiny shrub with terminal spines, spineless parvifolia shrub, magueyales, agave, lechugilla, Hechtia glomerata, etc., chaparral, arid sandy desert vegetation	Mezquital (in part), chaparral, submountainous shrub, fleshy stem shrub, desert shrubland, rosetophilous shrubs, micropylar desert shrubland	Mezquital (in part) Xerophile shrubland	Xerophile shrubland

(continued)

Table 2.7 (continued)

Rzedowski (1978)	Miranda y Hernández X. (1963)	Flores-Mata et al. (1971)	Palacios-Prieto et al. (2000)	González-Medrano (2003)
<i>Quercus</i> forest	Holms	Oak forest	Hardwood forest	Temperate forests (part) Non-hydrophilic forest (in part)
Coniferous forest	Pines, fir forest	Pine forest, fir forest	Coniferous forest, coniferous– hardwood forest	Temperate forests (part) Non-hydrophilic forest (in part)
Mountain cloud forest	Mid or low evergreen jungle, deciduous forest (in part)	Deciduous forest	Mountain cloud forest	Tropical mountain forest?
Aquatic and subaquatic vegetation	Mangrove swamp, <i>Thalia</i> <i>geniculata</i> , tulares, reed beds, etc., deciduous forest (in part)	Mangrove, <i>Thalia geniculata</i>	Hydrophilic vegetation	Hydrophilic forests Freshwater hydrophilic vegetation

Inventory. As can be seen in the aforementioned examples, the physiognomic, structural, and floristic (not necessarily in that order) characteristics are those most prevalent.

Phytosociological Approach

Rigorous research from the phytosociological approach in Mexico is scarce. In general, the regions of the Baja California Peninsula (Delgadillo et al. 1992; Alcaraz et Delgadillo 2010) and the centre of the Trans-Mexican Volcanic Belt (Velázquez and Cleef 1993) stand out. There also exist isolated studies on coastal dunes (Morena-Casasola et al. 1982; Castillo et al. 1991), humid tropical regions (Guevara et al. 1994; Sánchez-Sánchez and Islebe 2002), and dry tropical regions (Pérez-Vega 2008).

In the phytosociological analysis of the salt marshes and mangrove swamps of Baja California, Delgadillo et al. (1992) found a total of 16 **associations**, which were later covered by Peinado et al. (1994b). Another phytosociological study was carried out by Peinado et al. (1994a) in the Sierra de San Pedro Mártir in Baja California. It describes five vegetation storeys and provides their climatic characteristics, denominated as follows: Infra-Mediterranean, Thermo-Mediterranean,

Table 2.8 Some contributions to knowledge on the classification of vegetation from the prevalent school in Mexico

Author(s)	Region or location of study	Levels and nomenclature
Zamudio et al. (1992)	Querétaro State	Level I: Vegetation types
		Level II: Vegetation types
		Level III: Others vegetation types
Ramos and Novelo (1993)	Yuriria Lagoon, Guanajuato	Level I. Associations
González-Elizondo et al. (1993)	“La Michilía” Biosphere Reserve, Durango	Level I. Temperate forest
		Level II. Vegetation types
		Level III. Units of vegetation
		Level IV. Associations
Madrigal (1994)	Eastern Michoacán	Level I. Formation
		Level II. Subformation
		Level III. Associations
		Level IV. Series
		Level V. Facies
Labat (1995)	North-eastern Michoacán	Level I. Formation
		Level II. Groups
		Level III. Communities
Pennigton and Sarukhán (1998)	Hot humid zone of Mexico	Level I. Vegetation types
Rzedowski and Rzedowski (2001)	Valle de México	Level I. Vegetation types
		Level II. Others Vegetation types
		Level III. Associations
		Level IV. Communities
Briones and Villarreal (2001)	Vegetation and flora of on ecotone between the province of “Altiplano” and “Planicie Costera” in the north-east of Mexico	Level I. Vegetation types

