UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO

POSGRADO EN GEOGRAFÍA
CENTRO DE INVESTIGACIONES EN GEOGRAFÍA AMBIENTAL
FACULTAD DE FILOSOFÍA Y LETRAS

EL USO DEL SUELO EN GEOFORMAS DE ORIGEN FLUVIAL EN VALLES DE LA SIERRA COSTA DE MICHOACÁN

TESIS
QUE PARA OPTAR POR EL GRADO DE:
MAESTRA EN GEOGRAFÍA

PRESENTA:
ITZI GAEL SEGUNDO MÉTAY

TUTOR
DR. GERARDO H.R. BOCCO VERDINELLI
CIGA-UNAM

MÉXICO, D. F. AGOSTO 2014

“EL *USO DEL SUELO* EN *GEOFORMAS* DE ORIGEN FLUVIAL EN VALLES DE LA SIERRA COSTA DE MICHOACÁN”

“*LANDFORM* AND *LAND USE* ASSOCIATIONS IN VALLEYS OF THE *SIERRA-COSTA* REGION IN MICHOACAN, MEXICO

A MIS PADRES.

Merci maman,

Merci papa.

La ejecución de este proyecto se hizo posible gracias a los apoyos otorgados por CONACyT (beca nacional para estudios de posgrado) .También gracias a los proyectos PAPIIT “Abandono y reapropiación paisajística a escala local en América Latina: casos en México y Argentina (IN305010)” y “Pequeñas localidades y redes de estructuración territorial en lo remoto: México y Argentina (IN301914)”

AGRADECIMIENTOS

Primero, quisiera reconocer a mi asesor, Gerardo Bocco, por su impecable labor como director de este proyecto. Gracias por aceptar ser parte de mi formación.

También quiero mencionar, muy especialmente, el apoyo absoluto que recibí por parte de Konrad Gajewski y cada uno de los miembros del laboratorio de Paleoclimatología (LPC lab) de la Universidad de Ottawa. Agradezco infinitamente a Alejandro Velázquez por su disposición y amabilidad en todo momento ¡Gracias por hacerme sentir en familia! También, a Federico Fernández por recibirme siempre con las puertas abiertas.

No puedo dejar de agradecer a Gabriela Cuevas, por su amabilidad, buena disposición y orientación en todo momento, y a Adrián Ghilardi, por su buen humor y acertadas observaciones. Reconozco también las valiosas aportaciones de mis profesores: Manuel Mendoza y Ángel Priego.

Gracias a mis compañeros del posgrado por sus aportaciones, comentarios y sugerencias pero, sobre todo, por sus amistades. A Lupita Cázares por sus altos niveles de eficiencia y competencia. También agradezco la disponibilidad de Ruth Mora y la eficacia de Manuel Bollo. Una especial mención para Acacia, Carina y Pedro de los que he aprendido mucho con el tiempo. A Silvia y Arturo por asistir las cuestiones cartográficas. En general, a todo el CIGA que forma parte de esta maravillosa Universidad.

Para finalizar, quiero agradecer a Ulises por ayudarme a plantear aspectos que no contemplaba. También por convertirte en uno de mis grandes motores de inspiración. A "*Pollito*" a quien adoraré siempre, aunque no sea este el verdadero motivo de mi agradecimiento ¡Gracias las aclaraciones, los mapas y tu buen gusto! A todos los Segundo por estar presentes. También a mis abuelos, siempre a ellos. A Antoine, Louis y Jules nada más porque los quiero.

INDEX

1ST CHAPTER

2ND CHAPTER

3RD CHAPTER

4TH CHAPTER

TABLE INDEX

FIGURE INDEX

ABSTRACT

The purpose of this research project is to analyze associations between *landforms* (a major physical component of landscape), *land cover* (a hybrid attribute) and *land use* (the result of a social activity on land), in a *man-land* frame of landscape studies. The *Nexpa* Valley, in *Michoacán, México,* has been chosen because it fulfils the geographic criteria needed for the analysis at a local scale (1:10,000). The general question is: how *man-land* relationships occur in the lower *Nexpa* Valley? More specifically, how *landform, land cover* and *land use* intersect in landscape? A difference between steep (denudational slopes) and plain (fluvial valley bottom) areas is expected in terms of the activities and formal attributes related to each one of them. *Land use* should therefore vary according of *landform* and *land cover.*

For this aim, multivariate statistics was used as a primary resource for the interpretation of these specific *man-land* interactions. First, a classificatory system for each layer of spatial information (*landform, land cover, land use*) was carefully put together through ground survey and using remote sensing (RS). Later, the cross tab matrices containing the intersected area between layers were assembled. Finally the results were submitted to an ordination process, through a Correspondence Analysis (CA), that enables the landscape structure for interpretation through a graphical representation of the spatial associations.

Results show that there is a strong correspondence between geomorphologic, formal and functional attributes in landscape. However, while features do differentiate in terms of terrain, patterns do not

respond to the traditional land suitability perspectives. Apparently, the distribution of *land use* patterns could be better explained by adaptative strategies developed by the population, rather than by conditions of terrain itself.

In addition to the original thesis, a 4th chapter was included so that the results of the flooding, following a major storm during the study period, could be explained as part of the *man-land* interactions taking place in landscape and forcing adaptative strategies to emerge.

CHAPTER 1

LANDSCAPE COMPONENTS AND THEIR SPATIAL ASSOCIATIONS

1.1 INTRODUCTION

The main purpose of this research project is to interpret associations between *land* (as a biophysical dimension of geographic space) and *territory* (as humanized space). In more specific terms, the objective is to explore relations between *landform* (as an expression of *land*) and *land use* (as an expression of *territory*). Therefore, the goal is to contribute to a better understanding of how *land* affects and is affected by *human activities.*

We assume relationships between *landform* and *land use* take place in a geographical *continuum*, that is, everywhere. Thus, we could associate these two landscape features in many ways at many places. The questions are: Which area (as a proportion of space) of analysis has to be chosen? How should the relation between features be evaluated?

As delimiting areas is a fundamental aspect of geographical research, one of the first things that need to be done is to determine the scales that are appropriate for the question at hand. In this particular case, we are interested in examining relations in landscapes at a very high level of detail. The local scale seems suitable for this purpose[1]. For this reason, the research is developed based on case studies.

To establish logical criteria for choosing the area of study, we use geomorphological characteristics of landscape because these are easily identifiable attributes which suggest presence or lack of certain processes and phenomena in landscape. For example, the presence of slopes and peaks are indicative of erosional dynamics, shallow soils and perhaps a lower rate of social dynamic compared to piedmonts or valleys, which are characterized by accumulation process, presence of deeper and richer soils, flat surface, and, generally, greater water availability. Following this argument, we establish *valleys* as one of the most dynamic *landforms* because of their fluvial origin and this implies more change and activity in relatively smaller periods of time than other *landforms*. Consequently, our main criteria of area selection will be places with *valleys.*

---

[1] We will explain technical details of the local scale in further sections. The important thing at this moment is to clarify that we won't be using global or regional scales for this particular research.

The second criterion may be cultural characteristics in the landscape as an expression of *territory*[2]. We therefore propose to use *valleys* in the Sierra-Costa region in Mexico that lead to the Pacific Ocean, where there is coexistence of indigenous population and *mestizo*[3] groups where *land use* dynamics are expected to be diverse and heterogeneous.

About *valleys* in the Sierra-Costa region, Carl Sauer in 1941:357 wrote: "… the lands of the highest quality, of the most intensive use, of main dependability were the valley bottoms. Many of these are used today for a succession of crops throughout the year. During the dry season they may still hold enough moisture for cropping and are the called *tierras de humedad*". This quote, even if made decades ago, supports the idea that the area is suitable for the analysis. Details and background information about study area will be given below.

Once concerns about study area have been covered, the aspect of - how the relation between features should be evaluated? - can be brought into the discussion. Features in landscapes can be classified depending on their spatial arrangement, distribution and occurrence. The intention is to measure the spatial coincidence between *landforms* and *land use* in order for different levels of correlation to be ranked. Specific approaches and methodologies that can be used to determine spatial relationship between landscape features will be discussed, but first it is important to settle a general framework that will lead this research.

First, it is important to speak about Geography so that definitions and tendencies beyond "Geography is what geographers do" may be set. Even if our priorities are not about making a contribution to conceptual or theoretical discussions in the discipline, it is still important to discuss what is being done regarding *man-land*[4] studies.

---

[2] We understand *territory* as a concept referring to the proportion of *geographical space* that is built upon symbols and culture. Thus, *territory* is a "geosymbol" where cultural values and *identity*, as social attributes, take place (Bonnemaison, 1981)

[3] The term *mestizo* is a Spanish word making reference to a person or group of people that have a mixed origin of European and Indigenous cultures.

[4] It is important to point out that although we believe that term "*human*" is more appropriate than "*man*", because it is now considered to imply an exclusion of genders, many researchers have worked through the *man-land* concept (Patisson, 1964; Bower & Kobusiewicz, 1988; Christiansson *et al.,* 1991; Chen *et al*., 2004; Qiao *et al.,* 2006) and therefore it is important to present it this way in the text.

Environmental Geography (as a current trend in geographical studies) and Pattison's (1964) *Four Traditions of Geography* may work as basic approaches that frame *man-land* research at present.

In recent years, the debate about reintegrating Geography as an undivided discipline has been increasing (Massey, 1999; Lane, 2001; Thrift, 2002; Demeritt, 2009), much of it is associated with the "boom" of environmental studies[5]. The term *Environmental Geography* has been proposed as an alternative to reunite the two poles of geographical knowledge: physical and human. In this regard, *Environmental Geography* has opened the opportunity for a dialogue that reconsiders perspectives and tools for an integral study of the link between society and nature (Bocco & Urquijo, 2010).

The discussion in terms of the aims of *Environmental Geography* is rather scant (Bocco, 2010). Nevertheless, some authors have dealt with this issue by reviewing what is actually being done. The book by Castree *et al.* (2009) "A Companion to Environmental Geography", for example, discusses the course this trend has been taking for the past decade.

According to Castree *et al.,* (2009), most academics in this domain would recognize there is a clear division between Human and Physical Geography and it is this dualism that still dominates the way that the discipline is structured. Even if geographers concerned about an integrated understanding of *space* aren't the majority, some efforts are being made to provide a unified linking between these two divisions. In their perspective, this 'geographical experiment' of reintegration of spatial knowledge is what *Environmental Geography* is all about. In this sense, this tendency could be defined as "any form of geographical inquiry which considers formally some element of society or nature relative to each other"[6].

---

[5] In the scientific domain concerning the *environment* there is a tendency to privilege integrative, interdisciplinary and hybrid models aimed at reducing distances between biophysical and sociocultural fields of knowledge. This tendency is founded on an interest to generate holistic approximations about the actual environmental complexities. It has its origin in the 1960s as social demands over global ecological crisis emerged (Bocco & Urquijo, 2010).

[6] "In our view, the expanded definition of environmental geography that we are working with here – namely, *any form of geographical inquiry which considers formally some element of society or nature*

"*Geografía y ambiente en América Latina*" (Bocco *et al.* 2011) offers an examination of the theoretical and conceptual conditions of *Environmental Geography*, especially in Latin America. One of the important ideas of this book is the notion that perhaps *Environmental Geography*, as a concept, is somewhat redundant because *Geography*, at least at its origins, has been both human and environmental at the same time.

As the notion of an integrative geographical inquiry turned into a concern in the discipline, human-environment research grew considerably along with the increased public awareness of environmental issues:

> "[*Environmental Geography*] practitioners spread across the geographic landscape, inhabiting such niches (…) as environmental hazards, environmental perception and behavioural geography, cultural ecology, contemporary agricultural and rural land use, water resources, and the human dimensions of global environmental change (…), to which political ecology should be added as a de facto group operating among the others. The research agenda has subsequently expanded to include issues of environmental management and application (…) and global environmental change (…) Entering the new century, the questions of the human-environment relationship have been elevated throughout the academy and public at large, and geography is recognized as possessing unusual strength in integrated, human-environment science. The discipline has pragmatically taken advantage of this moment, but it has done so while maintaining various positions" (Turner, 202: 59-63).

