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Un nuevo enfoque metodológico

para la representación geoespacial de los ecosistemas neotropicales

A new methodological approach for the geospatial representation of neotropical ecosystems

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Resumen

La importancia de representar los ecosistemas neotropicales surge de la necesidad de generar cartografía que facilite comprender su segregación en el espacio. El objetivo de nuestro trabajo fue diseñar un modelo de representación cartográfica de ecosistemas, a través de procesos que integran los insumos cartográficos y sus respectivas escalas, asociados a un sistema de clasificación jerárquica. Para ello, se determinaron niveles jerárquicos con base en criterios geofísicos y biofísicos, característicos de los ecosistemas neotropicales, se seleccionaron insumos cartográficos en cada nivel jerárquico asociado a su respectiva escala. Se concluye que los ecosistemas neotropicales deben ser representados a mayores escalas, ya que es la única forma de obtener el detalle necesario de los atributos que los caracterizan, esta necesidad está determinada por la complejidad derivada de la diversidad geofísica y biológica de esta región.
PALABRAS CLAVE: clasificación jerárquica; ecosistemas; criterios geofísicos y biofísicos; escalas de alta resolución.

Abstract

Provides cartography to represent neotropicals ecosystems helps to understand segregation in space. When mapping ecosystems, ecologists have some problems, some are related to scales and cartographic inputs. The goal of our work was to design a model of cartographic representation of ecosystems, through processes that integrate cartographic inputs and their respective scales, associated with a hierarchical classification system. For this purpose, we determine hierarchical levels based on geophysical and biophysical criteria, characteristic of Neotropical ecosystems. We select cartographic inputs in each hierarchical level associated with their respective scale. We conclude that the Neotropical ecosystems must be represented at greater scales, since it is the only way to obtain the necessary detail of the attributes that characterize them, this need is determined by the complexity derived from the geophysical and biological diversity of this region.
KEY WORDS: hierarchical classification; ecosystems; geophysical and biophysical criteria; high-resolution scale.

1. Introduction

Remote sensing techniques applied in ecology have demonstrated the usefulness that remote sensing gives us to know several fundamental aspects in the physiology of ecosystems. An example of this is the transformation of natural ecosystems to anthropic systems (Kerr & Ostrovsky, 2003) or how it shows (Coppin *et al.*, 2004). In the change of the strata of the forests to less robust vegetation and to systems intervened. But when defining the limits of the ecosystem, the ecologists ask ourselves questions like: Is the ecosystem boundary correct? or Is the scale of detail correct? These issues/questions are important to delineate the heterogeneity of landscapes and provide spatial frameworks for environmental management (Xu *et al.*, 204).

Different models have been proposed for the representation of ecosystems, such as Ecophysiological models (e.g. Walter & Breckle, 1975, 1985; Walter & Box, 1976), physiognomic models (e.g. Hueck & Siebert, 1972; Mueller-Dombois & Ellenberg, 1974) and bioclimatics (e.g. Holdridge, 1947, 1967; Koppen, 1936). Nevertheless, we believe that this is a debate, due to the way of conceiving the ecosystem. This has provoked a discussion to choose the set of factors that will serve for the elaboration of the classification system. For instance, the concept of 'landscape ecosystem' by Rowe & Barnes (1994) in which emphasizes that inside the ecosystem the species are subject to or controlled by the environment characteristics. Another approach is the 'bio-ecosystem' which is considered as a biotope of several geophysical characteristics that allow defining a particular geographical area, but also includes the importance of the mutual relationship with its biocenosis (flora and fauna). These conceptions allow us to understand that for each theoretical model exists a greater weight of the geophysical or the biological, which is called Geo-Systems versus Bio-Systems (Comer *et al.*, 2003).

Considering the aforementioned, there are some criteria to classify ecosystems, which directly leads to the way of representing them cartographically. The cartographic methodologies use different concepts, for example the concept of 'Levels of detail', which allows to determine the cartography of ecosystems based on characteristics or attributes of geographic objects. These can be associated with different scales, for instance (Sierra *et al.*, 1999), developed the map of plant formations at a scale of 1: 250,000 based on levels of detail. Another concept is that of 'hierarchical levels', that has the intention of being organized. Since it uses a system of submission of attributes, but in this concept, there is the problem of the high number of variables that sometimes tend to arise. This is precisely the problem that happens in the ecosystems of the Neotropics. Since due to its geophysical and biophysical complexity, many variables are considered that sometimes do not even exist in the cartographic inputs of the same, causing the first error, which is to propose exaggerated cartographic variables.