Meso-Mediterranean, Supra-Mediterranean, and Mesotropical. In each of these levels, units of vegetation are identified using the term **association** as per phytosociological methods. Later, Rivas-Martínez (1997) and Rivas-Martínez et al. (1998, 1999b) determined a series of bioclimatic storeys delimited by temperature changes and precipitation (thermoclimata and ombroclimata) for North America, and, in the same way, presented a phytosociological synthesis of forest vegetation in the north of Mexico which includes six **classes** and eight **orders**, 19 **alliances**, and 64 **associations**. Guevara et al. (1994) examined the vegetation and flora of paddocks in the Sierra de los Tuxtlas, obtaining, as a result, floristic groupings, which they called **floristic sets**.

Few studies taking this approach maintain the regulation available regarding the levels of aggregation and nomenclature. Outstanding among these studies are those of Almeida-Leñero et al. (1994) and Almeida-Leñero (1997), in which they report on various levels of **order**, **alliance**, **community**, **association**, and **subassociation**. Three further examples are those of Giménez et al. (1997, 2003—Monarch Butterfly Region) and González et al. (2002—Sierra de Catorce).

The Challenge of Producing an Integrative and Inclusive Proposal

The preceding is but an outline of what exists in Mexico in terms of vegetation studies emphasizing the classification and nomenclature aspects of the object of study. The number of scientific contributions would be overwhelming if all the taxonomic, floristic, and especially ecological researches were totalled. An example of this can be seen in the publications of various universities, both national and state, which have accumulated hundreds, if not thousands, as in the case of UNAM, of theses and articles. At the same time, enormous databases such as the ones available for consultation at CONABIO (<http://www.conabio.gob.mx>) and INECC (<http://www.inecc.gob.mx>) are examples of the great effort being made to systemize existing information on vegetation and its flora. Another piece of evidence is the number of works presented in various botanical fora in the form of both national and international congresses. Faced with this situation, it is crucial to have a system which does not disown experience already accrued and which systemizes existing knowledge, but which is also congruent and consistent with the levels, criteria, and nomenclature of the various categories of vegetation. The final aspect is of capital importance, given that nomenclature becomes an index of the degree of beta diversity which is established based on the number of native vegetation types found in the region of study (e.g. the province, municipality, or watershed). The inconsistent use of terms results in vocabulary incompatibility between regions as illustrated below:

1. The use of toponymic terms—for example, the —Matorral Tamaulipeco|| to describe the shrubland found in the Tamaulipas State, the term implying the shrubland found there is somehow unique to the region (e.g. Dinerstein et al. 1995).
2. The use of the dominant tree genus in preference to the phenology. The case of —Holm forest|| with at least three connotations—deciduous, perennial, and subperennial, which implies a reduced diversity through the sole use of the genus (Rzedowski 1978).
3. The use of the mesoclimatic condition, the most obvious example being that of —Mesophyll forest||, which denomination refers to the leaf type, when, in reality, it is making reference to the type of mesoclimate. Other examples are —Xerophile shrubland|| and —Arid desert vegetation|| (Rzedowski 1978; Miranda and Hernández X 1963).
4. The use of geomorphological or physiographic terms—again bringing up the terms —Mountain mesophyll forest||, —Alpine prairie||, —Coastal dunes||, and —Arid sandy desert vegetation|| (Miranda 1947; INEGI 1999).
5. The use of local names or words such as —Tetechera|| (named after the dominant species: *Neobuxbaumia tetetzo*), —Nopalera||, —Popall||, —Tular||, —Izotal||, and —Carrizal||, among others (Miranda and Hernández X 1963).

To be complementary, the ideal system would need to be compatible with the systems developed for other parts of the world, especially North America, inclusive of Central America, in order to meet macroregional demands as an effect of global change. Additionally, the proposal for the ideal system derived from this review would need to address the cartographic expression of the categories, that is to say the creation at the same time of legends on various scales, which would allow for consistency between the classification system and its respective proposed legend at any given scale. This concept will be developed in the following chapters and represents the core of this work.