Looking for a rigorous definition of what *Environmental Geography* is (more accurately: what *Geography* is) might be a pointless task because of the fact that geographical inquiry covers a wide spectrum of knowledge. Therefore, Pattison's "Four Traditions"[7] is included as a proposal that "instead of trying to produce a

---

relative to each other- is usefully open-ended. It opens up a much broader landscape of shared knowledge and practice, whose richness and potential only becomes apparent once we shake off the older version of environmental geography as necessarily symmetrical" (Castree *et al.*, 2009:6)

[7] "Pattison's 'Four Traditions" was an excellent statement of the central core and main themes in geography (…) but geography, like other disciplines, has changed. Are Pattison's traditions still suitable in terms of present trends in geography? (…) The four traditions are a useful framework for discussion of the content of purposes of geography as a discipline (…) Despite the changes, trends, and narrowing focus of interests in geography, the four traditions seem to provide an effective structure for describing the philosophy of our discipline (…) Although there have been excesses in the promotion, acceptance, and rejection of these traditions, they have remained central to most geographic investigations… " (Robinson, 2007:521)

definition, which would receive general agreement, consolidate[s] the concepts and themes of geography into those few which have been persistent throughout the development of the discipline in the past century. Thus, he [Pattison] identified geography's four traditions: spatial, area studies, man-land, and earth science" (Robinson, 2007:520).

We will emphasize the *man-land tradition* according to Pattison (1964) and the *Four Traditions*' revision made by Robinson in 2007. Pattison first offers an historical background of the tradition by introducing to Hippocrates' publication entitled "*On Airs, Water and Places*", written in the 5th century B.C. and which is considered one of the first *man-land* approaches. Eventually, *geographical determinism* became the main tendency. Later on, *environmentalism* became the leading approach which, by the way, "came to be confused with the whole man-tradition in the minds of many people" (Pattison, 1964:214). As a reaction to *environmentalism,* a reply of cultural and historical geographers that went beyond "man appearing as an independent agent, and the land as a sufferer from action" (Pattison, 1964:215) emerged.

Robinson's review (2007) is key to this discussion as well because it provides an update of the 'Four Traditions' discussion. He exposes the *man-land tradition* as derived from the concern that geographers have about probing associations between society and its physical *milieu*. The research supporting this tradition has followed numerous methodological and philosophical arguments leading towards a better understanding of a relationship that, undoubtedly, exists. As a matter of fact, studying the actual relations between *man* and *land* may help us realize "how little we know about the 'man' part of the relationship, and how little we understand about the totality of the 'land'". Robinson claims this tradition by pointing out that there is no purpose for "studying man floating in space with no earthly roots or studying earth processes without the complication of man's interference".

Our research is therefore intended as a contribution to *Geography*, not physical nor human, with preferential focus on *man-land* aspects of geographical surface. Even if geomorphological and *land use* features are chosen as an analytical axis, these attributes won't be studied as independent from their spatial context, that is, independent from *landscape*.

In the following sections, the discussion will use these concepts as a framework to analyse the particular landscape features. The first section will describe *landforms in landscape*, which will emphasize the landscape approach from physical geography. Secondly, *land use in landscape* will be brought into the discussion emphasizing tropical *land use* systems, and, the concept *land cover* (as an expression of *land use*) will be reviewed.

1.2 *LANDFORMS* IN LANDSCAPE

As Geography subdivided into Human and Physical, the study of the *landscape* has separated as well. On the one hand, Human Geography has focused on territorial dynamics of the landscape through economic, political, cultural and historical aspects. On the other hand, Physical Geography attempts to understand biophysical aspects of landscape through geological, geomorphological, climatological, hydrological and ecological processes[8]. We will now focus on the study of landscape from the point-of-view of Physical geography, specifically the study of *landforms* as a major physical component of landscape.

A large body of research in Physical Geography is directed towards the analysis of patterns of biophysical processes in landscape across various spatial and temporal scales and their application to environmental management (Preston, 2011). Therefore, *landscape* is considered to be "a physical expression of the surface and near surface, which typically consists of multiple, varied *landforms* that are systematically arranged in space relative to their setting, which is dictated by large-scale geologic structure" (Haschenburger, 2004:772). Aspinall (2010) describes the role that Physical Geography has played in geographical research over the past decades:

---

[8] "… most physical geographers understand their task to be to ascertain the physical processes or events that have shaped the earth's biotic, geomorphological and climatological systems, and have conceived humans to be separate from and external to these 'natural' systems, which are assumed to be independent from, prior to, or unaffected by humans (…) Human geographers, on the other hand, for some time debated a set of explicitly ontological questions about the relation between human and nature, and over the past three decades this has given rise to a diverse literature (Castree *et al*, 2009:22-23)

> "There has been considerable debate on the nature of physical geography, its methods, the human-physical divide, and the nature of geography as a single discipline (…) Physical geography has always made use of a wide variety of methodologies and approaches and there tends to be a focus on the technical tools available for use [p. 1054] There are several trends in the evolution of geography, and particularly physical geography (…) These trends include emphases on principles of field-based observation and generalization, classification, and understanding of processes and dynamics of environmental systems using diverse methodologies [pg. 1056]"

Lately, *landscape* has been analysed as a *system* in an attempt to embrace it within an integrative and explanatory framework. This 'method of thinking', as Inkpen (2005) establishes it, offers a common framework for regarding to the whole of the *physical milieu*. The system's approach places emphasis on forms, process and relationships between them and it has been a largely accepted approximation for identifying landscape attributes at different scales (Renwick, 1992). Thus, the attention in Physical Geography is being placed upon the comprehension of the forcing processes in association with the features' response within *landscape*. Therefore the focus of Physical geography has been placed upon the stratification of landscape into relatively homogeneous tracts of land. Different kinds of *land* classification methods are being used to provide biophysical data for mapping at diverse scales (Pasuto *et al.*, 1999).

In classifying *landscape,* we can give priority to the categorization of *landforms* (which is one of the main goals of geomorphologic enquiry). The geomorphologist "will attempt to map the distribution of phenomena that have been identified (…) In addition to mapping, the geomorphologist is concerned with processes, changes and hazards" all relevant to human affairs[9] (Goudie, 1994: 206-7). Geomorphologists carve *landscapes* into *landforms* through the development of taxonomic systems that, in a certain way, "facilitate the production of knowledge about the earth's physical landscape" (Rhoads, 1999:766).

---

[9] "Physical Geography has come a long way in the last two decades to the benefit of itself, but also to the benefit of Geography as a whole. It is relevant to human existence, it describes the framework in which human activity works, it shows that the earth is not homogeneous, and it demonstrates that environments are as dynamic and changing as are human societies" (Goudie, 1994: 208)

Geomorphological mapping is important for the interpretation of Earth surface processes and landscape evolution as well as for the evaluation of natural hazards and natural resources monitoring. It requires the partitioning of *land* into smaller spatial units that have been conceptually established from morphological, genetic, compositional, structural and chronological criteria[10] (Bishop, 2012). In this way, the classification of *landforms* aims for the use of standard criteria that leads us towards a more accurate identification of certain *landscape* features. Nevertheless, it is important to point out that this "standardization of criteria" has been certainly problematic because of the diverse interests and purposes among researchers. Therefore, according to Beckinsale and Chorley (1991), it is important to search for the most suitable and satisfactory classification by having our specific purpose in mind.

Finally, although Physical Geography has been transforming over the past decades, the main changes have occurred in terms of methodology and concerning pragmatic issues (recently associated with spatial analysis and its new technologies). Nevertheless, relatively few physical geographers engage in philosophical, theoretical and conceptual discourse capable of dealing with the integration issues between Human and Physical Geography (Aspinall, 2010).

Landform classification will be used as a start to advance understanding of certain *man-land* relations in *landscape.* This research is intended to become a contribution to Geography that will be solving methodological and pragmatic issues from Physical Geography but does not intend to ignore the human dimension of *landscape.*

---

[10] "These traditional mapping approaches emphazised qualitative interpretation, as frequently dictated by the inherent limitations associated with field-work, paucity of digital space-time data, and human a priori field/geographic experience and domain knowledge (…) Relatively recent advances in remote sensing, geographic information science (GIScience), geospatial technologies, as well as developments in numerical modelling of surface proesses, have revolutionized the field of geomorphology" (Bishop *et al.*, 2012:5-6)

1.3 LAND USE AND *LAND COVER* AS DIFFERENT LANDSCAPE DIMENSIONS

It is now pertinent to focus on the *land use* concept as a part of the human dimension of *landscape* and as essentially different from *land cover*. Since the concept of *land use* seems to be inevitably linked with that of *land cover*, especially for modelling and planning purposes, the basic distinction between them remains understudied. The purpose of this research is not to track *land use* and land cover change (LULCC), nevertheless, one of the purposes is to analyze *land use* and *land cover* as two different geographical features within *landscape*. For this purpose, we will now start with a summary of the discussion held around the *land use* concept so we can then establish its differences with *land cover.*

In 1961, Burley exposed the term *land use* as part of the ambiguous terminology used in Geography. He first presents Sauer's original definition of *land use* as "the use to which the entire land surface is put". The term then emerged with a much broader and more ambiguous meaning when it began to be claimed by geographers and nongeographers who provided *land use* with different interpretations. Two connotations, however, remained of significance in geographical research: (a) "the using, or employment, of the land; and (b) "the setting in which the action takes place". In this respect, Burley was referring to the *function* and the *form* as the main attributes of *land use.*

Guttenberg & Nanetti (1974) question the so-called simplicity of the *land use* notion by exposing the broad significance it has taken. They analyze three important dimensions that help explain the totality of this concept: *the User*[11], *the Use*, and the *Use Effect*[12]. Specifically, the term *land use* "involves the following elements: a site, a

---

[11] "The term 'land user' encompasses two broad categories –the legal owner of a tract and the occupant. The legal owner may further be classified as to whether he is an actual person or (…) a corporation or trust. By occupant we mean the one who actually resides upon the land or uses it as a place of business or for some other purpose. The legal owner may also be the occupant (…) For the purposes of our analysis, however, it is important to distinguish between the occupant's legal, that is, his proprietary characteristics as such, and his cultural characteristics, such as his race, religion, class, profession or occupation" (Guttenberg & Nanetti, 1974: 4)

[12] "The use effect is an essential part of the use itself but its current prominence justifies our singling it out for special consideration (…) It is a question here of the characteristics of the activity or facility at each site which make it a good or bad neighbour to surrounding sites, such as activity size (…); rhythm

facility, an activity, a type of economic or social enterprise, and an activity effect". Their review of the major *land use* dimensions provides a solid framework for further systematic identification and classification of *land use.*

Many authors refer to Rhind & Hudson's book "Land Use" published in 1980 as one of the first important reviews directed towards the clarification of the concept (Foody, 1996; Johnston & Sidaway, 1997; Bibby & Sheperd, 2000; Graizbord, 2002; Gitas *et al.,* 2003; Bakker & Veldkamp, 2012). The authors go through the definitional aspects of the *land use*. They then examine different kinds of modelling of *land use* patterns from more 'traditional approaches' to newer perspectives. Like Burley, Rhind & Hudson (1980) recognize a difference between *land use* as relative to some *activity* (functional) carried on different places and *land cover* inherent to the physical characteristics of a place (formal). Beyond the definitional aspects of *land use*, the book presents a "desiderata of a classification system" which underlines the principles of *land use* classification process.

Hill (1984) also makes a distinction between *formal* and *functional* approaches. For Hill, the *formal* approach "focuses upon the shape, the form of 'geographical individuals' on the land, whether these be fields or buildings. It is a question of *land cover* rather of *land use*". The *functional* approach, on the other hand, "attempts to answer the question, what is the land used for?" The main difference between Hill's and Burley's descriptions , is that Hill associates *land cover* with *form* as a rather independent feature, while Burley defines *land use* as comprising both *land cover* and *land utilization*[13].

In 2000, Bibby & Shepherd analyzed *land use* in relation to GIS applications and the inception of advanced technological tools for geographical analysis (such as remote sensing) in the early 1970's. They begin by pointing out that even when *land use* relates to a physical form, it derives from a social purpose. Based on this idea, the

---

or time shape; realm or range of influence of the activity or facility (…); and material impact on the human senses (Guttenberg & Nanetti, 1974: 4)

[13] "To distinguish between these two basic concepts, the following terminology is suggested: (a) *land cover*- the setting in which action takes place, i.e., the vegetation and artificial constructions covering the *land surface*; (b) *land utilization*- the action, i.e, the employment of the *land surface* through the medium of *land cover*" (Burley, 1961: 19)

authors define *land cover* as a concept that refers to "the 'stuff' that cover the surface of the earth in terms of physical structures and may be *natural*, such as trees or water, or *artifacts* such as concrete or tarmac". In contrast, these authors recognize *land use* "defined as a social purpose" which is distinguished by a function[14]. Moreover, Bibby & Shepherd recognize that *land use* may be analysed through representational systems, i.e. GIS, as long as "data cease to be simple attributes of physical objects" and start being regarded as features shaped by particular social and cultural organizations".