Hierarchical procedures and methodologies of classification have been generated in places where the ecosystems have homogeneous characteristics, such as North America and Europe (e.g., Comer *et al.*, 2003; Host *et al.*, 1996). These systems have been used and replicated in the Neotropical region (e.g., Josse *et al.*, 2003). But the landscape reality of the Neotropics is very different from the European or North American regions, due to the great geophysical and biological diversity of this region. This great diversity is due to climatic heterogeneity and geological history, which allowed us to determine a complex structure and heterogeneous composition characteristic of the region (Burnham & Graham, 1999). The high diversity of ecosystems in the Neotropics occurs because this region extends between the Tropics of Cancer and Capricorn, and includes a vast diversity of vegetation that contains deserts, evergreen forests, humid tropical forests, mangroves, Andean paramo, etc. (Cayuela & Cerda, 2012). It is for this reason that we ask the question: is it appropriate to use methodologies and classification systems from other regions to generate cartography of Neotropical ecosystems? We observe the need for innovation of the classification systems to elaborate cartography. This is why our work focused on developing a methodology based on a hierarchical classification system, that integrates cartographic variables and their respective scale, in order to obtain high-resolution cartography of Neotropical ecosystems.

2. Materials and methods

2.1 Theoretical hierarchical model

Ecosystems can be defined, classified and spatially recognized. To meet these premises, we select the system of hierarchical classifiers, recognizing a hierarchical system that is characterized by organizing the structural and functional components in a domain range. The structural factors of the ecosystems or attributes are translated as descriptive factors in the geoinformation. These are represented at different scales. This is why our work starts from the use of low-resolution scales (1: 1,200,000), and we are increasing it, until reaching the highest scale considered to represent ecosystems of the Neotropics, which is 1: 25,000. In this context, the use of the constituent attributes of the ecosystems allowed us to relate the necessary inputs to determine the levels of homogeneity of the hierarchical classes (TABLE 1). We build our system considering six hierarchical levels:

2.1.1 Class (Biogeographical Zones and Climate Floors)

These regions are classified based on the physiognomy or appearance of the vegetation on a large scale, associated with general geophysical factors that accompany it (temperature, precipitation, potential evapotranspiration, latitude). For the classification of this great region, the limits of the life zones are defined by the annual mean values of said components (Holdridge, 1947). The bioclimatic floors are geophysical units that show the relation of the thermal indexes with the altitude (Ministerio del Ambiente Ecuador, 2012). The scales of these layers can range between 1: 1,200,000 or more.

TABLE 1. Matrix of levels of hierarchical classification, proposal for classification of ecosystems, inputs and related scales

Class	Biogeographical zones and Climate Floors (Live Zones maps, Climate floors maps, Biogeographical maps)	Scales: 1: 1,200,000 to 1: 1,000,000
Subclass	Geology (Geology maps)	Scales: 1: 1,200,000 to 1: 1,000,000
Macrogroup	Weather (Thermal maps, precipitation maps, evapotranspiration maps, weather maps)	Scales: 1: 250,000 to 1: 100,000
Group	Vegetal formation (Vegetal formation maps, natural cover maps)	Scales: 1: 250,000 to 1: 100,000
Order	Geopedology, Land Use (Geomorphology maps, soils maps, land use maps)	Scales:1: 50,000 to 1: 25,000
Specific group	Ecosystem	Scales: 1:25.000

2.1.2 Subclass (Geology)

They are formal lithostratigraphic units, which are bodies of rocks characterized by their composition and lithological structures. The geological unit is associated with the process of natural history of its space (Murphy & Salvador, 1999). The necessary scale of the inputs is 1: 1,000,000.

The cartographic synthesis of these first two groups (class and subclass) we denominate 'Homogeneous Zones', and to this first intermediate product we denominate it with the same name.

2.1.3 Macrogroup (Climate)

They are specific climatic characteristics of the 'Homogeneous Zones' (synthesis of the first two categories). The climate presents characteristics that are derived from the ecological relationship that exists between the climatic geophysical factors with the vegetation of the area. The macrogroup is important for the determination of an ecosystem due to the influence of climate on them. The amount of solar energy that is absorbed by the surface of the terrestrial ecosystem allows to exchange gases of importance for atmospheric dynamics (Meir *et al.*, 2006). The relationships are based on parameters of temperature, precipitation, and those derived from the relationship with vegetation (Arrazola *et al.*, 2000). The input of inputs for this component ranges from 1: 250,000.

2.1.4 Group (Plant formations)

Refers to the type of physiognomy and phenology of the vegetation. This is defined on the basis of structural criteria of the predominant plant communities associated with the geophysical conditions of its space (Huber & Alarcón, 1988).

In addition, it is a classifier that associates this hierarchical level with the geophysical conditions of the homogeneous areas. An example of this group is the name of the physiognomy associated with the climatic factor (e.g., dry forest, dry herbaceous vegetation, dry scrub). The necessary scales of the inputs range between 1: 250,000.

The synthesis of the 'homogeneous zones' with the 'Group and Macrogroup' generates a new intermediate product that we call 'Environmental Unit'.