References

- Alcaraz F, Delgadillo J (2010) Matorrales suculentos y desérticos del desierto central de Baja California afectados por la maresia. *Braun-Blanquetia* 46: 85–100.
- Almeida L, Cleef AM, Herrera A, Velázquez A, Luna I (1994) El zacatonal alpino del Volcán Popocatepetl, México y su posición en las montañas tropicales de América. *Phytocoenologia* 22(3): 391–436.
- Almeida-Leñero (1997) Vegetación, fitogeografía and paleoecología del zacatonal alpino and bosques montanos de la región central de México. Tesis doctoral, Universidad de Amsterdam.
- Archibold OW (1995) *Ecology of World Vegetation*. Chapman & Hall, London.
- Bojórquez-Tapia LA, Azuara I, Escurre E (1995) Identifying conservation priorities in Mexico through geographic information systems and modeling. *Ecol. Applic.* 1: 215–231.
- Briones O, Villarreal JA (2001) Vegetación and flora de un ecotono entre las provincias del Altiplano and de la Planicie Costera del Noreste de México. *Acta Botánica Mexicana*. Instituto de Ecología A.C. Pátzcuaro, Michoacán México, 55: 39–67.

- Cain SA (1932) Concerning certain phytosociological concepts. *Ecological Monographs* 2: 475–508.
- Cain SA, Castro GM (1959) *Manual of vegetation analysis*. Harper & Brother, New York.
- Carabias J, Landa R (2006) Agua, medio ambiente and sociedad: hacia una política integral de los recursos hídricos. El Colegio de México-UNAM-Fundación Gonzalo Río Arronte, México.
- Castillo S, Pompa J, Moreno-Casasola P (1991) Coastal sand dune vegetation of Tabasco and Campeche, Mexico. *Journal of Vegetation Science* 2: 73–88.
- Dallas EJ (2000) *Métodos Multivariados Aplicados al Análisis de Datos*. Internacional Thomson, México.
- Dansereau P (1951) Description and recording of vegetation upon a structural basis. *Ecology* 32: 172–229.
- Davis TAW., Richards PW (1934) The vegetation of Moraballi Creek, British Guiana; and Ecological Study of a Limited Area of Tropical Rain Forest. I and II, *J. Ecol.* 21: 350–384 (1933) and *J. Ecol.* 22: 106–155.
- Delgadillo J, Peinado M, De La Cruz M, Martínez-Parras J, Alcaraz F., De La Torre A (1992) Análisis fitosociológico de los saladares and manglares de Baja California, México. *Acta Botánica Mexicana*. Instituto de Ecología, A. C. Pátzcuaro, Michoacán. México, 19: 1–35.
- Dinerstein E, Olson D, Graham D, Webster A, Primm S, Bookbinder M, Ledec C (1995) Una evaluación del estado de las eco-regiones terrestres de América Latina and el Caribe. Banco Mundial, WWF. Washington D.C.
