A synecological classification of tropical terrestrial ecosystems: a first approach

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Abstract: Classification of terrestrial ecosystems is a very important task in the understanding process of vegetation patterns. It is a tool to mathematically organize the available information in understandable entities without loosing the perspective of the whole. The proposed classification method provides, in quantitative terms, a classification of ecosystems (associations) found within a life zone, *in sensu* Holdridge. It is based on the assumption that plants are the best environmental indicator available to research, and that this fact can be used, through the method of synecological coordinates, for practical purposes. The method was used with 19 mature tropical premontane moist forest plots in Costa Rica. This life zone was characterized according to moisture, nutrient, heat, and light synecological coordinates, and particular ecosystems or associations were determined. The results were the ones expected from empirical knowledge.

Key words: vegetation, classification, synecology, quantitative approach, life zones, tropical ecosystems, Costa Rica

Climate is generally accepted as one of the major determinants of vegetation. In the words of F. I. Woodward (1987), "The central thesis for plant ecology is that climate exerts the dominant control on the distribution of the major vegetation types of the world." The relation between climate and distribution of species has been described as early as 1807 by Humboldt. Present-day ecosystematic approaches include climate as a major component of the classification, and together with physiographic classifications constitute the indirect elements for the classification of ecosystems (Kimmins, 1987).

Along with the many ecological classifications of environments, there have also been numerous climatic classifications (de Candolle 1874; Köppen 1923 and Thornthwaite 1931, 1948 cited by Kimmins 1987; Budyko 1974; Walters et al. 1975; Walters 1979). Some of these classifications result in the preparation of climatic maps, others present individual climatic diagrams for various geographical locations. These diagrams for the whole world have been published by Walters et al. (1975), and the resulting Climatic Diagram Maps have been synthesized into world climatic maps. Furthermore, Walter (1979) has proposed a classification of vegetation of the world based on the seven genetical climate belts distinguished by meteorologists plus two more subdivision of polar zones. He takes these nine climate zones, what he calls zonobiomes (a biome being a large and uniform environment within the geo-biosphere or terrestrial ecosystems), and which are characterized by a particular type of climate diagram, and make them correspond to a soil type and zonal vegetation. Later these subdivisions are broken down to more categories depending on particular characteristics of the geobiosphere.

The approach taken by Holdridge (1947, 1967), as mentioned by Woodward (1987), is an exemplary approach to the understanding of the climatic control of plant distribution based on a taxonomy of vegetation and climate. The vegetation of a particular area may be simply classified in overall physiognomic terms, for example, Holdridge's term 'tropical moist forest'.

However, higher levels of classification need to be developed in quantitative terms to be able to understand the complex interactions present in tropical ecosystems.

Holdridge's system offers such levels of classification but from a subjective avenue. The objective of this paper is to present a quantitative method that can be used to classify ecosystems, or the second level of Holdridge system, the association level, within a life zone.

A REVIEW AND THE PROPOSAL

The Life Zone System

The Holdridge Life Zone System (1947, 1966, 1967) allows the grouping into natural units of many common associations of the earth. Holdridge's System separates 120 distinct Life Zones, provided that the subunits of the subtropical region and premontane belt are counted as Life Zones. The system consists of three levels of classifications. The climatically defined Life Zones constitute the primary level. These are subdivided into associations which are differentiated on the basis of local physical environmental conditions. The third level of classification is the subdivision of the associations on the basis of actual vegetation cover or land use (Holdridge et al., 1971).

The first level of Holdridge's system is a quantitative one, making it reproducible, and worldwide understood. However, the second level, i.e., the association level, has not been presented in quantitative terms. For instance, Tosi (1980) points out that "An association is identified, ideally, from the physiognomy of its mature, evolved, natural vegetation, but in the absence thereof, successional stage vegetation or even edaphic and other site factors may be used instead." Even the Holdridge complexity index does not seem to actually discriminate associations within life zones. Furthermore, it seems to be not very well understood. Holdridge (1967, p. 40) points out that "the complexity index value for a hexagon remains the same across the whole range of the life zone, provided that one does not change to a more, or less favorable (*favorable to what?*) association." However, one paragraph below, Dr. Holdridge tells us that "values of the complexity index do vary greatly within a life zone by associations". In one thing that I agree with Dr. Holdridge is that "the index needs extensive testing" before actually using it for association determination.

The complexity index is constructed in such a way to make it highly influenced by the dynamics of the site. Even in mature natural forests, vegetation communities change in structure, therefore, the use of basal area, height, and density, limits the usefulness of this index to identify plant associations that have evolved through the interaction of the abiotic and biotic components of the area.

Quantitative methods place out a common ground for investigators to be able to exchange ideas and understand patterns in nature. In order to have a consistent Life Zone System up to the ecosystem level, or association, I propose in this paper the use of the method of synecological coordinates as a means to classify ecosystems, or associations, within a life zone in Holdridge's classification system.

The method of synecological coordinates

The Method of Synecological Coordinates (MSC) was developed by Dr. Egolfs Bakuzis (1959) and since then it has been applied to ecological studies in some north central states of United States (Brand 1985, Kotar *et al.* (1987), Bakuzis and Kurmis 1978, Pluth and Arneman 1965), and to only one tropical country, Costa Rica (Gutiérrez-Espeleta and Mize 1993).

MSC assumes that plants are the best indicators to determine the environment of a site. It is a powerful technique that can be used to quantify the environmental factors of a site based upon the use of synecological scores assigned to each plant species present in the site. It uses prior information on the requirements of plant species to the environmental factors of moisture, nutrient, heat, and light, to assess the environment of the site where those plants are found.

Each environmental factor or synecological coordinate is assessed by assigning each plant species present in the site a rank from 1, for low requirement, to 5 for high requirement or adaptation of the plant species to the synecological coordinate under consideration (Bakuzis 1959, 1962, Gutiérrez-Espeleta 1991).