2.1.5 Order (Geopedology and Land Use)

Geomorphology defines the type of relief through a representative name which is framed within the geophysical characterization of the environmental unit. The geomorphic landscape has a close relationship with the ecological processes. The geomorphic processes and geographic features make up the distribution of biota and, biota modify geomorphological processes. In other words, there is a symbiosis between these two components, which is why biota becomes an ecological engineer of the geophysical processes (Stallins, 2006). According to the geopedological approach, the geographical features also define the modal soil profile for each type of geomorphological unit. The geomorphology and the soil association allow to define the limits of the ecosystem and its specific characteristics. Finally, the use of the soil is a factor of the dynamics of human production on the soil. This input is fundamental to model ecosystems since it allows to discriminate the areas of anthropic use. In addition, it allows to model the areas of ecosystems that are being modified, even generating new types of ecosystems intervened. The scale of the inputs is 1: 50,0000 to 1: 25,000.

2.1.6 Specific group (Ecosystem)

It is the result of the synthesis of all the hierarchical levels described. This level is the final product of the processes of synthesis of geophysical, biotic and social elements. This product has the attributes of each of the higher categories, allowing us to obtain the geoinformation of ecosystems with the attributes that make it up. The scale of the resulting product is 1: 25,000.

2.2 Cartographic inputs

The cartographic inputs of each hierarchical category entering the model was associated with the descriptive attributes of each category described in the hierarchical theoretical model. In this case, we look for existing cartographic inputs from the various institutions that generate thematic cartography to enter the model (TABLE 2).

In each country, the institutions in charge of generating geoinformation make the mapping according to their work plans and their needs framed within national policies. It is necessary to mention this because there may be a lack of inputs for modeling. In this case, it is necessary to find similar geoinformation available to cover the need for each hierarchical category indicated in this study.

2.3 Cartographic Synthesis

The interaction of all the components described above: inputs, hierarchical categories and scales, allow to generate synthesis geoprocesses. For this, we designed a process diagram that allows to observe the flow of the synthesis procedures, until reaching the final product (FIGURE 1).

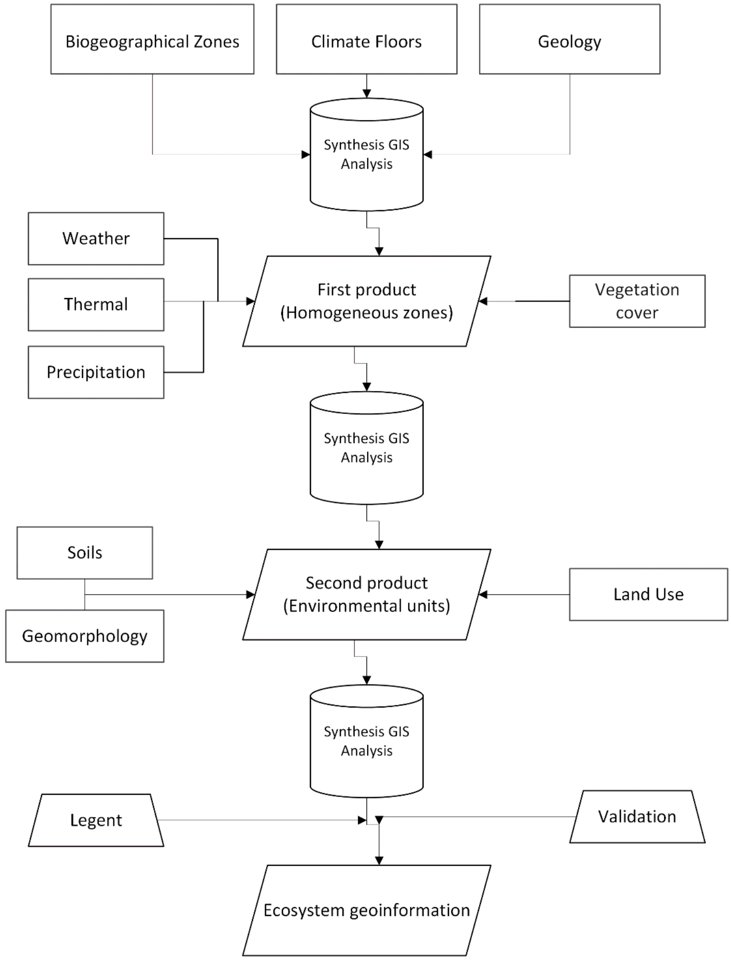
The geomatics processes were made in three groups. The first group constitutes the synthesis of the 'Class' and 'Subclass'. The input scales of these categories are: 1: 1,200,000 to 1: 1,000,000, generating an intermediate product called 'Homogeneous zones'. The second group corresponds to the synthesis of the 'homogeneous zones' with the inputs of the categories 'Macrogroup' (climate, thermality, precipitation) and 'Group' (plant formation). This synthesis generates an intermediate product called 'Environmental Unit'. The input scales for this synthesis are 1: 250,000 to 1: 100,000. The final synthesis corresponds to the 'Environmental unit' with the inputs of the category 'Order' (geomorphology, soils, and land use). The scales of these inputs are 1: 50,000 to 1: 25,000. This last synthesis allows the determination and delimitation of ecosystems.