- Equihua M (1991) Fuzzy clustering of ecological data. *Journal of Ecology*, 78: 519–534.
- FGDC (Federal Geographic Data Committee) (2005) *Nacional Vegetation Classification Standard Hierarchy Revisions Working Group*. Federal Geographic Data Committee, Vegetation Subcommittee. OverView July 2005. In: <http://biology.usgs.gov/fgdc.veg>.
- FGDC (Federal Geographic Data Committee) (2008) *National Vegetation Classification Standard, Version 2. Vegetation Subcommittee*. Federal Geographic Data Committee.
- Flores-Mata G, Jiménez L, Madrigal S, Moncayo R., Takaki T (1971) *Tipos de Vegetación de la República Mexicana*. Secretaría de Recursos Hidráulicos. México, D.F.
- Fosberg FR (1961) A classification of vegetation for general purposes. *Trop. Ecol.* 2:1–28 (Republished in modified form in Peterken GF 1967. *Guide to the Check Sheet for IBP Areas*. IBP Handbook 4. Blackwell Scientific. Oxford: 73–120).
- García E (2004) *Modificaciones al Sistema de Clasificación Climática de Köppen*. Instituto de Geografía. Universidad Nacional Autónoma de México. Serie Libros, 6. México, D.F.
- Giménez J, Escamilla M, Velázquez A (1997) Fitosociología and sucesión en el volcán Parícutín, Michoacán, México. *Caldasia* 19 (3): 487–505.
- Giménez JM, Ramírez IM, Pinto M (2003) Las comunidades vegetales de la Sierra de Angangueo: clasificación, composición and distribución. *Lazarroa* 24: 87–111.
- González-Medrano F (2003). Las comunidades vegetales de México. Propuesta para la unificación de la clasificación y nomenclatura de la vegetación de México. Instituto Nacional de Ecología, México, DF.
- González-Elizondo S, González-Elizondo M, A Cortés O (1993) Vegetación de la Reserva de la Biosfera - La Michilía, Durango, México. *Acta Botánica Mexicana*. Instituto de Ecología, A.C. Pátzcuaro, Michoacán. México. 22: 1–104.
- Good R (1953) *The geography of flowering plants*. II ed., Longmans, Green & Co., London.
- Granados SD, R Tapia V (1990) *Comunidades vegetales*. Universidad Autónoma de Chapingo. México, D.F.
- Guevara S, Meave J, Moreno-Casasola P, Laborde JJ (1994) Vegetación and flora de los potreros en la sierra de los Tuxtlas, México. *Acta Botánica Mexicana*. Instituto de Ecología, A.C. Pátzcuaro, Michoacán. México, 28: 1–27.
- Hill MO (1979) *TWINSPAN - A FORTRAN program for arranging multivariate data in an ordered two-way table by classification of individuals and attributes*. Cornell. University Press, Ithaca N.Y.
- Holdridge LR (1967) *Life zone ecology*, San José, Costa Rica.