Comber *et al.,* (2008) focus on the origin of conceptual confusion[15] between *land use* and *land cover*:

> "The origins of this illogical paradigm [*land use* and *land cover* as interchangeable concepts] lie in the 1970s when the availability of medium resolution imagery coincided with the wish of governments to better manage their land resource for a range (…) Andersons *et al.'s* (1976) outline the US Gegological Survey (USGS) land use and land cover classification specified a hybrid land use and land cover classification (…) Many subsequent inventories and initiatives have copied the land classification confusion of Anderson *et al.* (1976), developing hybrid classifications that confuse land use and land cover. Indeed the 'land cover/land use' couplet has become the *modus operandi* form many initiatives and most surveys were the differences between land cover and land use are frequently noted, but rarely accommodated" (Comber *et al*., 2008: 186-187).

Comber *et al.,* (2008) agree with Bibby & Shepherd in terms of the main difference between *land cover* and *land use*. Thus, *land cover* is defined as "the physical material

---

[14] "… a table is a table by virtue of its use, *not* its physical composition. A school represents a particular set of social actions associated with, but not defined by, a particular configuration of bricks and mortar. The descriptor 'school', or an equivalent code in a land-use classification, has no *formal* meaning but indicates how physical material is deployed for social purposes. The term school is an expression of collective intentionality or will. Objects of concern in land-use studies may thus be regarded as *intension* projected upon physical reality through the medium of natural language" (Bibby & Shepherd, 2000:585)

[15] "Today most land cover data include elements of land use and vice versa. Historically, mappings of and were concerned with land use and manually recorded socio-economic activities and land management practices. With the increased availability of remotely sensed imagery since the 1970s and the ability to process such data using computers, the principal concern of such mappings has been to record the phenomenon of land cover and land use" (Comber, 2008:199)

at the surface of the earth" while *land use* refers to "a socioeconomic variable describing how people *utilise* the land". Finally, the authors refer to Fisher *et al.* (2005) who discuss about the *many-to-many* relationships between *land cover* and *land use*[16]. In this respect, Cihlar & Jansen (2001) recognized four different kinds of relationships between *land cover* and *land use*:

- "Case 1: for each LU_i there is only one corresponding LC_j such that $a_{ij}= 1$; i.e., a 1:1 relationship. For example, a built up-cover type corresponds to urban land use.
- Case 2: for each LU_i there is more than one LC_j such that $a_{ij}= 1$; i.e., 1LU: several LC. For example, corn and wheat fields correspond to agricultural land use.
- Case 3: for each LC_j there is more than one LU_i such that $a_{ij}= 1$; i.e., several LU: 1 LC, but this relationship holds across the spatial domain of interest. For example, shrub cover within forest corresponds to the harvested trees or fire scars.
- Case 4: for a given LC_j there is more than one set of LU_i for which $a_{ij}= 1$; i.e., several LU: 1 LC. This relationship varies within the domain; that is, various combinations of LU_i are associated with a given LC_j" (Cihlar & Jansen, 2001: 279)

Authors may differ in certain aspects about *land use* and *land cover*. Nevertheless, they all seem to associate *land use* with both *functional* and *formal* attributes, and *land cover* as a physical feature in landscape that is covering the Earth's surface that may be also linked to *formal* attributes but does not have a *functional* dimension. Our further *land use* classification will then have to be different from *land cover* classification. Classification issues will be discussed over the next section.

---

[16] "Fisher *et al.* (2005) noted that land cover and land use have complex *many-to-many* relationships and cited the example of the cover 'grass' which can occur in a number of different land uses: sports grounds, urban parks, residential land, pasture, etc. Likewise, very few areas of homogenous land use have a single land cover. Furthermore, they pointed out that land use classifications do not necessarily fulfil the criteria of allocation features on the land surface uniquely into one class: a single point in space may quite legitimately have a number of different land uses at any given moment. Much land has multiple states of use which may be simultaneous or alternate: the field with cows may be the village football pitch at weekends; the reservoir may provide flood control but also angling, boating and water supply; and plantation forestry may also be used for several forms of recreation, including hunting and hiking, and even for grazing. The specification of any particular land use at any specific point in space is more problematic and contested because of these issues compared to land cover" (Fisher *et al.,* 2005 in Comber *et al.,* 2008: 188).

1.4 LAND COVER vs. *LAND USE* CLASSIFICATORY SYSTEMS

A description of two classificatory *land cover* systems, as derived from remotely sensed land categories will be now be presented. It seems appropriate to start with one of the most general initiatives directed towards a standardization of a global *a priory* classificatory scheme: FAO's Land Cover Classification System (LCCS)[17].

The LCCS offers three important aspects which are key to the establishment of *land cover* classes: (1) The structure of the classifiers follows a hierarchical logic which follows two main phases: an initial *Dicotomous Phase*, "where eight major land cover types are distinguished", and a subsequent *Modular-Hierarchical Phase*, "where the set of classifiers and their hierarchical arrangement are tailored to the major land cover type"(Table 1); (2) It leads to mutually exclusive classes which are based on a unique Boolean formula , a standard name and a unique numerical code; (3) The differentiation between "classification system" (as scale and source independent) and "legend" (as the application of a classification in a specific area using a defined mapping scale and a specific data set) (DiGregorio & Jansen, 2000).

The other example of a *land cover* classificatory system is the one carried out by Campos *et al.* (2012), derived from an innovative interdisciplinary approach for explaining changes in landscape. Part of this interdisciplinary approach was to establish a *land cover* classificatory scheme derived from remotely-sensed data, aerial imagery and ground-truth points. Three broad land-cover categories were derived using this data: natural, secondary and man-made. These three categories diversify with more specific lower leveled classes (Table 2). The proposal made by Campos *et al.* is of special importance because the study area is in the same region as the study area in our study.

---

[17] "The Land Cover Classification System is the result of an initiative to take a first step towards an internationally agreed reference base for land cover. The objectives of the Africover Programme of the Environment and Natural Resources Service (SDRN), FAO, are to develop an approach for conceptualizing, defining and classifying land cover that coincides with the UNEP/FAO initiative on harmonization of land cover and land use classifications." (DiGregorio & Jansen, 2000:v)

Table 1 LCCS structure of classifiers (DiGregorio & Jansen, 2000:12)

Dicotomous Phase	***Modular-Hierachical Phase***
1. Cultivated and Managed Terrestrial Areas 2. Natural and Semi-Natural Terrestrial Vegetation 3. Cultivated Aquatic or Regularly Flooded Areas 4. Natural and Semi-Natural Terrestrial Vegetation 5. Artificial Surfaces and Associated Areas 6. Bare Areas 7. Artificial Waterbodies, Snow & Ice 8. Natural Waterbodies, Snow & Ice	"Land cover classes are created by the combination of pre-defined classifiers. These classifires are tailored to each of the eight major land cover types"

Table 2 *Land cover* classification scheme for study area in ejido Ticuiz on the Pacific Coast of Mexico (Campos *et al*, 2000:411)

Broad Classes	**Inferior classes**
Natural types (*sensu* Velázquez, Médina & Reygadas, 2010)	Harbor tropical sub-humid perennial and sub-deciduous broad-leaved forests (mainly dominated by *Brosinum alicastrum, Pithecellobium dulce, Enterolobium cyclocarpum, Guazuma ulmifolia, Tabebuia rosea, Manilkara zapota, Rizhophora mangle, Pachira aquatic* and *Conocarpus erectus*)
	Tropical humid evergreen narrow-leaved grasslands (dominated by *Typha dominguensis, Phragmites* sp., and *Cladium jamaicense*)
Secondary types	Successional stages of natural types
	Recovery stages of man-made types
Man-made land cover	Permanent orchard plantations (*Musa sp., Cocos nucifera, C. papaya*)
	Rain-fed crops (most commonly *Zea mais*)

A series of *land use* classificatory systems will now be reviewed in order to: (1) examine the classes that have been used to study spatial patterns and (2) analyze the difference between *land use* and *land cover* within classification proposals. Special emphasis will be placed on tropical *land use* systems schemes.

In 1951, Shapiro examined "conventional" *land use* classification systems and suggested that: (1) they were generally unsuccessful for describing and recognizing generally-alike units, (2) they were usually not useful for grouping geographical units with definable characteristics in common and (3) they were failing to reflect the purposes they intended to serve. For this cause, Shapiro suggested that *land use* classification should be based on "Primary Activity" categories in association with the "corresponding types of establishment" (Table 3). This approach focuses on urban dynamics but may still be useful for *land use* classification purposes in general and is included in this revision because of its consistency.

Table 3 Example of *land use* classification scheme proposed by Shapiro (1951:154-5)

Primary Activity	Corresponding Types of Establishments
Advising	Accountant, Consultant, all types
Assembling	Buyer Residence Buyer
Buying	Buyer Residence Buyer
Cleaning	Broadcasting and Receiving Station Newspaper Publishing Establishment
Designing and/or Drawing	Architect, all types Engineer, all types
Dining and/or Drinking	Cocktail Lounge Restaurant
Extracting	Coal Mining Firm Gravel Pit
Wholesale	Building Materials Yard Produce Dealer
Transporting	Railroad Trackage

More recently, Cihlar & Jansen (2001) worked on a systematic *land use* mapping approach in association with *land cover* data. The authors explored the relationship between both features (*land cover* and *land use*) "with the intent of using LC maps as the primary data source for the preparation of LU maps". The proposal results in a *land use* classification based on a transformation of *land cover* classes through a mapping function[18] (Table 4). This function considers the fact that the relation between any type of *land cover* with any type of *land use* may or may not be unique.

---

[18] "When attempting to derive LU distribution from an LC map, the basic challenge is to specify the function

$$LU_i = f\,(LC_j, e_1, \ldots, e_n, sc_1, \ldots, sc_n)$$

Where *e* and *sc* represent environmental and socioeconomic/cultural variables respectively, and *i* and *j* are specific LU and LC types" (Cihlar & Jansen, 2001: 279)

This classification shows an effort to carefully integrate *land cover* and *land use* data without mixing both concepts.

Brown & Duh (2004) also worked through the relationship existing between *land cover* and *land use*[19]. However, their study approaches the relationship between them from the opposite direction. That is, "given a map of *land use*, for example from a spatial land-use model or plan, what does a possible map of tree cover look like?" The classification scheme is based on two land-use maps of the study area. Land-cover categories were determined through semantic translations of *land use* categories (Table 5). The final result was a simulation of 15 land-cover maps. Even when certain limitations to this approach can be found, this study is of value for the approach used for spatial coincidence analysis between *land use* and *land cover* in their formal dimension.

Table 4 Fragment of *land use* classification scheme proposed by Cihlar & Jansen (2001:277)

LC classes	**LU classes**	**LC →LU***
1. Urban areas (built up) 1a. Urban areas (non-built up)	A. residential, industrial, mining, and recreation (mix of different uses)	3
2. Horticulture	B. Horticulture	1
3. Field crops and fallow land (irrigated and nonirrigated)	C. Temporary cropping C1. Irrigated temporary cropping	2

---

[19] "Land-use and land-cover data have three major semantic differences that affect their interoperation. First, the *category definitions* of land use and land cover are different. For example, 'undeveloped forest' and 'developed urban' categories in land-use classification are not synonymous with the land-cover classes 'tree-cover' and 'impervious (…) The second difference is that land use and land cover have different *geometric expressions* (…) Land cover refers to biophysical condition at a location (i.e. grid cell) or in a homogeneous landscape patch (i.e. polygon). Land use refers to the economic function of a spatial unit, within which tenure may (i.e. ownership parcels) or may not (i.e. polygons or grid cells) be uniform. Land-use features are often composed of multiple land-cover features (e.g. patches of tree, impervious, grass, wetlands) (…) Finally, land use and land cover have *different spatial rules* to assign attributes to land-use/cover features. The class definitions of land use tend to integrate information about activities taking place within a spatial unit (e.g. parcels or zone), while those of land cover assess only the static and *in situ* conditions" (Brown & Duh, 2004:37-8)

	C2. Nonirrigated temporary cropping	2
4. Trees and perennial crops	D. Permanent cropping	
4a. Olives	D1. Olive cultivation	1
4b. Vineyards	D2. Grape cultivation	1
4c. Deciduous fruit trees	D3. Fruit tree cultivation	1
4d. Citrus or bananas	D4. Citrus and/or banana cultivation	1

* LC→LU makes reference to the four cases of possible relationship between land cover and land use explained in the section above

Table 5 *Land cover* classification scheme using *land use* as primary data by Brown & Duh (2004:44)

Land use	Land cover
“High-density residential (multi-family housing, strip residential, and mobile homes”	“Impervious (roof tops, driveways, sidewalks, paved streets, and any other hard surface)”
“Low-density residential (single-family housing and farm-steads)”	“Tree (large woody plants; coniferous and deciduous trees)”
“Urban (commercial, industrial, public assembly, infrastructure and transportation)”	“Herbaceous (grass, row crops, other herbaceous cover)”
“Agriculture (crop, pasture, confined feeding operations)”	“Wetland”
“Non-forested natural (outdoor recreation, cementeries, rangeland, and shrubland)”	“Water”
“Forested natural (all forested areas including plantations)”	
“Barren/extraction (beaches, sand dunes, and exposed rock, as well as any mining activities)”	
“Wetland”	
“Water”	

The following studies make reference to classification schemes attempting to encompass the heterogeneity in tropical landscapes. This review will help visualize which *land use* classes have been applied in previous surveys.