The syntheses were made with the geoprocess 'union', which consists of combining the attribu-

TABLE 2. Matrix of inputs and scales used by each process for modeling

Group	Inputs	Scale	Intermediate products
First process	Biogeographical regions (Ministerio del Ambiente del Ecuador (MAE) & Sistema Único de Información Ambiental (SUIA) 2018) Climate Floors (Ministerio del Ambiente del Ecuador (MAE) & Sistema Único de Información Ambiental (SUIA) 2018) Geological map (Egüez *et al.*, 2017)	1:1,200,000 1:1,200,000 1:1,000,000	Homogenous Zones
Second process	Weather (Ministerio de Agricultura, Ganadería y Pesca (MAGAP) 2018) Thermal (Ministerio de Agricultura, Ganadería y Pesca (MAGAP) 2018) Precipitation (Ministerio de Agricultura, Ganadería y Pesca (MAGAP) 2018) Plant Formation (Sierra *et al.* 1999)	1:100,000 1:100,000 1:100,000 1:250,000	Environmental Units
Final process	Soils (Instituto Espacial Ecuatoriano 2017) Geomorphology (Instituto Espacial Ecuatoriano 2017) Land use (Instituto Espacial Ecuatoriano 2017)	1:25,000 1:25,000 1:25,000	Ecosystem geoinformation

FIGURE 1. Flowchart of processes for the geospatial modeling of ecosystems. Rectangles show the input, parallelograms show the products, barrels show geoprocesses and the trapezoids show validation and legend



tes of the inputs and, adjusting the descriptive elements of the input layers with the elements of superimposed layers, the result of which presents information on the combination of inputs. It should be noted that this tool does not generate duplicate records by overlapping, but rather vector limits that show the combination of attributes of the layers after the superposition, one with respect to the other. We do this process using the QSIG v 3.2 software (QGIS Development Team, 2018).

It is necessary to consider that in each synthesis, it is necessary to purify the unnecessary attributes, because there are attributes of the geoinformation that are not useful (e.g., areas, codes, names of localities, etc.) These can generate variations in the geoprocesses since they are unnecessary attributes and are not useful for the intermediate products or the final product. This purifying can be done from the beginning before the input enters the geoprocess. This helps to obtain intermediate and final products with the sought after attributes.

2.4 Validation

The validation consisted of field verifications in the field 1350 observation points detected. This method aims to reduce the error of bias to its minimum and delimit an ecosystem as close as possible to reality. By having our final product, visiting places were planned to validate ecosystems and verify areas of anthropic use. Ecosystems were verified and validated by observing the landscape and confirming diagnostic plant species, based on the dominance of species in each ecosystem (Cañadas, 1983). It is necessary to mention that this validation is representative for the surface of the study area, due to its verification effort. This work involved two field missions of 10 days each in both Dry and Wet temporalities. The work was intensive and supported by 10 people.

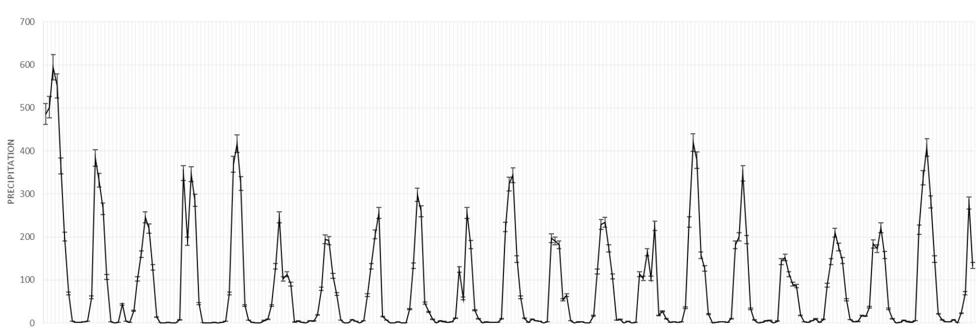
The legend used in this study was based on the determination of continental ecosystems of the Ministry of the Environment of Ecuador (Ministerio del Ambiente Ecuador, 2012). It is framed in the National Information System (SNI Spanish), which established the ecosystems of Ecuador in a descriptive way. This legend allowed us to describe the ecosystems that are found in the application area of the methodology.

2.5 Application Area

Our methodological proposal was applied in Montecristi, Ecuador (WGS84: 1° 9 '59 "S, 80° 45' 0" W). It is a canton with an area of 74,367.66 hectares. We selected this place due to the large amount of natural vegetation which is still preserved in good condition and because of its location on the coast of Ecuador. It is directly influenced by a combined effect of three natural currents: the cold oceanic current of Humboldt, the warm current of Panama and the movement of the Intertropical Convergence Zone (ITCZ), (Zambrano & Hernández, 2007). These currents generate rainfall from January to April, due to the displacement of water and warm air masses to the south.