- Holdridge LR, Grenke CW, Hatheawt HW, Liang T, Tosi AJ (1971) Forest environments in tropical life zones a pilot study. Pergamon Press., New York.
- Huber O, Riina R (2003) Glosario Fitoecológico de las Américas. Vol. 2. México, América Central e Islas del Caribe: países hispanoparlantes. Ediciones UNESCO. Corolab. Humboldt, Paris.
- Humboldt A (1805) Essai sur la geographic des plantes. In Voyage, Pt. 5, Physique generale et geologie, Paris.
- INEGI (Instituto Nacional de Estadística Geografía e Informática). (1999) Información Botánica en la cartografía temática del INEGI. Guía Normativo-Metodológica. Dirección General de Geografía INEGI. México.
- Jennings M, Loucks O, Glenn-Lewin D, Peet R, Faber-Langendoen D, Grossman D, Damman A, Barbour M, Pfister R, Walker M, Talbot S, Walker J, Hartshorn G, Waggoner G, Abrams M, Hill A, Roberts D, Tart D. (2002) Standards for associations and alliances of the U.S. national vegetation classification. Version 1.0. Vegetation Classification Panel, Ecological Society of America. Washington, D.C. USA.
- Kent M, Coker P (1992) Vegetation description and Analysis. A Practical Approach. Belhaven Press, London.
- Küchler AW (1949) A physiognomic classification of vegetation. Ann. Ass. Am. Geogr. 39: 201–210.
- Labat N (1995) Végétation du Nordouest du Michoacán, Mexique. Instituto de Ecología A.C.
- Larsen K, Holm-Nielsen B (eds) (1979) Tropical botany. Academic Press, London.
- Leopold AS (1950) Vegetation zones of Mexico. Ecology. 31: 507–518 (1735–1770).
- Lutz HJ (1930) The vegetation of Heart's Content, a virgin forest in northwestern Pennsylvania. Ecology II: 1–29.
- Madrigal X (1994) Características generales de la región forestal oriental del estado de Michoacán, México, UMSNH Morelia, México.
- Matteucci SD, Colma A (1982) Metodología para el estudio de la vegetación. Serie Biología OEA. Monografía 22. Washington.
- Miranda F (1947) Estudios sobre la vegetación de México. Rasgos de la vegetación en la Cuenca del Río de las Balsas. Rev. Soc. Mex. Hist. Nat. 8: 95–114.
- Miranda F, Hernández XE (1963) Los tipos de vegetación de México and su clasificación. Bol. Soc. Bot. Méx. 28: 29–179.
- Moreno-Casasola PE, van der Maarel E, Castillo S, Huesca ML, Pisanty I (1982) Ecología de la vegetación de dunas costeras: estructura and composición en el Morro de la Mancha, Ver. I. Biótica 7: 491–596.
- Mueller-Dombois D, Ellenberg H (1974) Aims and Methods of Vegetation Ecology. John Wiley & Sons, Manchester.
- Olson D, Dinerstein E, Wikramanayake D, Burgess D, Powell N, Underwood C, D'Amico A, Itoua I, Strand H, Morrison C, Loucks J, Allnutt F, Ricketts H, Kura Y, Lamoreux F, Wettengel W, Hedao P, Kassem R (2001) Terrestrial Ecoregions of the World: A New Map of Life on Earth. BioScience, 51(11): 933–938.
- Oosting HJ (1956) The study of plant communities. W. H. Freeman and Co., San Francisco.
- Palacios-Prieto JL, Bocco G, Velázquez A, Mas JF, Takaki-Takaki F, Victoria A, Luna-González L, Gómez-Rodríguez G, López-García M, Palma M, Trejo-Vázquez I, A Peralta H, Prado-Molina J, Rodríguez-Aguilar A, Mayorga-Saucedo R, F González M (2000) La condición actual de los recursos forestales en México: resultados del Inventario Forestal Nacional 2000. Investigaciones Geográficas, Boletín del Instituto de Geografía. UNAM. 43: 183–203.
- Peinado M, Bartolomé C, Delgadillo J, Aguado I (1994a) Pisos de vegetación de la Sierra de San Pedro Mártir, Baja California, México. Acta Botánica Mexicana. Instituto de Ecología A.C. Centro Regional del Bajío. Pátzcuaro, Michoacán. México, 29: 1–30.
- Peinado M, F. Alcaraz JL, Aguirre & Álvarez J (1994b) Vegetation formations and associations of the zoniomes along the North American Pacific Coast: From Northern California to Alaska. Plant Ecol. 129: 29–47.