Pascarella *et al.* (2000) proposed a *land use* determination based on features perceived on black and white aerial photographs from different years (going from 1937 to 1995) and interviews with local residents in the municipalities of Guayama and Patillas in Sierra de Cayey Mountains of south-eastern Puerto Rico. The purpose was "to examine the effect of historic land use on current forest structure and species composition". Even when social research through interviews is carried out, broad classes were first assigned through photograph's features (Table 6). This becomes a problem when the "land use classes" turn to be confused with *land cover* as they only make reference to the formal properties of polygons instead of deepening in their functional aspects.

Table 6 Land-Use Classes and their identifying features in Pascarella *et al.* (2000:220)

Class	Criteria
Sugar cane	"Even texture, uniform color, no trees, and distinct plow lines"
Pasture	"Dominated by grasses with no or little woody vegetation"
Shrub	"Dense shrubs with <50% forest tree cover"
Open forest	"> 50% to <80% forest tree cover with an even-structured canopy"
Dense forest	">80% forest tree cover and uneven canopy"
Urban	"Clusters of buildings and houses, including yards"

Later Abizaid & Coomes (2004) examined "the role of household characteristics and government policy in shaping *land use* and forest fallow management in a peasant community (*ejido*) in southern *Yucatán*, México". Even if this study does not offer a classification scheme as such, it is important to mention it because the authors determined *land use* within its functional, spatial and temporal dimensions. The spatial unit is then delineated based on the uses that are being given to the land: "For the purpose of this study, an individual field is considered to be the minimal land area devoted to a specific *land use* for unit of time (agricultural year).

A study by Fry (2011) is a description of *land cover*, *land use* and livelihood changes in Perote Valley of central Veracruz, Mexico. The author interprets landscape transformations through a review of theoretical conceptualizations of the linkage among urbanization, agricultural change, and the aggregate mining. The *land cover* types were classified based on field observation and photointerpretation of orthophotographs and satellite images (IKONOS); *land use* type classification was based on field observations and the subsequent classes were: active, abandoned, post-extraction agriculture, tree plantation, *bloquera*[20] or other. However, changes were mapped upon a land-use/land-cover classification (Table 7). The attempt to classify mines by the activity that is being developed is a good way of classifying its functionality and therefore we include this study in this review.

Table 7 *Land use* vs. LU/LC classification scheme by Fry (2011:1293-4)

Land Use classes (for mines)	Land-use/Land-cover classes
Active	Agriculture
Abandoned	Tree cover
Postextraction agriculture	Inhabited/urban
Tree plantation	Tepetzil mine
Bloquera	Other
Other	

Paneque *et al.* (2013) generated a land use/ cover (LUC) classification scheme based on field survey, remote sensed data and GPS points for a large area in the department of Beni, Bolivia. Eight broad LUC classes were determined: early-growth/degraded forest (EGDF), old-growth forest (OGF), water (W), bare soil/urban (BSU), pasture (P), savannah (S), semi-natural grassland (G) and scrubland (SC) (Table 8). This study offers a consistent methodology for assessing heterogeneity in tropical landscapes. However, it might be more applicable for pure *land cover* surveys as the classes privilege formal more than functional attributes of land.

---

[20] "After tepetzil [a mineral lightweight material] is extracted, much of it is processed into lightweight concrete blocks by local block-making facilities known as *bloqueras*" (Fry, 2011: 1290-1)

Table 8 LUC classification scheme by Paneque *et al.* (2013:374)

LUC class	Definition
Early-growth/degraded forest (EGDF)	"Forested areas with varying degrees of disturbance due to human activities (e.g., typically slash and burn agriculture or logging) or natural dynamics (e.g., flooding regimes). Typically composed of regenerating trees, dead trees and logs, crops such as rice, manioc and bananas, sometimes with scattered old big trees. The canopy is rather open, structurally simple, and the average tree height is 3-10m."
Old-growth forest (OGF)	"Forested areas with low levels of disturbance that consist of mature trees forming a dense and structurally complex canopy with a few gaps and a typical height range of 10-40 m"
Water (W)	"Water bodies such as creeks, rivers, shallow lakes, and deep lakes"
Bare soil/urban (BSU)	"Sand banks along rivers, urban areas including towns, unpaved streets and roads"
Pasture (P)	"Areas typically used for cattle ranching, both in deforested and savanna areas. In deforested areas, pasture species are frequently sown, while in savanna areas pasture species are usually natural. In both instances it is common to have varying amounts of bare soil"
Savanna (S)	"Low relief savanna areas that are seasonally inundated and may form swamps and marshes"
Semi-natural grassland (G)	"Grassland patches that occur mostly across the savanna areas, with very little or total absence of woody species"
Scrubland (SC)	"Open canopy areas dominated by bushes or short trees, commonly present across the savanna areas, growing on dry ground of low quality; sometimes in the fringe or vicinity of forested areas"

In general terms, *land use* classes tend to be confused with *land cover* classes. Moreover, even when authors specify previously that *land use* differs from the *land cover* concept, by the time a classification scheme is suggested, the boundary between *land use* and *land cover* has become vague.

One of the main purposes of this study is to propose three different classification schemes as to avoid the conceptual and semantic overlapping: (1) a *landform* classification (based on geomorphologic and morphometric parameters), (2) a land-cover classification (as derived from remote sensed data) and (3) a land-use classification (based on field data).

This brief examination of *land use* and *land cover* classification systems is certainly incomplete because it does not intend to review most of the classificatory proposals. Instead, the purpose of this review was to evaluate if the differences between *land use* and *land cover* are actually considered for the establishment of classes and to understand the logic of classification *per se*.

A limiting factor to accomplishing this review is the enormous number of studies that focus on "land use/land cover change" rates which do not tend to explain in detail which criteria were used for the establishment of land-use or land-cover classes. Thus, classificatory systems seem to be taken for granted or just briefly evaluated and modified.

1.5 SPATIAL RELATIONS BETWEEN LANDSCAPE FEATURES

In this section, we will discuss how spatial relationships between landscape features have been analyzed by other authors. Special emphasis will be placed on studies that: (1) focus on relationships that can be established through statistical procedures and geographical data analysis and (2) choose *landforms* or land-use as key components associated with other landscape features. Generally speaking, the studies found in our bibliographical research were realized by physical geographers and ecologists who analyze the association between vegetation and *landforms* or soils.

Hupp & Rinaldi (2007) interpreted the riparian vegetation distribution patterns and diversity in association to fluvial geomorphic channel patterns, *landforms* and processes for selected rivers of Tuscany in Central Italy. Vegetation data related to hydrogeomrphology was determined using BDA (binary discriminate analysis) and DCA (detrended correspondence analysis). The results of Hupp & Rinaldi's analysis suggest that "species richness increases from the channel bed to the terrace and on heterogeneous riparian areas, whereas species richness decreases from moderate to intense incision and from low to intense narrowing". Moreover, species were found to fall into three broad categories: (1) "those species with particular affinities for specific fluvial *landforms*", (2) "those species that normally occur in disturbed situations (successional, ruderal)" and (3) "those species with broad ecological amplitudes that are not indicative of any particular hydrogeomorphic condition".

Another study of the relationship between *landform* and vegetation is the one performed by García *et al.* (2007) where the distribution of plant communities was analysed in relation to *landform* properties. Eighty-nine species and three environmental variables (altitude, slope and aspect) were considered using multivariate classification and ordination analysis (TWINSPAN and DCA). The results were linked in a geographic information system (GIS) in order to calculate areas of each combination of vegetation and environmental values.

Other studies have investigated the association between physical and human features in landscape. For example, Hongliang *et al.* (2005) analyzed relationships between *land use*, *land cover*, soil salinity and *landforms* in China's Yellow River Delta. Although they confounded *land use* and *land cover* classification, as has been discussed above, the study is of value because it tried to determine the relationships among different landscape factors beyond the biophysical dimension. A Pearson's chi-square test was used to test dependence among variables and an ANOVA was performed to test different soil salt indices between selected pairs of soil types, *landforms* and *land uses*. Soil type, *land use/cover*, and *landform* data were later analysed within a GIS for spatial variation identification. Based on this methodology, regional geomorphology seems to strongly influence changes in *land use* and distribution of soils in this area.

Castillo *et al.* (2010) used a Geographic Information System (GIS) along with multivariate analysis (Hierarchical Cluster Analysis) to integrate environmental units derived from *landforms* and environmental data, such as *land use* in "La Malinche" volcano (central Mexico) "where there are highly contrasting biophysical conditions and land use over relatively short distances". Multivariate analysis was then used to validate what was empirically observed in the field and also to integrate different landscape attributes and classify them into environmental units.

Finally, a case study by Hudson *et al.* (2006), investigated the relationship between land use/cover and *landforms* in valleys of the Pánuco Basin in México. Again, land use/cover is conceived a unique entity derived from remote sensed data[21]. To delineate geomorphic floodplain units, satellite images were acquired during the wet and dry season. The mapping was rectified using field observations and topographic data. The main statistical tools employed to analyse the relationship between features were cross-tabulations[22], Pearson's contingency coefficient and chi-square test[23]. The analysis indicates that agriculture is mainly associated with coarse-grained natural levee and bar units close to the channel, while cattle grazing occurs primarily in distal and lower-laying reaches. The study therefore exposes "considerable variation in LULC [land use/land cover] related to spatial differences in floodplain environments and illustrates the importance of considering older anthropogenic influences on the landscape".

SUMMARY

In the current study, multivariate statistic data analysis will be used as a primary resource for the interpretation of *man-land* interactions within landscape. *Landforms* (as a physical dimension in landscape), *land cover* (as a hybrid dimension) and *land use* (as a human dimension) will be determined and classified separately but then will be evaluated by examining the degree of coincidence among them. The understanding of the association between these three features should, therefore, explain more about *landscape* as a unified geographical notion.

---

[21] A combination of unsupervised and supervised image classification was used for this purpose. Eventually, eight thematic classes, derived from remote sensing, were assigned to the statistically derived clusters: river, lake and streams, wetland, agriculture, pasture, barren, riparian, urban (Hudson *et al.,* 2006: 492-3)

[22] "The crossed-tables were evaluated using statistics for nominal data. Here we employed the contingency coefficient and residuals and proportional area statistics. The residual analysis is based on normally distributed probabilities (…) but only positive probability was considered for interpretation, indication disproportional spatial co-occurrence. The area proportions provide further normalized indicators for detailed spatial analysis" (Hudson *et al.,* 2006: 494)

[23] "The chi-square test between the observed and estimated occurrences was highly significant for the entire floodplain surface and for each of the individual floodplain segments" (Hudson *et al.,* 2006: 495)

One of the main challenges of this research will be to solve methodological and pragmatic issues without overlooking on conceptual background. For this purpose, this review of previous work on *landforms*, *land cover* and *land use* provides a framework that will help build a coherent methodological proposal which will lead to a logical criterion for interpreting data and results. The next chapter of this thesis will therefore focus on the classificatory and methodological proposal emphasizing the study area characteristics.