The maximum and minimum temperatures at the study site vary from 28 °C from December to March; from 23-25 °C from July to September, respectively. The average annual precipitation is 330 mm (Chorillos Meteorological Station, National Institute of Meteorology and Hydrology of Ecuador - INAMHI, period 1998-2018), but with a high inter-annual variability CV = 82.45%, (FIGURE 2). This site is affected by the 'Garúa', a well-established climatic phenomenon produced by a variation of evapotranspiration during the dry season that occurs from May to November (Best & Kessler, 1995). The drizzle is one of the most

FIGURE 2. Monthly rainfall (mm) in Montecristi, period 1998-2017. Chorrillos Meteorological Station (M453 INAMHI)



important factors in the humidity of the area, as can be seen in FIGURE 2. The precipitations are low, but due to the drizzle the area has a higher humidity regime. This is intercepted by the Segment Membrillal Coastal Range and the San Lorenzo-Montecristi-Portoviejo Segment Coastal Range, in which humidity allows the development of humid arboreal vegetation. This phenomenon is different from the lower parts of the zone, in which the dry vegetation is found.

The land use of this place is mostly comprised of natural vegetation covering 83.38%. The rest of the surface presents short cycle crops, mostly corn, the crop with the highest yield in the area. In addition, it has coffee, pine nut and plantain crops, which are mostly within small family plots called undifferentiated miscellaneous. Finally, there are small sectors of urbanization and industrial use making the total area of human use 16.62%.

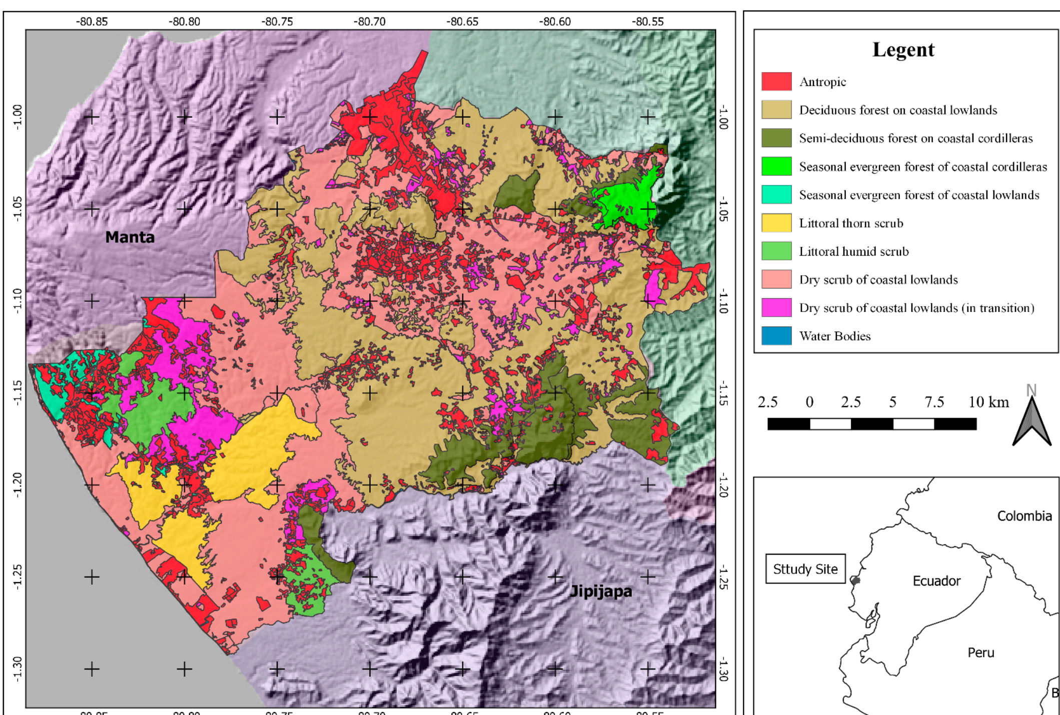
3. Results

Application of the proposed methodology in Montecristi enabled the determination of eight ecosystems with their geophysical and biophysical attributes. Furthermore, anthropic systems and water bodies were identified. The predominant ecosystems in the study site were dry scrub of coastal lowlands (22849.97 ha) and deciduous forest on coastal lowlands (20118.57 ha), while a small area was covered by seasonal evergreen forest of coastal lowlands (FIGURE 3).

3.1 Dry scrub of coastal lowlands (TVA2)

- *Geomorphology.* Class: coastal landscapes; Subclass: Manabí central basin; Macro group: sedimentary coastal and marine fluvial relief, structural land relief and tertiary hills; Order: marine mesa, hilly reliefs, colluvium, alluvium and alluvial-colluvial deposits.

FIGURE 3. Geospatial information of the ecosystems in Montecristi, the result of cartographic synthesis



- *Soils.* Slightly alkaline (pH > 7.5) with high concentration of Calcium carbonate across the profile (Calcic Haplustalfs, Calcic Haplustepts, Typic Calciustepts). These soils are interspersed with clay soils which present cracks on the surface and a neutral pH (Typic Haplustalfs, Vertic Haplustalfs, Typic Haplustepts, Vertic Haplustepts).
- *Biocenosis.* This ecosystem was dominant due to its extension, and it was found around to all Montecristi, if this system is altered, it can show trees between 5 to 12m height and the presence of cactaceas. Among the predominant plant species identified are: *Muntingia calabura L., Prosopis juliflora., Croton rivinifolius., Eriotheca ruizii., Acacia tenuifolia., Jacquinia sprucei Mez, Armatocereus cartwrightianus., Ipomoea carnea Jace., and Cordia lutea Lam.*
- *Climate.* Class: tropical; Subclass: equatorial; Macrogroup: thermo-hydric; Order: very dry to dry.