The combination or plotting of two synecological coordinates provides what it is known as a synecological field. Of the six possible combinations (Fig. 1), the combination of moisture and nutrient synecological coordinates, the edaphic field, and the combination of heat and light synecological coordinates, the climatic field, are considered the most important ones.

METHODS AND THE STUDY SITE

The proposal

It is hypothesized in this paper that there exists a range of environments that comprise the typical ecosystem of a life zone. These environments do not differ substantially from one another and show a regular and smooth pattern (cloud of points) in all synecological fields (ecographs). Any site or sites with environments located away from this cloud of points make a different ecosystem or association in that life zone with particular characteristics given by their location in the synecological fields.

Holdridge's definitions of the environments for the nine different associations can be located in the edaphic and climatic fields. The smooth and regular pattern within a life zone, mentioned above, would be, in Holdridge terms, the climatic or zonal association. Points in the ecographs away from that zonal pattern would then fit any of the Holdridge association classes. If a plot is found in the edaphic field to be too far right, then, it would represent a wet edaphic association; or, if it falls too far down, then it would represent a infertile edaphic association.

However, classification of ecosystems by using not one, but two or more environmental coordinates provides a better foundation for further ecological studies. The four synecological coordinates permit, in quantitative terms, a broader classification scheme of ecosystems. Whether a particular site is part of a specific ecosystem would depend on how far it is from the "cloud" of points in the synecological fields for a specific life zone. For this, a first attempt is to use an Euclidean distance between two sites (from a given site to its nearest neighbor) in the edaphic and climatic fields. Once these distances are obtained, the interquartile range is calculated[1] to decide which sites, if any, do not belong to the zonal or typical

[1]The interquartile range is obtained by calculating the median of the distances between sites and their nearest neighbor, the first (Q_1) and third (Q_3) quartiles, and then the Inter Quartile Range ($IQR=Q_3-Q_1$). I stated as a rule that all those sites falling out of the limits made by Q_1-3(IQR) and Q_3+3(IQR) should be considered as being part of an ecosystem distinct from the typical one. The width of the interval was determined by theoretical considerations.

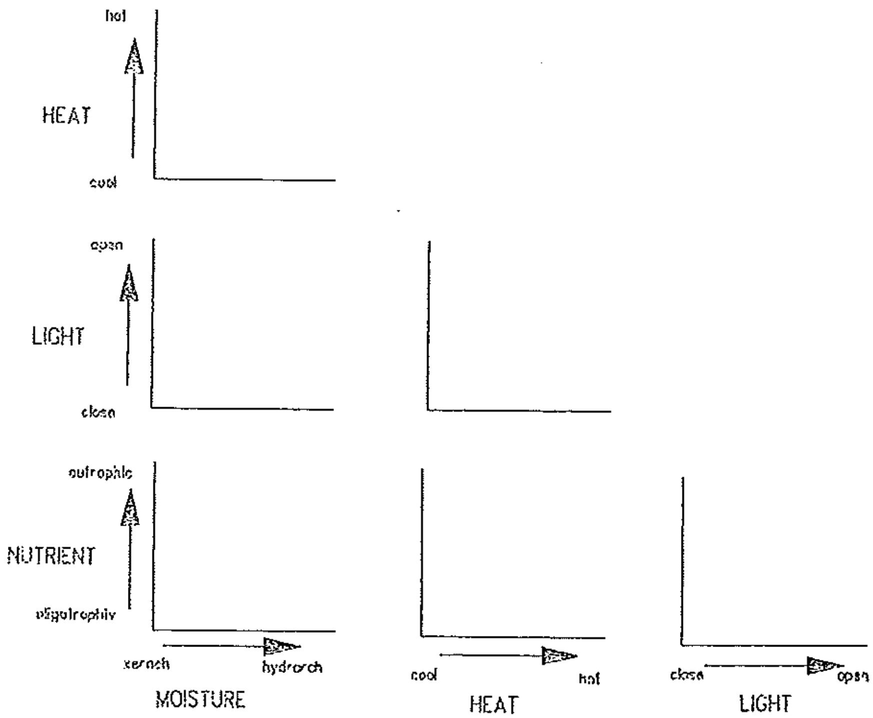

Figure 1 The six possible synecological fields and the gradients of each synecological coordinate. A synecological field is obtained by combining two synecological coordinates

ecosystem for that life zone. This criterion seems to work well in practice, however, further research on other sets of criteria (incorporating probabilistic statements, for example) is undergoing.

Any site, from any life zone, could be classified under one of the classes for each synecological coordinate shown in Table 1. Figure 2 shows the divisions in the edaphic and climatic fields. The unevenness about the spacing of the divisions in a synecological coordinate follows the assumption that if all the environments possible in a life zone are plotted against a single synecological coordinate (a gradient), a bell shaped form will result.

For the moisture coordinate, the term xerarch refers to xeric (dry) environments, and mesarch and hydrarch refer to mesic and very wet environments, respectively. About the nutrient coordinate, oligotrophic refers to nutrient-poor environments, and mesotrophic and eutrophic refer to moderate fertile and rich environments, respectively (Kimmins 1987). With respect to the heat coordinate, cool refers to a permanent cool environment, whereas hot refers to a permanent hot environment throughout the year. Finally, and related to the light coordinate, close refers to a closed forest canopy typical of mature forests, sparse refers to a slightly open forest, and open refers to a open or savanna type of forest. With this classification, any site can be classified with four attributes related, each of them, with the four essential environmental factors affecting any ecosystem.