CHAPTER 2

GEOGRAPHICAL ATTRIBUTES IN THE SIERRA-COSTA REGION: STUDY AREA AND METHODS

2.1 COASTS, MOUNTAINS AND VALLEYS: THE SIERRA-COSTA REGION IN MICHOACAN

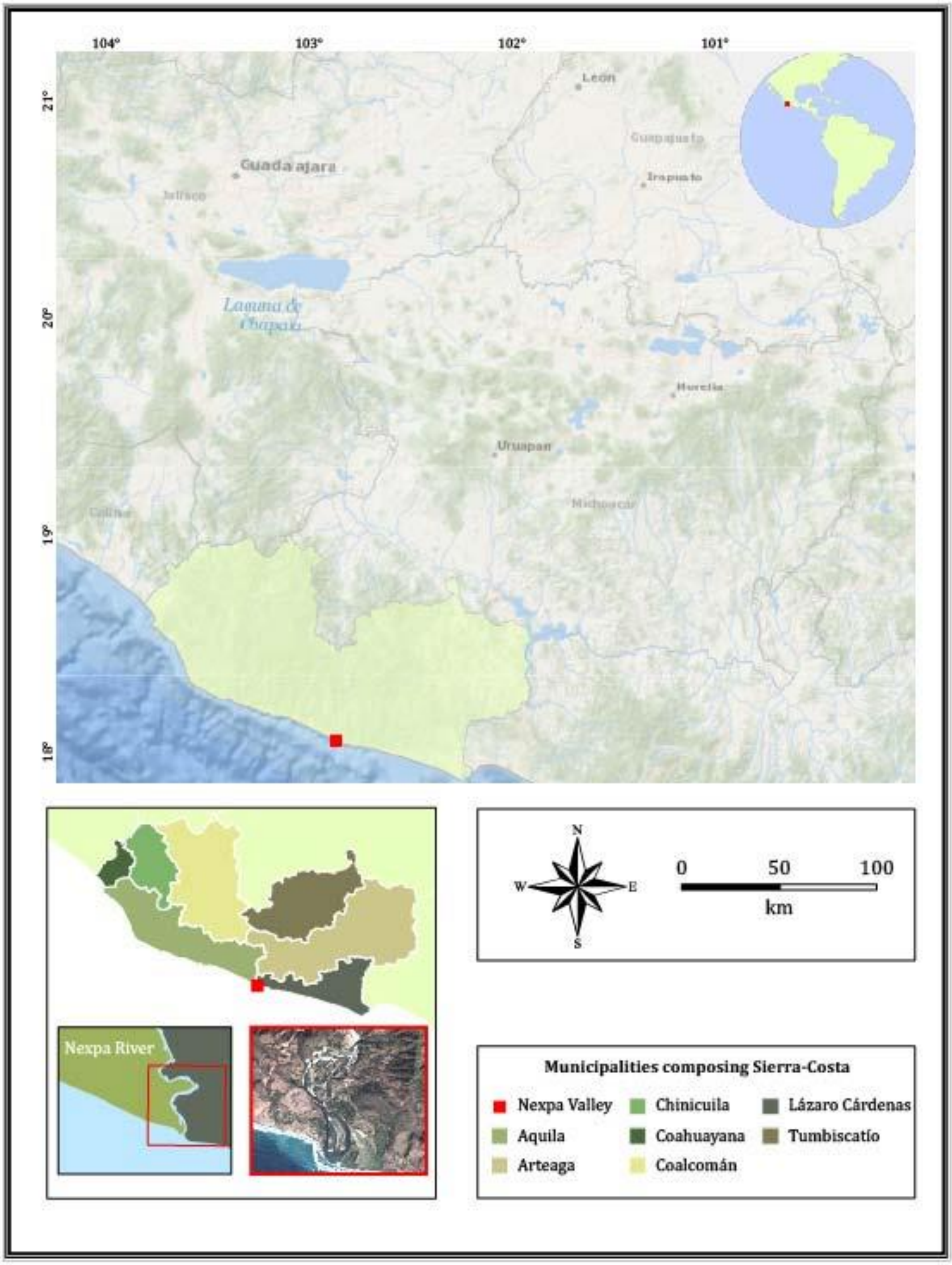
The *Sierra-Costa* region in Mexico is located in Michoacan state (Figure 1) and it has been internally delimitated by management, social, economic and political criteria. However, the *Sierra-Costa* denomination makes reference to its physiographic attributes: the prominent and mountainous land (*Sierra*) that faces the Pacific coastline (*Costa*).

The irregular relief is due to the presence of the *Sierra Madre del Sur*, a mountain chain that extends from the state of Jalisco to the west, to the state of Oaxaca to the east. On the other hand, the Pacific coast is an elongated landscape with relatively few large bays and coastal plains that abruptly interrupt the sharp and outstanding slopes. This general composition is the main setting of this impressively heterogeneous region[24].

---

[24] The following study area description has been written based on the following documents: "*Nueva Regionalización para la Planeación y Desarrollo del Estado de Michoacán*","*Programa de Desarrollo 2010-2012 Región IX "Sierra Costa" del Estado de Michoacán*", both obtained from governmental sources (CPLADE, 2010), and "*Bases para el Ordenamiento Ecológico de la Región Sierra-Costa de Michoacán*" ejecuted by the Center of Environmental Geography (*Centro de Investigaciones en Geografía Ambiental CIGA, UNAM*) (Priego *et al,* 2008).

Figure 1 Study Area: *Sierra Costa* region and *Nexpa* Valley in *Michoacán*, *México*



The climates in the area vary mostly due to elevation. A warm-dry climate predominates in the lowlands where the average temperature is between 28° and 30°C. At elevations above 1,500 masl, temperate climates dominate. Rainfall is seasonal, and occurs between May and October, with peaks in the months of August and September.

Leptosols, Regosols and Luvisols are the most common soils in the abrupt slopes of volcanic origin, while Fluvisols are the predominant class in lowlands of fluvial origin. Land cover closely follows climate patterns. Lowlands are dominated by tropical dry forests, while mixed (pine, oaks) forests dominate the temperate areas in the highlands. Together, forests account for 84% of the total area. Mangroves and coastal dune vegetation are also common at the coastland. Other land cover classes include scrublands and grasslands on slopes, (6.5% of the total) and crops (9.2%) on flatlands. Human settlements account for less than 1 % of the region (Cuevas, 2009).

The main economic activities developed in the Sierra-Costa region are agriculture, cattle-grazing, services and tourism. Rain-fed agriculture is the most important activity in the area, where corn, bean, lemon and coconut plantations are commonly found. In the coastal communities, closer to the Pacific side, fishing and tourist services stand as significant activities.

The Sierra-Costa region is composed of 7 municipalities: *Chinicuila*, *Coahuayana*, *Coalcomán*, *Aquila*, *Tumbiscatío*, *Arteaga* and *Lázaro Cárdenas* (Figure 1). The most important city is *Lázaro Cardenas* which stands out for its commercial and industrial attributes, followed by the town of *Coahuayana*. The total population living in this region is 269,055 inhabitants (Censo de Población y Vivienda INEGI, 2010), comprising 6.2% of the total population of Michoacan state. The population density averages 20 inhabitants per km^2 which is far below the state´s average density, a fact which points at a relatively scattered population with the exception of the two large towns already mentioned. Most of the municipalities have been categorized as economically disadvantaged, except for the municipality of *Lázaro Cárdenas*, because of its harbor (the most important on the Mexican Pacific coast) and considerable industrial development partly linked to the harbor´s activities (CONAPO, 2010).

The most extensive valleys in the *Sierra-Costa* are found in the transition between the *Sierra* and the coastal *milieu*, where rivers tend to widen and lead to the Pacific Ocean. These valleys, or *tierras de humedad*[25], are recognized by their dynamism because of their fluvial genesis but also because of the social and economic activity occurring within them. Fluvial lands in the region host both indigenous and *mestizo* populations and are mostly used for agricultural, livestock, forestry, fishing and tourism activities (CPLADE, 2010).

This description of the general characteristics of the *Sierra-Costa* region and its valleys shows its suitability for an analysis of *man-land* interactions within a landscape. But which of the valleys in this area should be chosen for study? In this case, the choice is somehow arbitrary but, for our particular purposes, the valley of the *Nexpa* River was selected because it fits the criteria of selection: 1) the valley covers an appropriate area suitable for geographical analysis at a local scale; 2) it is managed by differentiated models of land tenure: private property and *ejidal*[26], which makes it representative of the region; and 3) it may be considered as a dynamic and economically diversified area because of its closeness to the *Lázaro Cárdenas* harbor.

The *Nexpa ejido* was created by a 1983 presidential decree; the land –located in the territory of the *Lázaro Cárdenas* municipality—encompasses 5,994 ha managed by 68 *ejidatarios* who have access to a total of 5,994 ha (PHINA, 2013). The largest village is *Caleta de Campos,* actually a tract of the land granted to the ejido to establish the urban settlement at the seaside. According to the latest census (INEGI, 2010), Caleta has 2,580 inhabitants mostly devoted to fishing and tourism. Most of ejidatarios live in Caleta.

---

[25] Sauer, 1941:357

[26] The *ejidal* model makes reference to the *ejido* which is a type of social land tenancy established by the Mexican Constitution as early as 1917. *Ejido* members (*ejidatarios*) have the legal right to own a piece of land and benefit from it as long as they comply with collective agreements and authorities (Warman, 1985:7)

2.2 BERKELEY'S SCHOOL LEGACY: THE GEOGRAPHICAL INQUIRY IN COASTAL LANDSCAPES OF SOUTHWEST MEXICO

Geographical studies of the *Sierra-Costa* have a solid academic background because of the long-standing research carried out in the area. Although the Pacific coast of Mexico had been widely explored, mostly by naval expeditions since the sixteenth century, academic inquiry only began in the mid-twentieth century, with the onset of the field research in Mexico carried out by Carl O. Sauer and students of the Berkeley Department of Geography (Brand, 1957).

In the following paragraphs the Berkeley school's geographical approach will be explained through its contributions made explicitly about the Pacific Mexican coast. This review is relevant to our study because the Sauerian legacy has been recognized for its strong integrative contribution (Parsons, 1981; Mathewson, 2011). Therefore, it sets an authentic *man-land* interpretation of the landscape which helps to place environmental studies within a strengthened geographical tradition. Next, a brief listing of Berkeley's contribution is presented[27].

In a manuscript "The Personality of Mexico" (1941), Carl Sauer emphasizes the cultural, especially agricultural activities, developed in the Pacific areas of Mexico. Sauer broadly described the basic traits of the native domesticated plants, and recognizing the "large diversity of ecologically fixed crop types", explains "the route of dispersal of crops into the Indian agriculture" and highlights the importance of Southwestern archeologists for improving research. In this essay, he carefully describes the productive activities related to farming:

---

[27] The Berkeley school approach and contributions could have been discussed in the first chapter of this thesis because they can be thought of as a part of the general background. Nevertheless, this Sauerian reference is included in this second chapter because it enriches and highlights our study area and sets a starting point for our methodological approach.

> "To this day southern and western Mexico is lost in a smoke haze during spring, from rubbish burning on thousands of mountain deadenings, or *coamiles*, that are being prepared for planting. Many of them are still prepared and planted without the use of a plow, by means of a digging stick (or crowbar) and hoe. The seeds are punched into the ash-covered soil and left to the rains, without further attention except weeding. As no furrows are drawn, nor regular fields laid out, the native farmer picks his planting spot chiefly with an eye to the timber. The bigger the tree growth, the easier the clearing, the larger the increment of wood ashes, and perhaps also the better the cash return from charcoal. Slope matters almost not at all, and soil very little; for the crop is grown primarily on the fertility made available by woody growth, the *monte.* This untidy method of farming has given remarkable protection against soil erosion on steep slopes. Many such mountain slopes have gone through thousands of years of alternation of clearing (*desmontar*), planting, and regrowth to *monte*. The process is really a long-term rotation of crops and trees. Under this management fields and settlements have been able to spread over terrain that plow farmers would find impossible. Villages that have a nucleus of permanent *tierras de humedad* appropriate about themselves as well a wide fringe of hill country for their *coamiles* or *milpas*. Also colonization of later generations of villages takes place in mountain terrain, withouth permanent (valley floor) fields, and all the subsistence is derived from such shifting mountain clearings. In both cases the village is permanent; wandering villages are absent, or at least extremely rare" (Sauer, 1941: 358)

Moreover, Sauer emphasizes the productive dynamics in relation to population settlement over the valley bottoms: "The valley lands were carefully tended and improved and determined the site of many of larger villages. However, the frequent summer showers make possible also the growing of one summer, rain-season, or *temporal* crop on hill and mountain slopes. Growth of population soon forced expansion from the narrow valley bottoms to the far more extensive hill slopes" (Sauer, 1941:358).