3.2 Dry scrub of coastal lowlands (in transition) (TVH3)

- *Geomorphology.* Class: coastal landscapes; Subclass: Manabí central basin; Macrogroup: structural land relief and tertiary hills; Order: hilly reliefs, alluvium and alluvial-colluvial deposits.
- *Soils.* Heavy clay soils with deep cracks, neutral pH and plaster in the profile (Gypsic Haplusterts). These soils are little developed, without toxicity and with some agricultural proneness (Typic Haplustepts, Vertic Haplustepts).
- *Biocenosis.* In this ecosystem anthropic pressure was evident. When logging heavy in dry-forest ecosystems, it is highly probable that only herbaceous species prevail. Thus, vegetation in this ecosystem becomes stumpy and some dry branches are visible. Among the shrubby predominant species are*: P. juliflora, C. rivinifolius, E. ruizii, A. tenuifolia, I. carnea and C. lutea.*
- *Climate.* Class: tropical; Subclass: equatorial; Macrogroup: thermo-hydric; Order: very dry to dry.

3.3 Deciduous forest on coastal lowlands (TBN1)

- *Geomorphology.* Class: coastal landscapes; Subclass: Manabí central basin; Macrogroup: structural land relief and tertiary hills, sedimentary coastal and marine fluvial relief; Order: hilly reliefs, alluvium and alluvial-colluvial deposits, areas and watershed of marine mesas.
- *Soils.* Various soil types were identified: heavy clay soils with deep cracks and plaster in the profile (Gypsic Haplusterts); clay loamy soil on the surface and clay soils in shallow and deeper layers, saline soils in deep layers, and medium fertility (Typic Haplustepts, Vertic Haplustepts).
- *Biocenosis.* This ecosystem is distributed in the central part of Montecristi, as well as the eastern and western sides. Canopy in this ecosystem is between 10 and 25m. The dry season lasts around 4-5 months. Therefore, the vegetation loses its foliage falls, resulting in a plant appearance of dry sticks. Physiognomy and vegetation composition may vary depending on the level of intervention; some plant species remained in good shape, though. The predominant species were: *Pisonia aculeata L., P. juliflora, Tabebuia billbergii Standl., Ceiba trischistandra Bakh., Cordia alliodora Oken, Senna mollissima., Cochlospermum vitifolium Willd., Guazuma ulmifolia Lam.*
- *Climate.* Class: tropical; Subclass: equatorial; Macrogroup: thermo-hydric; Order: dry.

3.4 Semi-deciduous forest on coastal cordilleras (TBN9)

- *Geomorphology.* Class: coastal landscapes; Subclass: Manabí central basin; Macrogroup:

structural land relief and tertiary hills, coastal cordillera; Order: very high-hill reliefs, high-hill reliefs, medium-hill reliefs, low-hill reliefs, alluvial-colluvial deposits.

- *Soils.* These soils are little developed, of vertic features, interspersed with soils under erosive processes and rock at little depths, slightly alkaline without problems of high aluminium or carbonates concentrations (Typic Haplustepts, Vertic Haplustepts y Lithic Udorthents). Other soil types are heavy clay with plaster in the form of stripes (Gypsic Haplusterts).
- *Biocenosis.* This ecosystem is located mostly in the eastern part of Montecristi, and a remnant can be found in towards south-west direction. An irregular canopy of about 25m of deciduous species and an evergreen shrub layer are characteristic here. This ecosystem lays between 300 to 500m of altitude. The predominant species are: *Spondias mombin L., Brosimum alicastrum Sw., Alseis eggersii Standl., Lonchocarpus sp., Ficus trigonata L., Clarisia racemosa., Pachira trinitensis Urb., Clavija eggersiana Mez., Pseudobombax millei Standl., Ficus sp.*
- *Climate.* Class: tropical; Subclass: equatorial; Macrogroup: thermo-hydric; Order: dry.

3.5 Littoral humid scrub (TVA8)

- *Geomorphology.* Class: coastal landscapes; Subclass: Manabí central basin; Macrogroup: sedimentary littoral and marine fluvial reliefs, coastal cordillera; Order: alluvial-colluvial deposits, dissected surfaces and watershed of marine mesas, fan surface of ejecta, spreading of glaciers.
- *Soils.* These soils have a moderately alkaline pH with a slightly high concentration of carbonates interspersed with fertile soils and others under some erosive processes (Typic Haplustepts, Typic Ustorthents, Typic Calciustepts). These soils developed conjointly with udic soils and show a high fertility. Therefore, these are soils with for agricultural usage, with the obvious limitations due to stoniness.
- *Biocenosis.* This ecosystem shows conditions similar to evergreen forest, except for its state of degradation, owing to agricultural activities. Among the commonly found species are: *S. mombin L., C. alliodora, Castilla elastica Sésse., Cecropia litoralis Snethl., Ochroma pyramidale., Malpighia punicifolia Nied. These species help in diagnosing anthropic intervention. Specifically, the species used for this diagnosis in the site were: P. juliflora, S. mollissima, G. ulmifolia, Erythrina velutina Willd., Muntingia calabura L., Pithecellobium excelsum (Kunth)Mart.*
- *Climate.* Class: tropical; Subclass: equatorial; Macrogroup: thermo-hydric; Order: rainy-dry.