TABLE 1

Classes and symbols for the synecological classification of terrestrial ecosystems

SYNECOLOGICAL COORDINATE	CLASS	SYMBOL
MOISTURE (M)	xerarch	x
	mesarch	m
	hydrarch	y
NUTRIENT (N)	oligotrophic	g
	mesotrophic	s
	eutrophic	e
HEAT (H)	cool	c
	warm	w
	hot	h
LIGHT (L)	close	o
	sparse	a
	open	p

Beside the class symbols in the classification scheme, modifiers (+, -) can be used to point out the upper or lower limit, if any, where the site fits in the field. For example, a site might be (m^{+}_s_w_a), to indicate that this site is found in a high mesarch, mesotrophic, warm and sparse or sightly open forest ecosystem. Note that this notation denotes the moisture, nutrient, heat and light synecological coordinates, respectively. A small letter and its modifier can be used alone if only the environmental status of a site with respect to that synecological coordinate is desired.

The field work

The study was conducted in Costa Rica in the Tropical Premontane Moist Forest (bh-P) (the basal belt transition was not considered). It is located roughly within longitudes 83°45' and 85°00' and latitudes 9°45' and 10°40' north of the Equator[2], according to Tosi (1969).

The field work was conducted from February to April 1991. Because this life zone is primarily under agriculture and grazing use, only 19 10x25 m² plots of undisturbed natural forests could be located. Selected plots did not show any evidence of recent disturbance, such as stumps, grazing, dung, and alike, and did show well established forest canopy (stratification).

[2] A very small portion of this life zone NE of Costa Rica was not considered in this study.

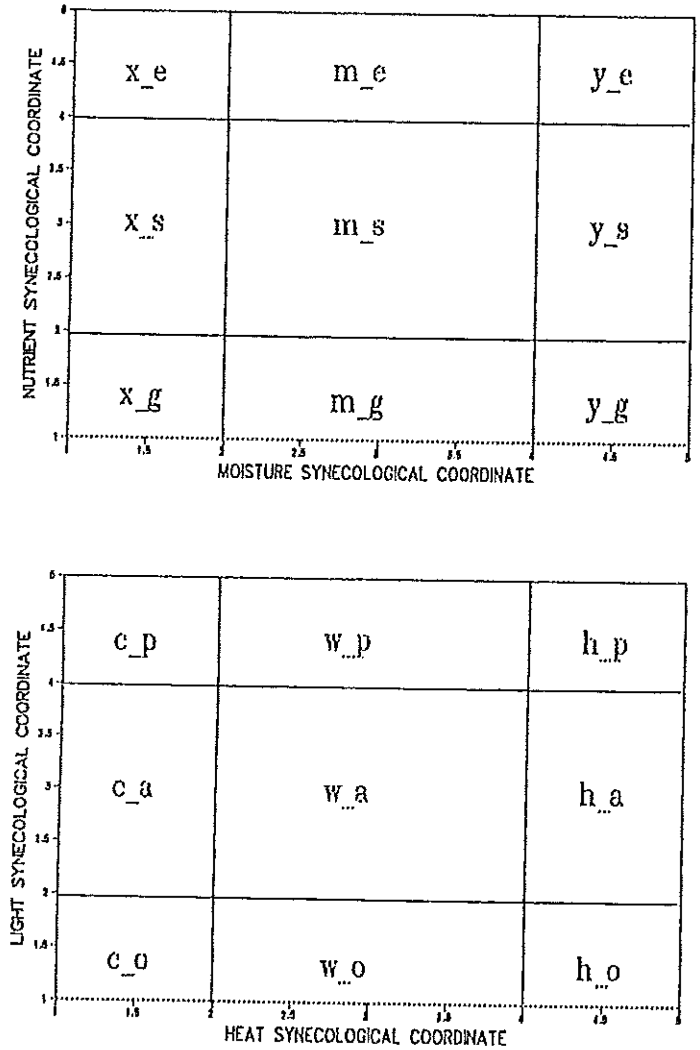

Figure 3 Synecological classes in the edaphic and climatic fields. Ecosystem types are defined by the combination of two classes from the edaphic and climatic fields, respectively

On each plot, plant species names were recorded for all plants over 1.3 m in height. They were grouped as trees, shrubs, herbs, lianas, and others. Three 1-m^2 quadrats were taken along the center line of the plot for lower than 1.3 m height vegetation sampling. For species not identified in the field, samples of green material were bagged and identified within one week at the University of Costa Rica Herbarium.

The list of plants identified to species level was independently given to two botanists who were very familiar with this life zone. They assigned the initial synecological coordinate scores for each plant species. These initial scores were later compared and disagreements (very few) were solved by means of consensus. Adjusted scores were obtained based on the species composition of sampled plots (combining plot and quadrat information) to more accurately reflect the local environmental preferences of a species.

SYCOOR (Gutiérrez-Espeleta and Brand 1993), a computer program for MSC, was used to obtain, for each plot, a numerical estimation of each synecological coordinate.

RESULTS

About 40% of the plants sampled in the quadrats, and about 80% sampled in the plots were identified. Of the total number of plants (214), 135 of them were identified to species. A complete list of all the plant species, sorted alphabetically, found in this study is presented in Table 2. In Table 2, each plant species is identified by its type (life form), and has its initial and adjusted (if any) synecological scores for moisture, nutrient, heat, and light. Table 3 presents the location of the sites, the number of identified plant species, and the site synecological coordinate scores.

From field observation, sites 15, 16 and 17 were different from the others in this life zone. Some of these differences consisted in that they were wetter, more dense, with thick and wet litter (at the end of February), and with some plant species never seen in the other sites (such as epiphytes). Sites 15, and 16 are located in Volio, San Ramón, and site 17 in Coris, Cartago. Because of their features, I consulted Mr. Rafael Bolaños from the Tropical Science Center, expert in the Holdridge Life Zone System, and from the field findings, these sites were classified within the wet atmospheric association.

Site 7 also presented some different characteristics from the rest. It was located on the summit of a hill in Guísaros (Atenas), Alajuela, and presented fewer shrubs and herbaceous plants, resembling some features of an open forest. There was no consultation on this site but from its characteristics I located it under the dry edaphic association, *in sensu* Holdridge.