In 1950, Daniel Stanislawski, part of the first generation of the Berkeley school, published a book entitled "The Anatomy of Eleven Towns" where an analysis of the "coastal mountains of Michoacan" was provided based on photographs and cartographic material. The region is described as an isolated area where steep areas remain pretty much inaccessible and where settlements generally have fewer than

2,500 inhabitants. Stanislawski described a rural *milieu* where economical activities are based, almost entirely, on subsistence farming and corn, beans, mango, guava, tobacco, sesame and coconut plantations are most commonly found.

In 1957, another Berkeley PhD student, Donald Brand, published the “Coastal Study of Southwest Mexico” where the political structure, historical process, geographical attributes, *landforms*, climatic, biological and cultural aspects of these places are related. This title includes an extensive appendix containing a chronological review of the Naval History related to Michoacan’s coasts and a summary of previous hydrographic research. This volume is particularly useful for our research because it offers photographs of the Nexpa River in the 1950’s and contains an analysis of the precipitation for several places around Nexpa.

In 1960, Brand published “Coalcomán and Motines Del Oro” derived from explorations made in Michoacan’s coast between 1950 and 1951. In the first part of the book, Brand exposed an historical reconstruction and area transformations through time based on archive research from the Spanish Conquest until 1950. It particularly explains the changes in territorial divisions, political and clerical structures, demographic and settlement organization, land tenure and the names of the towns. The second part is devoted to the natural history of the area: geology, paleontology and physiographic attributes of landscape. Here, Brand made use of geographical information such as pre-existing maps and aerial photography which revealed the exact location of the places Brand analyzed in his work (Wicke, 1967; Nicholson, 1962).

These examples and contributions lead us towards a more accurate interpretation of the Mexican Pacific landscape. Fortunately for us, it is this set of academic contributions that completes our spatial perspective of the area even if all of Berkeley’s bibliography is not available. Without these inputs, a unified geographical analysis would have been harder to pursue.

2.3 APPROACH AND DATA COLLECTION

Now that the framework, the study area and the geographical background have been identified, a crucial issue must be brought into the discussion: 1) how should the relationship between our landscape features be evaluated? and 2) what are we expecting to find? Even when the exercise of measuring landscape parameters may be considered as a reductionist approach, given the fact that other non-quantifiable but essential landscape attributes may be ignored, this measuring approach may lead to a basic understanding of certain environmental alliances that can be statistically analyzed and validated. The main methodological approach is then of a quantitative nature in order to recognize and quantify statistical relations between categories (or features).

In terms of what could be derived from this analysis, a difference, in terms of activities and formal attributes, is expected between steep (slopes) and plain (valley bottom) areas. Activities should then vary according to each the type of *landform* and *cover*. In the valley bottom, for example, we expect to find more diversified productive systems, such as farming activities; in steeper areas, on the other hand, a simpler pattern of activities may be revealed. Finally, the coastal *milieu* should be significantly different from the rest of the landscape.

In terms of the variables of interest for this kind of analysis, the basic comparable variable used to establish spatial coincidence between classes is the area (in hectares, ha). This means that after a classificatory system for our main three categories of information (*landform*, *land cover* and *land use*) was established and interpreted, matrices containing the area (ha) shared between different categories' classes were assembled (Table 9).

Table 9 An example of matrices assembled for data comparison between categories

		***Landform* classes**			
		1	2	...	n
***Land use* classes**	1	area (ha)	area (ha)		area (ha)
	2	area (ha)	area (ha)		area (ha)
	...	area (ha)	area (ha)		area (ha)
	n	area (ha)	area (ha)		area (ha)

		***Land cover* classes**			
		1	2	...	n
***Landform* classes**	1	area (ha)	area (ha)		area (ha)
	2	area (ha)	area (ha)		area (ha)
	...	area (ha)	area (ha)		area (ha)
	n	area (ha)	area (ha)		area (ha)

		***Land use* classes**			
		1	2	...	n
***Land cover* classes**	1	area (ha)	area (ha)		area (ha)
	2	area (ha)	area (ha)		area (ha)
	...	area (ha)	area (ha)		area (ha)
	N	area (ha)	area (ha)		area (ha)

The strategy for data collection encompassed two phases: (1) preliminary satellite imagery interpretation and (2) field verification and ground survey. The *landform* data was obtained from visual interpretation of images a detailed scale: 1:10,000, using 2008 QuickBird imagery with 0.6 m cell resolution. The satellite images were printed as stereoscopic pairs and *landforms* were delimited using a mirror stereoscope. Polygons were then attributed to a hierarchical classificatory *landform* system[28]. Afterwards, the polygons were digitized so that a vector data set could be incorporated to a GIS. This was our *landform* data input.

The same imagery input (QUICKBIRD) was used to obtain *land cover* data at the same scale (1:10,000). Unlike the *landform* data set, the *cover* polygons were delimited and attributed to their respective classes through digital on-screen interpretation by means of GIS software. The classificatory system was carefully put together so that no *land cover* class may be interpreted as a notion of *land use*. Once these activities were accomplished, data bases thus created were field verified.

The *land use* data set was determined exclusively from survey fieldwork. This relied on three principal activities: a) field recognition with local informants, b) semi-structured interviews with landowners and c) field mapping based on printed satellite imagery (QUICKBIRD). Once information on the whole area (Nexpa valley) had been

---

[28] See van Zuidam, 1986.

gathered and the classificatory system was structured, polygons were digitized and incorporated to a GIS as a vector data set.

The inputs for the evaluation of spatial relationships between *landforms, land cover* and *land use* were properly organized, consistent in terms of geometry and thematic accuracy, so that statistical analysis could be undertaken. The three layers of vector data were overlain in the GIS in the following order: a) *landform* data with *land cover* data, b) *land cover* data with *land use* data and c) *land use* data with *landform* data. The final result of this procedure was the three matrices containing the overlapping area values of the classes belonging to each category (*landform* vs. *land cover*; *land cover* vs. *land use*; *land use* vs. *landform*).

A multivariate statistical approach was used: ordination through Correspondence Analysis[29] which enabled landscape patterns and structure for interpretation through an arrangement of data in a low-dimensional space where "similar entities are close by and dissimilar entities far apart" (Gauch, 1982). The data treatment was similar to the one applied by Reyes (2008), García (2007) and Hupp & Rinaldi (2007); they employed binary discriminant analysis (BDA), detrended correspondence analysis (DCA), and the two-way indicator analysis (TWINSPAN)[30] to examine data grouping and relation between environmental variables.

For the particular purposes of this study, a correspondence analysis (CA) was used as the primary ordination technique because of the nature of its simplicity and interpretation easiness. "Correspondence analysis is a technique that represents graphically the row and column categories and allows for a comparison of their "correspondences", or associations, at a category level" (Beh, 2004:258). Moreover, CA has been chosen because it is a descriptive method that isn't model based, which makes it "a very versatile method of data analysis in all situations where exploratory or more in-depth analysis of categorical data is required" (Beh, 2004:280).

---

[29] This statistical procedure will be executed using R© 3.1.0 using the FactormineR library for exploratory multivariate analysis

[30] "The two way indicator analysis (TWINSPAN) is a numerical method of polythetic divisive classification and DCA is an indirect ordination technique that ordinates the floristic data [or other] independent of any environmental data; eigen values obtained indicate the explanation power of these gradients." (García, 2007:4)

SUMMARY

The *Sierra Costa* region is identifiable for its physiographic attributes while its population is scattered in small localities both at the Sierra and at the Costa. In order to explore so-defined *man-land* relationships in this area, the Nexpa valley has been chosen because it fulfills the geographic criteria needed for the type of analysis that we wish to do at a local scale.

This spatial analysis explores the relationships that take place in a particular landscape. A statistical validation of these alliances is pursued by applying a Correspondence Analysis (CA) to the data containing the overlapping area values between *landform*, *land cover* and *land use* classes. Nevertheless, because our methodological approach could lead us to a simplistic explanation of the relationships within landscape, the Berkeley school approach has been presented in order to set a solid and integrative geographical framework for this study.

CHAPTER 3

ANALYSING DATA PATTERNS AND LANDSCAPE ASSOCIATIONS

3.1. DESCRIPTIVE ATTRIBUTES OF CLASSIFICATION SCHEMES

As previously suggested in "Approach and Data Collection" (Ch. 2), the strategies for data classification varied according to *landform, land cover* and *land use* criteria. The general procedures to delimit spatial units were: a) previous classification schemes and b) visual interpretation of satellite imagery. Derived from these procedures, and the particular ones developed for each category, the following schemes were set:

3.1.1. *LANDFORM* CLASSIFICATION SCHEME

This *landform* classification is based on criteria proposed by van Zuidam (1986) who used a terrain analysis approach to map at different scales and levels of detail. A brief description of the use of this approach for every *landform unit* follows (Table 10).

Table 10 *Landform* class description

***Landform* class**	**Description**	**Reference**
Summit surface	"Nearly flat, undulating and rather small area on top of denudational slopes"	Adapted from van Zuidam, 1986
Denudational slope and hills	"Gentle to moderately steep slopes/undulating to rolling topography. Slightly to moderately dissected"	van Zuidam, 1986:43
Footslope	"Relatively short, nearly horizontal to gentle slopes. Nearly flat undulating topography. Not or slightly dissected"	van Zuidam, 1986:43
Valley Area		
V.1. Major stream channel	A river bed, "nearly flat, irregular topography varying water cover and having erosion and accumulation parts"	van Zuidam, 1986:44
V. 2. Minor stream channel	"Nearly flat, slightly irregular topography, regular/seasonally flooded; basically subject to silting up by fluvial accumulation"	van Zuidam, 1986:44
V.3. Stream channel deposits	Sandy, silty and, sometimes, clayey materials developed by slow accumulation of fine material, or cobbles and pebbles developed by fast accumulation of coarse material	Adapted from van Zuidam, 1986
V.4. Lower fluvial terrace	"They are relatively flat, horizontal, or gently sloping surfaces, sometimes long and narrow, which are bound by steeper ascending slope on one side and by a steeper descending slope on the opposite side". Fine and coarse materials depending	van Zuidam, 1986:43

	on the type of accumulation (slow or fast). This class makes reference to the most recently formed terraces	
V.5. Upper fluvial terrace	The highest (upper) terrace seems to be the oldest one with more “rounded forms and more extended vegetation”	van Zuidam, 1986:198
Coastal plain	Mostly beaches. “Nearly flat, gentle slopes, regularly flooded at high tide, frequently irregular topography due to beach lines, bars, swales and sand deposits reworked by wind”	van Zuidam, 1986:45

3.1.2. *LAND COVER* CLASSIFICATION SCHEME

The main criteria for *land cover* classification were the formal (not functional) attributes of the landscape. Therefore, the standard for the *land cover class* classification was what could actually be seen on the image, meaning forms, colors and patterns.

Our chosen scheme was based on Brown & Duh’s (2004) *land cover* classification system. It assumes that vegetation is an observable, and very clear, formal attribute in the landscape. Categories were “trees”, "shrubs" “herbaceous”, etc. Based on our own landscape conditions, this broad classification was adapted into: “arboreal (trees)”, “shrubs”, “herbaceous”, “bare land” and “water”. Subclasses were then set based on imagery interpretation and field verification (Table 11).