- Pérez-Vega A (2008) La contribución de los atributos del relieve para explicar la distribución espacial de la vegetación: estudio de caso en una zona de montaña de alta diversidad. Tesis de Doctor en Geografía. Universidad Nacional Autónoma de México. Morelia, Mich.
- Pérez-Vega A, Velázquez A, Giménez de Azcárate J (2010) Aproximación geobotánica de bosque tropical seco caducifolio en la microcuenca del Río San José de Chila. Michoacán, México. *Braun-Blanquetia* 46: 351–359.
- Ramos L, Novelo A (1993) Vegetación y flora acuática de la laguna de Yuriria, Guanajuato, México. *Acta Bot. Mex.* 25: 61–79.
- Raunkaier C (1934) The life forms of plants and statistical plant geography. Clarendon, Oxford.
- Richards, P.W., A.G. Tansley and A. S. Watt. 1940. The Recording of Structure, Life Form and Flora of Tropical Forest Communities as a Basis for Their Classification. *Journal of Ecology* 28(1):224-239.
- Riley D, Young A (1966) *World Vegetation*. Cambridge University Press. London.
- Rivas-Martínez S (1997) Syntaxonomical synopsis of the potential natural plant communities of North America, I. *Itinera Geobot.* 10: 5–148.
- Rivas-Martínez S, Giménez de Azcárate J, Penas-Merino A, Palma-Muñoz M (1998) Esbozo bioclimático de México. In: Libro de Resúmenes VII Congreso Latinoamericano de Botánica. XIV Congreso Mexicano de Botánica. Sociedad Botánica de México. México, D.F.: 201–202.
- Rivas-Martínez S, Sánchez-Mata D, Costa M (1999) North America boreal and western temperate forest vegetation (Syntaxonomical synopsis of the potential natural plant communities of North America II). *Itinera Geobot.* 12: 5-316.
- Rzedowski J (1978) *Vegetación de México*. Limusa. México, D.F.
- Rzedowski C, Rzedowski J (2001) *Flora fanerogámica del Valle de México*. Instituto de Ecología y Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. Pátzcuaro, Michoacán, México.
- Sánchez-Sánchez O, Islebe GA (2002) Tropical forest communities in southeastern Mexico. *Plant Ecology Kluwer Academic Publishers, Plant Ecology* 158: 183–200.
- Sanders EM (1921) The natural regions of México. *Geog. Rev.* 11: 212–226.
- Schaminée JHJ, Weeda EJ, Westhoff V (1995) *De vegetatie van Nederland. Deel 2. Plantengemeenschappen van wateren, moerassen en natte heiden*. Opulus Press, Uppsala-Leiden.
- Shelford E (1926) Terms and concepts in animal ecology. *Ecology*, 7(3): 389.
- Shimwell DW (1971) *Description and classification of vegetation*. Sidgwick and Jackson, London.
- Smith AC, Johnston IM (1945) A phytogeographic sketch of Latin America. *Plants and plant science in Latin America*, 11–18.
- Spurr SH, Barnes BV (1982) *Ecología forestal*. A.G.T. Editor, S. A. México, D.F.
- Takhtajan A (1986) *Floristic regions of the World*. University of California Press, Berkeley, Los Angeles, London.
- Ter Braak CJF (1986) Canonical Correspondence Analysis: a new eigenvector technique for multivariate direct gradient analysis. *Ecology* 67: 1167–1179.
- Ter Braak CJF, Prentice IC (1988) Theory of gradient analysis. *Adv. Ecol. Res.* 18: 271–317.
- Velázquez A, Cleef AM (1993) The plant communities of the volcanoes Tláloc and Pelado, México. *Phytocoenología* 22: 145–192.
- Velázquez A (1994) Multivariate analysis of the vegetation of the volcanoes Tláloc and Pelado, Mexico. *Journal Vegetation Science* 5: 263–270.
- Velázquez A, Romero FJ (eds) (1999) *Biodiversidad de la región de montaña del sur de la Cuenca de México: bases para el ordenamiento ecológico*. UAM-X-SEMARNAP. ISBN: 754 24 2867 8.
- Velázquez A, Mas JF, Fiaz-Gaellgos JR, Mayorga-Saucedo R, Alcántara PC, Catsro R, Fernández T, Bocco G, Palacio JL (2002) Patrones y tasas de cambio del uso del suelo en México. *Gaceta Ecológica* 62: 21–37.
- Velázquez A, Durán E, Mas JF, Bray D, Bocco G (2006) Situación actual and prospectiva del cambio de la cubierta vegetal and usos de suelo en México. En *México ante los desafíos del desarrollo del Milenio*. Consejo Nacional de Población. 391–416.

- Velázquez A, Mas JF, Bocco G, Palacio-Prieto JL (2010a) Mapping Land Cover Changes in Mexico, 1976-2000 and applications for guiding environmental management policy. Singapore Journal of Tropical Geography 31: 152–162.
- Werger A (1974) On concepts and techniques applied in the Zurich-Montpellier method of vegetation survey. Bothalia, 11: 309-323.
- Whittaker R (1962) Classification of natural communities. Botanical Review, 28: 1–239.
- Zamudio R, Rzedowski J, Carranza E, Calderón G (1992) La vegetación en el estado de Querétaro. Instituto de Ecología, A.C.- CONCYTEQ.

Standardized Hierarchical Vegetation Classification
Mexican and Global Patterns

Velazquez, A.; Medina García, C.; Durán Medina, E.;

Amador, A.; Gopar Merino, L.F.

2016, XXIII, 143 p. 6 illus., 4 illus. in color., Hardcover

ISBN: 978-3-319-41221-4