All the data were used to develop the synecological fields. It can be seen from the edaphic and climatic fields (Figures 3 and 4, respectively) that bh-P ranges from xerarch, oligotrophic, warm and sparse forest to mesarch, mesotrophic, hot, and less open forest ecosystems ($x\_g\_w\_a \rightarrow m\_s\_h\_p^-$), showing a typical, smooth "cloud" of points ranging from low xerarch, low oligotrophic, high warm, high sparse forest to mesarch, mesotrophic, hot and less open forest ecosystems ($x^+\_g^+\_w^+\_a^+ \rightarrow m\_s\_h\_p^-$).

TABLE 2

Species list with species synecological coordinate values

TYPE : 1 TREE 2 SHRUB 3 HERB 4 LIANA 5 OTHER (*) INTRODUCED SPECIES

SPECIES	FAMILY	TYPE	SYNECOLOGICAL COORDINATES INITIAL M N H L	SYNECOLOGICAL COORDINATES ADJUSTED M N H L
Acacia costaricensis Schenck	Fabaceae/Mimosoideae	2	2 2 4 5	2 2 4 5
Aegiphila costaricensis Moldenke	Verbenaceae	1	2 3 3 3	2 3 3 3
Albizzia adinocephala (Donn.Sm.) Britt.&Rose	Fabaceae/Mimosoideae	1	2 2 4 5	2 2 4 5
Allophylus occidentalis (Sw.) Radlk.	Sapindaceae	1	2 2 4 5	2 2 4 5
Amyris sylvatica Jacq.	Rutaceae	2	3 3 2 2	3 3 2 2
Anacardium excelsum (Bert. & Balb.) Skeels	Anacardiaceae	1	5 4 4 5	5 4 4 5
Andira inermis (Sw.) H.B.K	Fabaceae/Papilionoideae	1	2 3 4 5	2 3 4 5
Annona cherimolia Mill.	Annonaceae	1	3 2 3 4	3 2 3 4
Annona pittieri Donn. Sm.	Annonaceae	1	3 3 2 3	3 3 2 3
Apeiba tibourbou Aubl.	Tiliaceae	1	2 2 4 5	2 2 4 5
Aphelandra scabra (Vahl.) Smith	Acanthaceae	2	1 1 5 5	1 1 5 5
Ardisia compresea H.B.K	Myrsinaceae	1	3 3 2 3	4 4 2 3
Ardisia revoluta H. B. K	Myrsinaceae	1	1 2 4 5	2 2 5 5
Asclepias curassavica L.	Asclepiadaceae	3	2 1 4 5	2 1 4 5
Brosimum costaricanum Liebm.	Moraceae	1	3 3 4 2	3 3 4 2
Bunchosia pilosa H. B. K.	Malpighiaceae	1	2 3 4 4	2 3 4 4
Bursera simaruba (L.) Sarg.	Burseraceae	1	1 2 4 5	1 2 4 5
Byrsonima crassifolia (L.) D.C.	Malpighiaceae	1	1 1 4 5	1 1 4 5
Casearia arguta H.B.K.	Flacourtiaceae	1	2 2 4 5	2 2 4 5
Casearia nitida (L.) Jacq.	Flacourtiaceae	1	2 2 4 4	2 2 4 4
Casearia sylvestris Swartz	Flacourtiaceae	1	2 2 4 4	2 2 4 4
Casimiroa edulis Llave & Lex.	Rutaceae	1	2 3 3 4	2 3 3 4
Cassia maxonii (Britt. & Rose) Schery	Fabaceae/Caesalpinioidea	1	2 2 4 4	2 2 4 4
Cecropia peltata L.	Moraceae	1	1 2 4 5	1 2 4 5
Cedrela odorata L.	Meliaceae	1	2 3 4 5	2 3 4 5
Cestrum lanatum Mart. & Gal.	Solanaceae	2	2 2 3 4	2 2 3 4
Chrysophyllum cainito L.	Sapotaceae	1	2 3 4 5	2 3 4 5
Cissampelos pareira L.	Menispermaceae	4	2 1 4 5	2 1 4 5
Citharexylum donnell-smithii Green.	Verbenaceae	1	3 3 3 4	3 3 3 4
Citrus sinensis (L.) Osbeck (*)	Rutaceae	1	3 2 3 5	3 2 3 5
Clarisia biflora Ruiz Lopez & Pavon	Moraceae	1	3 3 3 4	3 3 3 4
Clethta mexicana A.D.C.	Clethraceae	1	1 1 3 5	1 1 3 5
Coccoloba porphyrostachys Gomez-Laurito	Polygonaceae	1	4 3 3 3	4 3 3 3
Cochlospermum vitifolium Willd.	Cochlospermaceae	1	1 2 4 5	1 2 4 5
Coffea arabica L. (*)	Rubiaceae	2	3 4 3 5	5 4 2 2
Cordia alliodora (Ruiz & Pavon) Oken	Boraginaceae	1	3 4 4 5	3 4 4 5
Cordia panamensis Riley	Boraginaceae	1	2 3 4 5	2 3 4 5
Crossopetalum tonduzii (Loes.) Lundell	Celastraceae	1	3 3 3 4	3 3 3 4
Croton glabellus L.	Euphorbiaceae	1	3 2 3 3	3 2 3 3
Croton gossypiifolius Vahl.	Euphorbiaceae	1	2 2 3 5	2 2 3 5
Croton niveus Jacq.	Euphorbiaceae	1	3 2 3 4	3 2 3 4

(table 1 continues)