3.6 Seasonal evergreen forest of coastal cordilleras (TBN11)

- *Geomorphology.* Class: coastal landscapes; Subclass: Manabí central basin; Macrogroup: coastal cordillera; Order: very high and high-hill reliefs.
- *Soils.* These soils are of little development with vertic characteristics, and sometimes with few erosive processes with stoniness at shallow depths. The pH is slightly alkaline without aluminum of carbonates toxicity (Typic Haplustepts, Vertic Haplustepts y Lithic Udorthents). Formation: Dry tree vegetation.
- *Biocenosis.* This ecosystem was found in the north-eastern and south-eastern side of Montecristi. It shows an irregular canopy up to a level of 35m height (i.e., with trees between 25 to 35m). This ecosystem lies along the cordillera, and it is mainly influenced by climatic effects of marine currents, such as Humboldt. These effects are increased cloudiness from May through September, i.e. Garúa. Due to the intensive alteration in its physiognomy

and botanical composition, some areas in this ecosystem are mostly covered by shrubs. However, some species remained in higher altitudes, such as *C. elastica., C. alliodora,,G. ulmifolia., Coccoloba obovata Kunth., E. velutina., Tabebuia chrysantha., S. mombin.*

- *Climate.* Class: tropical; Subclass: equatorial; Macrogroup: thermo-hydric; Order: rainy-dry.

3.7 Seasonal evergreen forest of coastal lowlands (TBN10)

- *Geomorphology.* Class: coastal landscapes; Subclass: Manabí central basin; Macro group: sedimentary littoral and marine fluvial reliefs. Order: surface and watershed of marine mesa, alluvium.
- *Soils.* These soils are sandy-loam type with good drainage, shallow, moderately alkaline pH (8.2), with medium fertility and with agricultural aptitudes slightly limited (Udic Haplustolls).
- *Biocenosis.* This ecosystem was heavily affected by agricultural activities and exotic species introduction. There is a dense forest with a few deciduous species; the canopy reaches 40m height. The understory is rich in palm species such as *Geonoma, Bactris and Oneocarpus, and lays below 300 meters above sea level (masl). The species found in this ecosystem are: Ceiba pentandra Gaertn., C. alliodora, Virola sebifera Aubl., M. calabura, C. rivinifolius, E. ruizii, A. tenuifolia, J. sprucei and C. elastica.*
- *Climate.* Class: tropical; Subclass: equatorial; Micrograph: thermo-hydric; Order: rainy-dry.

3.8 Littoral thorn scrub (TVA1)

- *Geomorphology.* Class: coastal landscapes; Subclass: Manabí central basin; Macro group: sedimentary littoral and marine fluvial reliefs; Order: dissected surface and watershed of marine mesa, low-lying hilly relief.
- *Soils.* These soils present a highly dry regime and superficial plaster (Gypsic Haplustepts).
- *Biocenosis.* This ecosystem occurs in the south-west side of Montecristi. No anthropic pressure was detected. Observed vegetation was shrub with a canopy of 4 to 6m height; some thorn scrubs exist along the coastal line of the study site. The species composition was poor and highly restricted due to the altitude (0 to 100 masl). Some of the registered species were: *Armatocereus cartwrightianus., Opuntia sp., Monvillea difusa., Pithecellobium excelsum., Hilocereus polyrhizus.*
- *Climate.* Class: tropical; Subclass: equatorial; Macro group: thermo-hydric; Order: aridic.

4. Discussion

We believe that developing a methodology for classification of ecosystems requires logical criteria related to the processes of cartographic development. We have arrived at this conclusion because some classification systems mention a wide series of variables to classify ecosystems in theory, but they are not considered or used later in the cartographic development. In fact, cartographic procedures developed with the use of supervised or unsupervised satellite image classifications are observed. This is a contradiction between theory and method.

Remote sensing allows us to identify homogeneous sectors based on reflectance and the physics of light, but we should consider their limitations. For instance, within a homogeneous coverage, there are other geophysical elements under the canopy, which the optical sensor does not capture, or in certain cases, areas of natural vegetation cover are determined. In the field validations it is identified as aroma cocoa plantations (Theobroma cacao). This plantation is characterized by having a very high and compact canopy, the spectral response of which is similar to that of a forest. This allows us to show some limitations of image classifications in ecosystem studies. For this reason, we do not recommend leaving all ecosystem classification work in the hands of remote sensing. In this context, the importance of the use of interpretation based on superposition of layers is evident.