Table 11 *Land cover* class description

***Land cover* class**	**Description**	**Reference**
Arboreal (tree)		
Tropical dry forest	A dominantly wooded area with relatively short (in stature) vegetation (as compared to tropical wet forests); phenology strongly influenced by seasonal rainfall	Adapted from Murphy & Lugo, 1986:69
Mango tree	“Man-made” mango plantations distributed mostly around the valley	Field observation and analysis
Palm tree	“Man-made” palm plantations (used for coconut oil production) mostly found all over the coastal plain but also in the valley	Field observation and analysis
Riparian forest	Vertical and lateral gradients of vegetation whose distribution pattern is determined by the stream’s influence, water availability and	Adapted from Richardson *et al.,* 2007:127

	flooding	
Shrub		
Scrubland	Areas dominated by shrub species that have medium vegetation cover and are mostly found in rather steep terrain	Adapted from Moreno & Villafuerte, 1995:81
Herbaceous		
Undifferentiated grassland/cropland	Areas where the vegetation structure is mostly composed by gramineal species distributed both in flat and steep lands	Field observation and analysis
Bare land	Displayed along vertical and lateral gradients; rocks and sediments dragged by fluvial action and have no apparent vegetative cover	Field observation and analysis
Water		
Fluvial stream	The Nexpa river stream flow	Field observation and analysis
Reservoir	A man-made water body of small dimensions	Field observation and analysis
Seascape	The geographic unit that “includes open sea, shoreline and the interrelationship between land and sea”	Adapted from Cornwall Council UK government, 2012

3.1.3 *LAND USE* CLASSIFICATION SCHEME

This system was defined as the feature relating to both formal and functional, attributes in landscape. Formal, because *use* can be displayed and mapped in space; functional because it inherently refers to the *activities* developed in a given area (Rhind & Hudson, 1980). As previously established on “Approach and Data Collection” (Ch. 2), the *land use class* procedures were based on three principal stages: a) field recognition with local informants, b) semi-structured interviews with landowners and c) field mapping based on printed satellite imagery. Derived from this procedure, the following scheme was obtained:

Table 12 *Land use* class description

***Land use* class**	**Description**
Agriculture	
Rain-fed	A crop and orchard production delimited area identified by its seasonal attributes. Rainfall is the main source of water. Mango and palm orchards, corn, tomatoes and beans are examples of products raised by rain-fed agriculture.
Localized irrigation	Proportion of area where the irrigation is carried on by an engineered system that applies water directly into the plantation. Mango, beans, tomato, papaya, chili are mostly produced by means of this technique
Mixed irrigation system	Mostly located over wetlands that are naturally humid and encourage plant growth and, still, where localized irrigation systems have been

	installed to control water availability and piping
Cattle grazing	
Grazing	The proportion of space that is intended for livestock (herbivore) feeding. Areas of planted or natural pastures are used for this purpose
Barnyard	A rustic building where livestock is gathered, and that forms part of a household system
Artisanal fisheries	Places where fish and crustacean harvesting is developed usually using self-made, improvised nets and traps. River shrimp, *tilapia*, bass, catfish and sea products are obtained from this activity.
Brick production	A manufacture activity where clays and sands are extracted from the soil in order to produce blocks, as building materials, and dry them with solar energy and firewood.
Residential	The Nexpa settlement
Recreation	
Swimming area in the river	Villagers use some portion of the river stream to swim especially during the mid-dry season, on their spare time. Barbecues and social gatherings are associated to this activity
Sports (volleyball)	Volleyball courts scattered by the river or the residential area. It is the most popular sport in Nexpa.
Swimming area in the ocean	On the beaches all year long
Tourism	Unlike recreational activities, tourism is carried mostly by foreigners that visit Nexpa to enjoy from seascape.
Extractive activities	
Building material	Extraction of raw materials such as gravel and sands for construction purposes mostly
Wood and fuel	Extraction of lumber and firewood
Game hunting	This activity is developed in the most isolated places of the area. Deer and mourning doves are the species hunted seasonally

One of the attributes of *land use* is the occurrence of various activities in the same area; thus, how can we know which activities occur simultaneously in which places? The technical solution to this problem was to delineate, for each class, an absence/presence layer containing detailed information for each predominant activity. This means that each class was organized in a "presence/absence" scheme where the total study area was considered for each one of the classes. In "agriculture", for example, the area was delimited according to the predominance of "rain-fed", "localized irrigation" or "mixed irrigation system".

Once all nine (9) layers were built (for "agriculture", "cattle grazing", "artisanal fisheries", etc.), they were all intersected in the GIS, so that the newly created polygons would have all of the information for each class. Derived from this procedure, 25 classes were created:

Table 13 Intersected *land use* classes

1	Barnyards
2	Barnyards - wood and fuel - game hunting
3	Swimming area in the ocean– tourism
4	Swimming area in the river
5	Brick production
6	Building materials
7	Grazing - wood and fuel - game hunting
8	Localized irrigation
9	Localized irrigation - barnyards - brick production – residential
10	Localized irrigation – grazing
11	Localized irrigation - grazing – tourism
12	Mixed irrigation system
13	Mixed irrigation system – barnyards
14	Mixed irrigation system – grazing
15	Rain-fed
16	Rain-fed - barnyards - brick production – residential
17	Rain-fed – grazing
18	Rain-fed - grazing – tourism
19	Rain-fed – tourism
20	Artisanal fisheries (river shrimp, tilapia, catfish)
21	Artisanal fisheries (river shrimp, tilapia, catfish) – Swimming area in the river
22	Artisanal fisheries (river shrimp, tilapia, catfish) – tourism
23	Artisanal fisheries (sea products)
24	Tourism
25	Wood and fuel - game hunting

The original 9-class scheme will be used for the description of the land-use system. The 25-class scheme will be used for the statistical and geographical analysis because it reflects, more accurately, the assignment of activities for each one of the units.

3.2. GEOMETRIC ATTRIBUTES OF POLYGONS AND CLASSES

In terms of *landform* class geometry (Figure 2), there are a total of 89 polygons, 42 of which belong to the "summit surface" class (Table 14). However, in terms of area, it is one of the smaller classes. The "denudational slopes and hills" is the class that occupies the largest proportion of land compared to other classes (794 ha, 56.6%), followed by the "coastal plain" (317 ha, 22.6%). The total "valley area" represents 14.7% of total surface.

Table 14 Geometric attributes of *landform* classes

Landform class	Number of polygons	Area (ha)	Percentage of total area (%)	Average polygon area per class (ha)
Summit surface	42	31	2.2	1
Denudational slopes and hills	9	794	56.6	88
Footslope	16	55	3.9	3
Valley area				
V.1. Major stream channel	1	55	3.9	55
V. 2. Minor stream channel	9	24	1.7	3
V.3. Stream channel deposits	4	55	3.9	14
V.4. Lower fluvial terrace	5	43	3.0	9
V.5. Upper fluvial terrace	2	30	2.1	15
Coastal plain	1	317	22.6	317
Total	89	1,404	100	

For *land cover* classes (Figure 3), there are a total of 94 polygons, with 25 of them classified as “undifferentiated grassland/cropland”. Nevertheless, in terms of area proportion (Table 15), the largest class is still “tropical dry forest” (544 ha), followed by the “herbaceous” class (259 ha). Generally, the “arboreal” structured covers dominate, in terms of land proportion, over “shrubs”, “herbaceous”, “bare land” and “water”. The least observed class is “reservoir” with only one polygon with a 2 ha area.

Table 15 Geometric attributes of *land cover* classes

Land cover class	Number of polygons	Area (ha)	Percentage of total area (%)	Average polygon area per class (ha)
Arboreal				
Tropical dry forest	8	544	38.8	68
Mango tree	8	80	5.7	10
Palm tree	5	57	4.1	11
Riparian forest	12	88	6.3	7
Shrub				
Scrubland	21	144	10.3	7
Herbaceous				
Undifferentiated grassland/cropland	25	259	18.4	10
Bare land	12	19	1.4	2
Water				
Fluvial stream	1	57	4.1	57
Reservoir	1	2	0.1	2
Seascape	1	154	11.0	154
Total	94	1,404	100	

For *land use* (Figure 4), in its original classification, each class has been organized into a “presence/absence” scheme where the total area is considered for each of the classes. “Agriculture”, for example, can be found in approximately 29.23% of the total area (Table 16). Its most common subclass is “rain-fed” agriculture that occupies about 17.99% of total land, followed by “mixed irrigation system” agriculture (9.53%) and, finally, “localized irrigation” agriculture (1.83 %).

Table 16 Geometric attributes of *land use* classes

Land use class	Number of polygons	Area (ha)	Percentage of total area (%)	Average polygon area per class (ha)
Agriculture				
Rain-fed	33	251	17.9	8
Localized irrigation	7	26	1.8	4
Mixed irrigation system	9	134	9.5	15
No “agriculture” land	45	994	70.8	22
Total Area	94	1,404	100	
Cattle grazing				
Grazing	38	355	25.3	9
Barnyards	10	27	1.9	3
No “cattle grazing” land	46	1,022	72.8	22
Total Area	94	1,404	100	0
Artisanal fisheries	8	211	15.0	26
No “artisanal fisheries” land	86	1,193	85.0	14
Total Area	94	1,404	100	
Brick production	7	14	1.0	2
No “brick production” land	87	1,390	99.0	16
Total Area	94	1,404	100	
Residential	7	14	1.0	2
No “residential” land	87	1,390	99.0	16
Total	94	1,404	100	
Recreation				
Swimming area in the river	6	10	0.7	2

Sports (volleyball)	1	0.4	0.03	0.4
Swimming area in the ocean	1	8	0.6	8
No “recreation” land	86	1,386	98.7	16
Total Area	94	1,404	100	
Tourism	8	126	9.0	16
No “tourism” land	86	1,278	91.0	15
Total Area	94	1,404	100	
Extractive				
Building material	16	28	2.0	2
Wood and fuel	33	755	53.8	23
No “extractive” land	45	621	44.3	14
Total Area	94	1,404	100	
Game hunting	37	761	54.2	21
No “game hunting” land	57	643	45.8	11
Total Area	94	1,404	100	

“Cattle grazing” occupies a similar proportion to “agriculture”, that is, around 27.20% of total area. “Grazing” is the predominant subclass with 355 ha. As naturally expected, “barnyards” are only found in approximately 1.90% of the land. “Artisanal fisheries” occupy 15.02% of the total area and 8 polygons, while “brick production” and “residential” are found in about 1.00% of the area. “Recreation” is dominated by “bath in the river” that develops around 0.69% of the area and is followed by “bath in the ocean” with 0.56%. “Sports” occupy a relatively low area because of the size and number of courts. “Tourism” covers a larger area as compared to “recreation”, and occupies 126 ha, that is 9.00% of total land.

The “extractive” and “game hunting” classes are both activities that demand a large area: 55.740% and 54.19%, respectively, of total area. The predominant “extractive” activity, by far, is “wood and fuel”. Nevertheless, “building material” is also important.