TYPE = 1 TREE 2 SHRUB 3 HERB 4 LIANA 5 OTHER (*) INTRODUCED SPECIES

SPECIES	FAMILY	TYPE	SYNECOLOGICAL COORDINATES INITIAL M	N	H	L	ADJUSTED M	N	H	L
Croton panamensis Muell.	Euphorbiaceae	1	3	2	4	5	2	3	4	5
Cupania glabra Swartz	Sapindaceae	1	2	3	3	5	5	4	3	1
Cupania guatemalensis Radlk.	Sapindaceae	1	2	2	4	4	1	1	4	5
Desmopsis bibracteata (Rob.) Saff.	Annonaceae	1	3	2	2	3	3	2	3	4
Diphysa americana (Mill.) M. Sousa	Fabaceae/Papilionoideae	1	3	2	4	5	1	1	4	5
Enterolobium cyclocarpum (Jacq.)Griseb.	Fabaceae/Mimosoideae	1	3	3	4	5	3	1	4	5
Eriobotrya japonica Lindl. (*)	Rosaceae	1	3	4	3	4	3	4	3	4
Eugenia cartagensis Berg.	Myrtaceae	1	2	3	3	4	3	3	3	4
Eugenia truncata Berg.	Myrtaceae	1	2	3	3	3	2	3	3	3
Eupatorium glaberrimum D.C.	Asteraceae	1	2	2	3	4	2	2	3	4
Eupatorium morifolium Miller	Asteraceae	1	3	3	3	3	1	3	3	3
Faramea quercetorum Standl.	Rubiaceae	2	3	3	2	3	3	3	2	3
Ficus costaricana (Liebm.) Miq.	Moraceae	1	2	3	3	5	2	2	3	5
Ficus jimenezii Standl.	Moraceae	1	2	3	3	5	2	3	3	5
Guarea rhopalocarpa Radlk.	Meliaceae	1	3	3	3	3	3	3	3	3
Guatteria diospyroides Baillon	Annonaceae	1	3	3	2	3	3	3	2	3
Guazuma tomentosa H.B.K.	Sterculiaceae	1	2	2	4	5	1	1	4	5
Hamelia patens Jacq.	Rubiaceae	2	2	3	3	5	2	3	3	5
Hauya lucida Donn.Sm.	Onagraceae	1	3	3	3	3	3	3	3	3
Heliocarpus appendiculatus Turcz.	Tiliaceae	1	3	3	3	5	3	3	3	5
Hymenaea courbaril L.	Fabaceae/Papilionoideae	1	3	3	4	5	3	3	4	5
Inga punctata Willd.	Fabaceae/Mimosoideae	1	2	2	3	5	2	2	3	5
Lonchocarpus atropurpureus Benth.	Fabaceae/Papilionoideae	1	2	2	3	5	2	2	5	5
Lonchocarpus costaricensis (Donn. Sm.) Pitt.	Fabaceae/Papilionoideae	1	2	3	3	4	1	1	4	5
Lonchocarpus sericeus Benth.	Fabaceae/Papilionoideae	1	2	3	3	4	2	3	3	4
Luehea speciosa Willd.	Tiliaceae	1	2	2	4	5	1	1	4	5
Machaerium biovulatum Micheli	Fabaceae/Papilionoideae	1	2	2	4	5	2	2	4	5
Malpighia glabra L.	Malpighiaceae	2	3	3	3	3	3	3	3	3
Malvaviscus arboreus Cav.	Malvaceae	1	3	3	3	4	5	4	2	2
Mauria birringo Tulasne	Anacardiaceae	1	3	3	3	3	3	3	3	3
Mauria heterophylla H.B.K.	Anacardiaceae	1	3	2	3	3	3	2	3	3
Miconia argentea (Sw) D.C.	Melastomaceae	1	2	3	3	5	2	3	3	5
Mollinedia costaricensis Donn. Sm.	Monimiaceae	2	3	3	3	2	3	3	2	2
Myrcia oerstediana Berg.	Myrtaceae	1	2	3	3	4	2	2	4	4
Myriocarpa longipes Liebm.	Urticaceae	2	3	3	3	3	3	3	3	3
Nectandra cufodontisii (Schm.)C.K.Allen	Lauraceae	1	3	3	3	5	3	3	3	5
Nectandra sinuata Mez.	Lauraceae	1	3	3	3	3	3	3	3	3
Neea psychotrioides Donn. Sm.	Nyctaginaceae	2	3	3	3	2	3	3	3	2
Ocotea veraguensis (Meissn.) Mez	Lauraceae	1	2	3	4	4	1	2	4	5
Onoseris onoseroides (H.B.K.) B.L.Rob.	Asteraceae	2	2	2	4	5	2	2	4	5
Oreopanax xalapensis (H.B.K.) Done.& Planch.	Araliaceae	1	3	3	2	4	3	3	2	4
Paullinia costaricensis Radlk.	Sapindaceae	4	2	3	3	4	2	3	3	4
Persea caerulea (R.& P.) Mez	Lauraceae	1	2	3	3	4	2	3	3	4
Phoebe brenesii Standl.	Lauraceae	1	2	3	3	5	1	1	4	5

(table 1 continues)