The hierarchical classification systems and criteria for Neotropical ecosystems cannot be approached by taking models from other regions, such as in the United States and Europe. We conclude this because they are regions of different geophysical and biophysical structures, represented mainly by their landscape homogeneity. The Neotropical region due to its geophysical and biophysical diversity, as detailed by Burnham and Graham (1999), Mardones (2006) presents an ecological complexity different from the other regions of the world. It is because of this complexity that the process of mapping this region is a challenge. Consequently, the criteria for generating a hierarchy proposal must be different and must be innovated.

Scales are essential to determine ecosystems. Low resolution scales identify categories such as biomes or ecoregions, which in certain jobs are considered as ecosystems. This can be easily identified when observing regional maps in which countries of the Neotropics with few 'Ecosystems' are observed. In Josse *et al.* (2003), Ecuador for example, has four divisions. He mentions that within each of these divisions there is a certain number of ecosystems, which are not delimited or visible on the map. At present, the Ministry of the Environment of Ecuador has determined 91 ecosystems for continental Ecuador (Ministerio del Ambiente Ecuador, 2015). For this reason, the need to use high resolution scales to generate information on Neotropical ecosystems is evident. Besides, this scale allows to determine the level of detail and the necessary attributes of a layer of heterogeneous ecosystems. In conclusion, the recommended scale for representing Neotropical ecosystems would be 1: 25,000.

We emphasize that the effort of verification in the field must be intensive. We consider the area of analysis in this work to be relatively small, in comparison to works that carry out cartography of ecosystems in extensive regions and scales of low resolution. If we consider these scales and extensive regions, it would be impossible to perform an extensive field validation, which allows to verify and confirm the prediction of a model. This further supports our validation of the use of high-resolution scales to spatialize the Neotropical ecosystems.

5. Conclusions

The systems of classification of countries of homogeneous landscapes generate inconveniences at the time of being applied as a base to generate cartography in the Neotropics. For instance, Josse *et al.* (2003), mentions nine phases of refinement for all the ecosystems of Latin America and the Caribbean. Considering it as a qualitative approach, it focuses on reviews of secondary information from various sources: regional, national and consulted with experts; describing the process as 'Modular'. This proposal is based on a combination of variables, a hierarchical classification system, which is taken from 'The Nature Conservancy'. It concludes that this way of ranking would help to interpret diagnostic criteria that would allow a visual expression of the combinations that define each unit of the ecological system. He also mentions that European classifiers give guidance to establish hierarchies.

Josse's work has been the basis for generating proposals for ecosystem classification systems in several countries of the Neotropics (e.g., Báez *et al.*, 2010; Beltrán *et al.*, 2009; Pacheco *et al.*, 2010).

However, we consider that there is no correlation in understanding the order of association of the proposal with the method, especially the classification of the inputs used within each hierarchical order and its respective scale. In fact, the inputs that were used for the model are not presented, nor are they present in the geoprocesses and procedures used to obtain the final product in a GIS. We believe that all proposals should have an explanation of the classification system with its respective hierarchies, linked to inputs, scales and geoprocesses. This would help avoid methodological gaps.

Ecology has shown us throughout the planet's evolution, that the dynamics of ecosystems is constant. It is a process that is subject to changes in the biotope and biogenetic relationships. This interrelation between both factors has generated the process of 'ecological dynamics', which has allowed to define ecosystems over time. From the appearance of man, the social matter and the first production activities; they provoked a new process of ecological relationships, never before seen in the history of the planet (Arendt, 2009). Consequently, an accelerated process of ecosystem transformation. For this reason, that the presence of new ecosystems since the Holocene, correspond to ecosystems built and constituted with human presence, and their production activities (Socio-ecosystems). An example of this transformation is done by Schulz *et al.* (2010), in which it develops the process of transformation of the ecosystems of evergreen forests to shrubs, due to the intervention of production activities.

We mention this because in our work we find and detail the transformation of the Dry scrub of coastal lowlands (in transition). We determine the transformation of its geophysical characteristics, such as soil, geomorphology and climate. For this reason, vegetation cover should not be considered as the only changing element of the ecosystem, but all its constituent elements. This is an ecosystem intervened and transform from the Dry scrub of coastal lowlands. Although the Montecristi canton preserves its largest surface area with little vegetation coverage, we find this ecosystem in this dynamic of transformation, especially due to the insertion of corn production systems.

It is common to consider ecosystems as pure units which have not been modified. However, ecosystems are elements that are part of the consumption and production of space, as mentioned Lefebvre (1992). For these reasons, we have to consider for future research, that ecosystems are geographic units related to the social matter. This is known as society-nature metabolism (Host *et al.*, 1996). This is why we recommend considering ecosystems as historical units which undergo transformations in time and space.

We must continue to explore the ways of classifying ecosystems so that even more social categories can be integrated into the models. The complexity of ecosystems goes beyond understanding the geophysical or biological factors. The academic debate remains on the table. The forms of generating theoretical models that are associated with methods of spatialization of ecosystems is the focal point of this work. We call on the academic community to continue developing efforts to continue the mission.

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