TYPE = 1 TREE 2 SHRUB 3 HERB 4 LIANA 5 OTHER (*) INTRODUCED SPECIES

SPECIES	FAMILY	TYPE	SYNECOLOGICAL COORDINATES INITIAL M N H L	ADJUSTED M N H L
Phyllanthus lathyroides H.B.K.	Euphorbiaceae	3	3 2 3 5	3 2 3 5
Picramnia antidesma (D.C.) W. Thomas	Simaroubaceae	1	3 2 3 3	2 2 5 4
Picramnia teapensis Tulasne	Simaroubaceae	1	2 2 3 3	2 2 3 3
Piper marginatum Jacq.	Piperaceae	2	3 2 3 4	3 2 3 4
Pisonia aculeata L.	Nyctaginaceae	1	2 2 4 4	2 2 4 4
Pithecoctenium crucigerum (L.) A. Gentry	Bignoniaceae	4	2 3 3 4	2 3 3 4
Pseudobombax septenatum (Jacq.) Dugand	Bombacaceae	1	3 3 3 4	3 3 3 4
Pseudolmedia oxyphyllaria Donn. Sm.	Moraceae	1	3 3 3 3	3 3 3 3
Psidium guajava L.	Myrtaceae	1	2 3 3 5	2 3 3 5
Psychotria carthaginensis Jacq.	Rubiaceae	1	2 3 3 3	2 3 3 3
Quercus ocarpa Liebm.	Fagaceae	1	3 3 2 5	3 3 2 5
Quercus seemannii Liebm.	Fagaceae	1	3 3 2 4	3 3 2 4
Randia armata (Sw.) D.C.	Rubiaceae	2	2 2 2 3	2 2 2 3
Randia karstenii Polak.	Rubiaceae	2	2 2 2 3	3 3 3 2
Randia subcordata Standl.	Rubiaceae	1	2 2 3 3	2 2 3 3
Rapanea ferruginea (R. & P.) Mez	Myrsinaceae	1	3 2 3 4	3 2 3 4
Rapanea pellucido-punctata (Oerst.) Mez	Myrsinaceae	1	2 3 3 4	1 1 4 5
Rivina humilis L.	Phytolaccaceae	2	2 2 2 3	2 2 2 3
Roupala montana Aubl.	Proteaceae	1	3 3 3 4	3 3 3 4
Ruellia paniculata L.	Acanthaceae	2	1 1 4 5	1 1 4 5
Russelia verticillata H.B.K.	Scrophulariaceae	3	2 2 3 4	2 2 3 4
Sapium thelocarpum Schum. & Pitt.	Euphorbiaceae	1	3 3 3 3	3 3 3 3
Schizolobium parahybum (Vell.) Blake	Fabaceae/Caesalpinioidea	1	3 3 4 5	3 3 4 5
Sciadodendron excelsum Griseb.	Araliaceae	1	2 3 4 5	2 3 4 5
Sideroxylon persimile (Hemsl.) Penn.	Sapotaceae	1	3 3 3 4	3 3 3 4
Siparuna griseo-flavescens Perkins	Monimiaceae	2	2 2 3 2	2 2 3 2
Sloanea brenesii Standl.	Elaeocarpaceae	1	3 3 2 3	3 3 2 3
Solanum brenesii Morton & Standl.	Solanaceae	2	3 3 3 4	1 1 4 4
Sorocea trophoides W. Burger	Moraceae	1	3 3 3 3	3 3 3 3
Spondias mombin L.	Anacardiaceae	1	3 3 4 5	3 3 4 5
Stemmadenia alfari Donn. Sm.	Apocynaceae	1	4 3 3 3	4 3 3 3
Stemmadenia donnell-smithii (Rose) Woodson	Apocynaceae	1	2 3 4 4	2 3 4 4
Stemmadenia glabra Benth.	Apocynaceae	1	2 3 3 4	2 3 3 4
Symphonia globulifera L.f.	Clusiaceae	1	3 3 2 3	3 3 2 3
Syzygium jambos (L.) Alston (*)	Myrtaceae	1	2 3 2 4	2 3 2 4
Tabebuia rosea (Vertol.) D.C.	Bignoniaceae	1	3 3 4 5	3 3 4 5
Tecoma stans (L.) H.B.K.	Bignoniaceae	1	2 2 4 5	2 2 4 5
Thouinidium decandrum (H.& B.) Radlk.	Sapindaceae	1	2 3 4 4	2 3 4 4
Tournefortia glabra L.	Boraginaceae	2	2 2 3 4	2 2 3 4
Trichilia havanensis Jacq.	Meliaceae	1	3 3 4 5	3 2 3 4
Trichilia martiana C.D.C.	Meliaceae	1	2 3 4 4	2 2 5 4
Trophis racemosa (L.) Urban	Moraceae	1	3 3 3 2	3 3 3 2
Turpinia occidentalis (Sw.) G. Don.	Staphyleaceae	1	3 3 3 3	3 3 3 3
Ulmus mexicana (Lieb.) Planchon	Ulmaceae	1	3 3 2 4	3 3 2 4
Vernonia patens H.B.K.	Asteraceae	2	3 1 3 5	3 1 3 5

(table 1 continues)

TYPE = 1 TREE 2 SHRUB 3 HERB 4 LIANA 5 OTHER (*) INTRODUCED SPECIES

SPECIES	FAMILY	TYPE	SYNECOLOGICAL COORDINATES INITIAL M N H L	ADJUSTED M N H L
Vismia guianensis (Aubl.) Pers.	Clusiaceae	1	3 2 4 5	3 2 4 5
Zanthoxylum elephantiasis Macfad.	Rutaceae	1	3 3 3 4	2 2 5 4
Zanthoxylum limoncello Planch. & Oerst.	Rutaceae	1	3 3 3 2	3 3 3 2
Zanthoxylum microcarpum Griseb.	Rutaceae	1	3 3 3 4	1 1 4 5
Zanthoxylum monophyllum (Lam.) P.Wilson	Rutaceae	1	3 3 3 4	3 3 3 4

From the edaphic field, the distance to the nearest neighbor median was 0.13, and the IQR was 0.11. The typical bounds are distances from 0 to 0.46, distances beyond those limits are suspected to belong to a different ecosystem or association. The distance from site 7 to site 6 was 0.48, therefore, and under the established rule, there is evidence of site 7 belonging to other association than the typical one (the cloud). Because site 7 did not present "suspicious" behavior in the climatic field (Fig. 4), it was classified as belonging to a xerarch, oligotrophic, low hot and sparse forest ecosystem (x_g_h⁻_a) within the premontane moist forest.

With respect to the climatic field (Fig. 4), the median distance was 0.18 with an IQR of 0.13. Therefore, the bounds for the typical association are from 0 to 0.57. The nearest neighbor of site 17 is site 18, and they are 0.60 units apart. Therefore, that distance falls outside the "cloud" boundary. If site 17 does not belong to the zonal association, sites 15 and 16 will not evidently, therefore, these three sites belong to a different ecosystem or association. It was then concluded that those sites belong to a mesarch, mesotrophic, warm, and sparsely forest ecosystem (m_s_w_a) which is different from the range of the zonal one. These sites represent an ecosystem within bh-P different from the typical or zonal one, particularly, in the climatic field (heat and light coordinates).

DISCUSSION

The use of the proposed ecosystem classification methodology resulted in a synecological classification of terrestrial ecosystems within the sampled Tropical premontane moist forest Life Zone. This means that it was possible to determine not only the range of variation of a zonal or typical ecosystem for this life zone, but also, the determination of two different ecosystems from the typical one: one in the edaphic field and the other in the climatic field. This result confirmed the initial classification made from observational information only, but with the difference that the researcher does not have to be an expert on Holdridge Life Zone System to do the ecosystem identification.

TABLE 3

Plot list and geographical and synecological information

Plot ID	Location	No. spp	SYNECOLOGICAL COORDINATES moisture	nutrient	heat	light
01	214,501	20	2.10	2.40	3.90	4.80
02	213,502	18	2.06	2.00	3.89	4.50
03	220,504	14	1.93	1.86	3.64	4.21
04	221,505	12	2.08	2.50	3.50	4.25
05	221,505	15	2.47	2.67	3.53	4.07
06	217,493	11	1.64	1.91	4.09	4.64
07	217,493	10	1.40	1.50	4.10	4.40
08	217,493	17	2.24	2.18	3.76	4.18
09	222,499	33	1.76	2.00	3.91	4.45
10	211,515	28	1.82	1.86	3.79	4.54
11	211,515	21	1.81	1.81	3.81	4.76
12	206,531	19	2.68	2.63	3.26	3.74
13	206,531	18	2.44	2.33	3.33	4.11
14	207,530	17	2.71	2.53	3.24	3.76
15	235,487	24	2.96	2.96	2.83	2.88
16	235,489	13	3.23	3.08	2.54	3.08
17	204,535	16	3.06	2.88	2.81	3.13
18	208,543	18	2.83	2.78	2.72	3.72
19	204,549	12	2.83	2.75	3.00	3.92

We have been brought up in a very biodiverse part of the world and we ought to keep it like that if we want our children enjoy it with dignity. For this reason, we must recognize that one of the most urgent tasks to tropical foresters is to develop methodologies that appropriately allows for a wise use of natural forests.

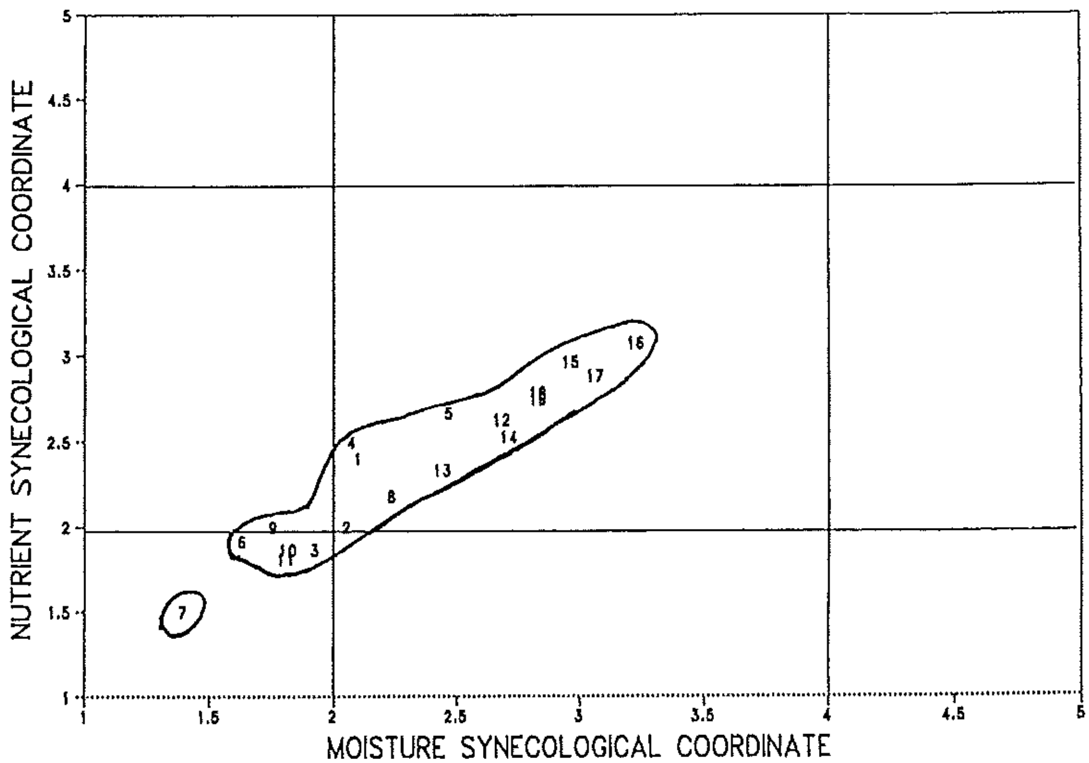

Figure 4 Nutrient-Moisture (edaphic) field. Relative scale, from 1 to 5, indicates a gradient to wetter and more fertile sites in the Tropical premontane moist forest Life Zone. Costa Rica

Gutiérrez-Espeleta (1991) stated that a forest consists of all the biotic and abiotic elements contained in a specific vegetated location, with trees as the most obvious physiognomic characteristic. A forest is continuously changing because of the interaction between the environment and its biotic components, therefore, vegetation is relatively unstable, while the environment is essentially stable within the time frame associated with forest management (Klinka *et al.* 1984). Because the environment affects directly tree growth, site quality determination requires the study of environmental properties of ecosystems. It is possible to use those properties to differentiate ecosystems in units with similar biotic potential (quality) (Klinka *et al.* 1984). The proposed classification aims to that target.

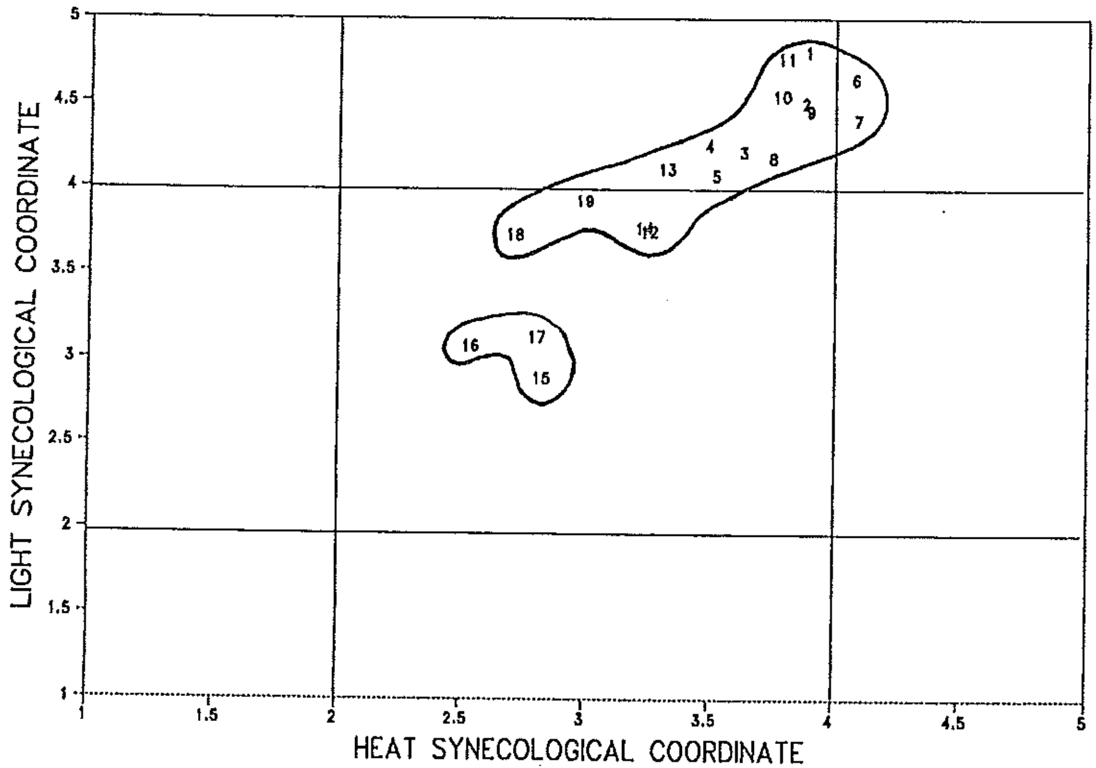

Figure 5 Light-Heat (climatic) synecological field. Relative scale, from 1 to 5, indicates a gradient to a more open and hotter forest sites in the tropical premontane moist forest Life Zone. Costa Rica

The ecosystem classification presented here is still in the initial stages. More research is needed to test the goodness of the employed criteria. Other concepts might be added in order to obtain a biogeoclimatic ecosystem classification; for this, the use of geographic information systems becomes mandatory. However, the principles for a quantitative ecosystem classification system have been established.

ACKNOWLEDGMENTS

Carlos Morales and Lizeth Díaz identified plants in the field and at the Universidad de Costa Rica Herbarium; Quírico Jiménez, and Carlos Morales assigned initial synecological coordinate values to species; Rafael Bolaños provided an update of the bh-P life zone limits. Luis Fournier gave, very timely, ecological and field advice. Pia Paavy and Gary Brand made useful comments on the manuscript. The Vicerrectoría de Investigación of the Universidad de Costa Rica and the Farnsworth Memorial Fellowship at the Department of Forestry of Iowa State University provided financial support.

The author thanks them all.

RESUMEN

Una tarea de suma importancia en el proceso de comprensión de los patrones que se observan en las comuninades de plantas, es el desarrollo de una metodología para la clasificación de aquellas unidades que muestran características similares. La clasificación cuantitativa es una herramienta matemática que permite organizar la información disponible en entidades comprensibles sin perder la perspectiva del todo. El método de clasificación que se propone provee, en términos cuantitativos, una clasificación de ecosistemas (asociaciones) que se encuentran en las Zonas de Vida, *in sensu* Holdridge. Este método se basa en el supuesto de que las plantas son los mejores indicadores del ambiente en un sitio, y que por medio del método de coordenadas sinecológicas, se pueden utilizar para efectos prácticos. Este método fue usado en 19 parcelas de bosque maduro de la zona de vida: Bosque Tropical Húmedo Premontano, en Costa Rica. Esta Zona de Vida fue caracterizada según las coordenadas sinecológicas de humedad, nutrimentos, calor y luz, permitiendo la determinación de ecosistemas o asociaciones particulares. Los resultados fueron similares a los esperados a partir del conocimiento empírico.

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CRÉDITOS EDITORIALES:

Portada:
Georgina Garcia Herrera

Fotografía:
J. Monge-Nájera

Digitación:
Alexandra Sanabria

Ficha bibliográfica:
Marta Castillo

Primera Edición
Universidad Estatal a Distancia
San José, Costa Rica, 1994

338.91
D441d Desarrollo sostenible: la visión desde los países menos industrializados - Sustainable development: the view from the less industrialized countries / Editor Julián Monge-Nájera. — San José, Costa Rica: UNED, 1994
400 p.; 21 cm

Edición bilingüe
ISBN 9977-64-78-5

1. Desarrollo sostenible. I. Monge-Nájera, Julián. II. Título.

Impreso en Costa Rica
en la Oficina de Publicaciones de la UNED.