Figure 2 *Landform* map

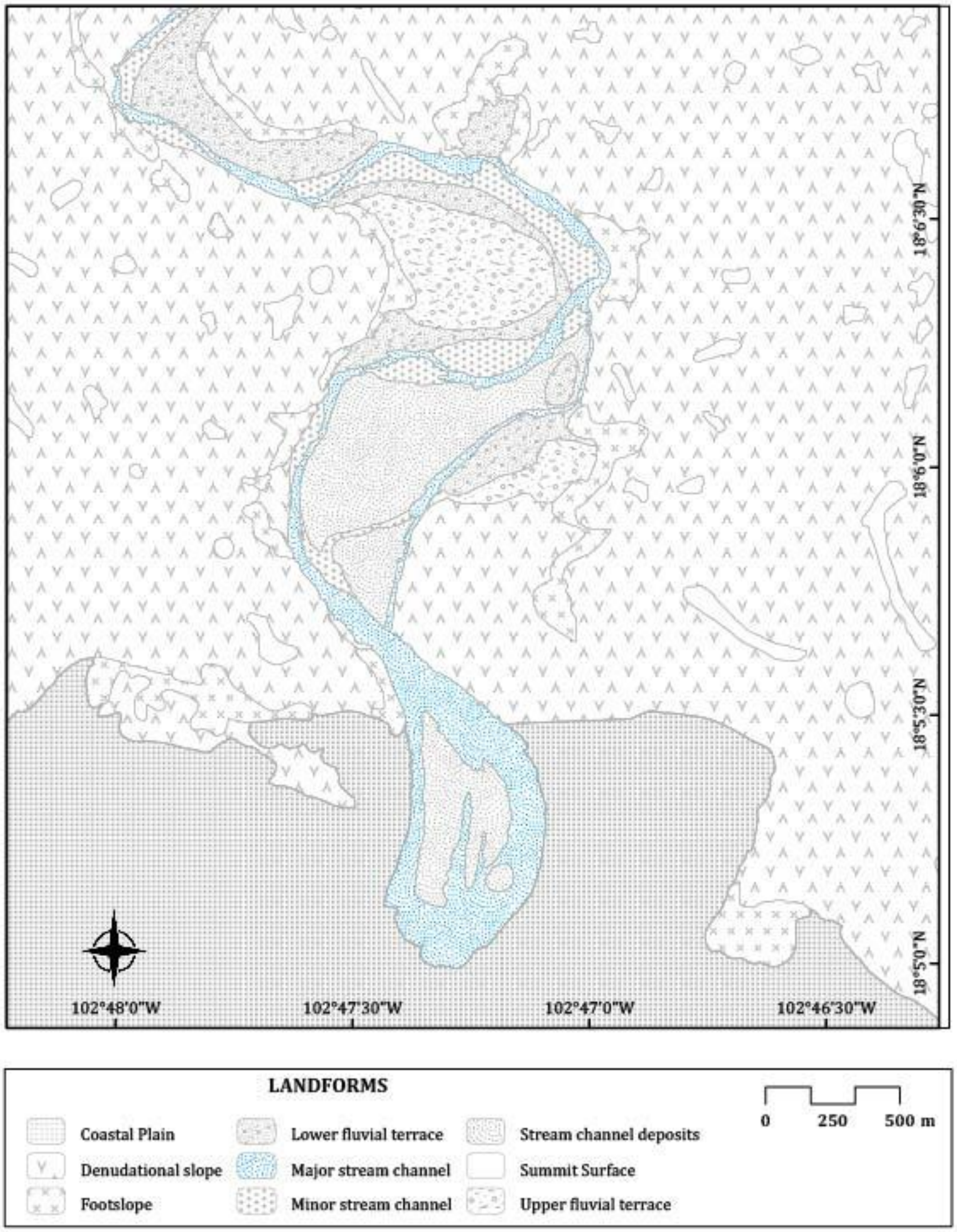


Figure 3 *Land Cover* map

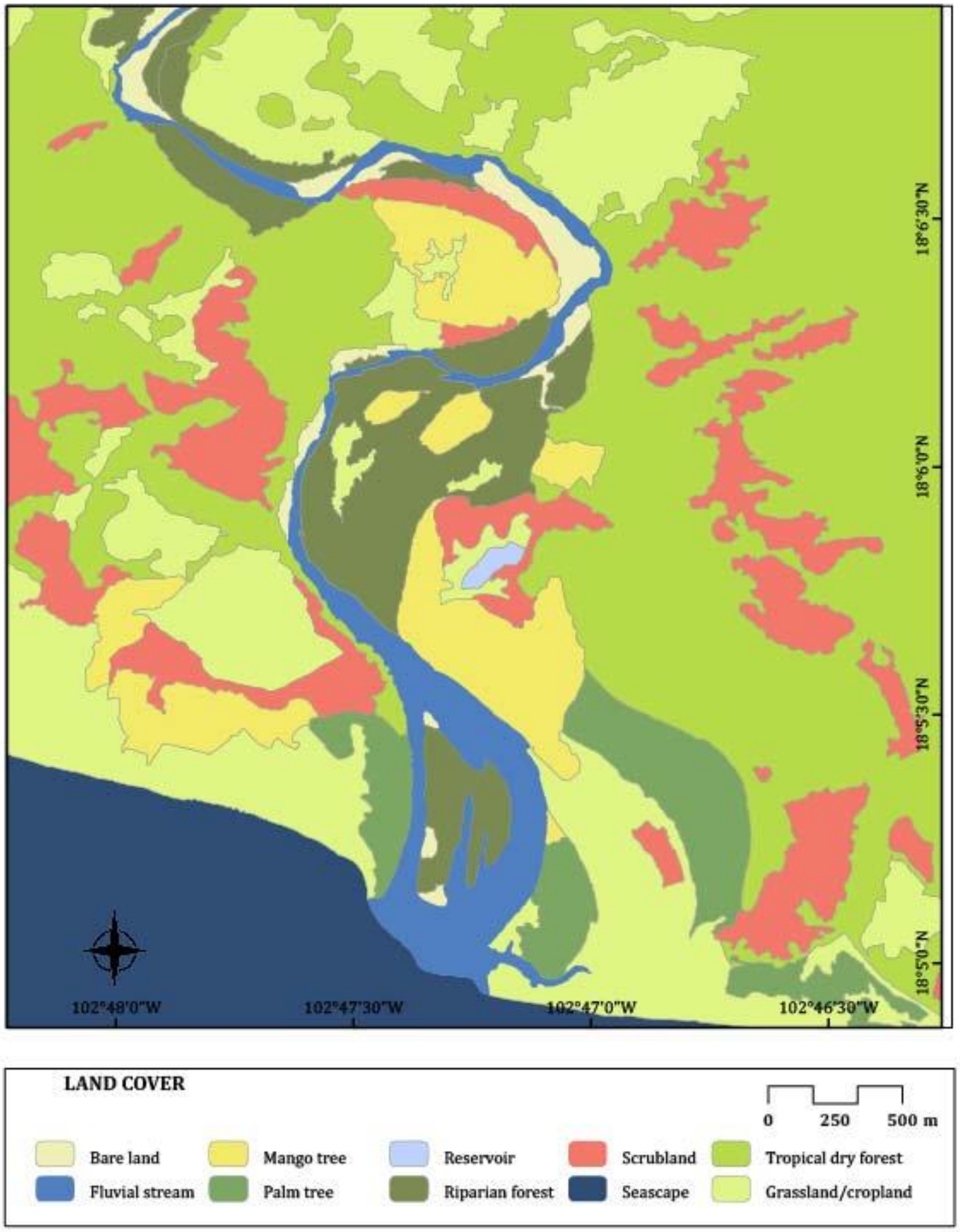
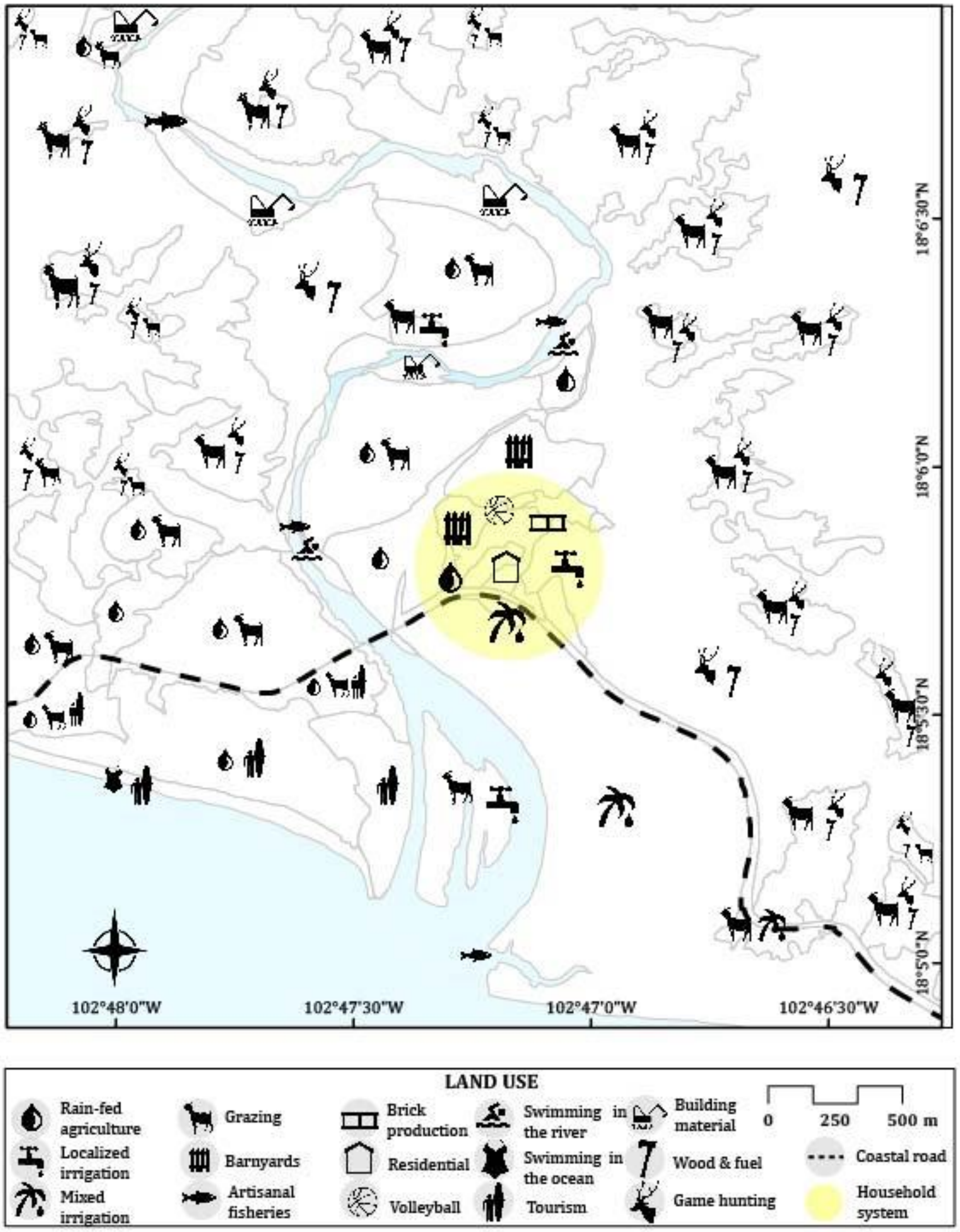


Figure 4 *Land use* map



3.3. STATISTICAL ANALYSIS OF SPATIAL DATA

As pre-established on Chapter 2, the three layers of vectorial data (*landform*, *land cover* and *land use* polygons) were overlaid in the GIS. The final result of this procedure was three (3) main cross tables containing the overlapping area values (in hectares, ha) of the polygons belonging to each class (Tables 17, 18, & 19):

Table 17 Input data matrix: area values (ha) shared between polygons of *landform* and *land cover* classes

	Bare land	Fluvial stream	Mango tree	Palm tree	Reservoir
Coastal Plain	0.00	4.55	5.79	53.39	0.00
Denudational slope	1.85	0.00	37.27	2.64	1.85
Footslope	0.00	0.00	7.79	0.90	0.00
Lower fluvial terra*	3.37	0.00	0.00	0.00	0.00
Minor stream channel	11.97	0.00	0.00	0.00	0.00
Major stream channel	0.00	52.11	0.00	0.00	0.00
Stream channel depo*	2.12	0.86	5.54	0.00	0.00
Summit Surface	0.00	0.00	0.00	0.00	0.00
Upper fluvial terra*	0.00	0.00	23.30	0.00	0.00

	Riparian forest	Scrubland	Seascape	Tropical dry forest	Grassland/cropland
Coastal Plain	0.00	2.93	154.22	7.12	90.26
Denudational slope	10.40	122.65	0.00	483.60	140.97
Footslope	0.00	7.83	0.00	29.56	6.36
Lower fluvial terra*	17.02	6.53	0.00	2.75	13.77
Minor stream channel	12.00	0.00	0.00	0.00	0.00
Major stream channel	2.71	0.00	0.00	0.00	0.00
Stream channel depo*	43.68	0.00	0.00	0.00	2.68
Summit Surface	0.00	2.17	0.00	20.34	3.31
Upper fluvial terra*	2.40	1.02	0.00	0.80	1.59

Table 18 Input data matrix: area values (ha) shared between polygons of *land cover* and *land use* classes

	Bare land	Fluvial stream	Mango tree	Palm tree	Reservoir	Riparian forest	Scrubland	Seascape	Tropical dry forest	Grassland /cropland
Barnyards	0.00	0.00	3.63	0.00	0.00	6.39	0.00	0.00	0.76	1.13
Barnyards - Wood and fuel - Game hunting	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	0.00	0.00
Swimming area in the ocean – Tourism	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.92
Swimming area in the river	3.89	0.00	0.00	0.00	0.00	1.30	0.00	0.00	0.00	0.00
Brick production	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00
Building materials	9.97	0.00	1.93	0.00	0.00	20.85	6.03	0.00	6.54	1.41
Grazing - Wood and fuel - Game hunting	0.00	0.00	0.00	0.00	0.00	0.00	104.29	0.00	0.00	103.19
Localized irrigation	0.00	0.00	2.22	0.00	1.84	0.00	0.00	0.00	0.00	0.00
Localized irrigation - Barnyards - Brick production - Residential	0.00	0.00	0.00	0.00	0.00	0.00	2.89	0.00	0.00	3.09
Localized irrigation – Grazing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.22
Localized irrigation - Grazing – Tourism	1.10	0.00	0.00	0.00	0.00	12.62	0.00	0.00	0.00	0.00
Mixed irrigation system	0.00	0.00	22.91	45.3	0.00	0.00	2.15	0.00	1.88	57.01
Mixed irrigation system – Barnyards	0.00	0.00	0.00	0.00	0.00	0.00	1.50	0.00	0.00	0.00
Mixed irrigation system – Grazing	0.00	0.00	0.00	0.00	0.00	0.00	3.38	0.00	0.00	0.00
Rain-fed	0.42	0.00	10.01	0.00	0.00	13.74	0.00	0.00	2.49	0.00
Rain-fed - Barnyards - Brick production – Residential	0.00	0.00	0.00	0.00	0.00	0.00	5.54	0.00	0.00	0.00
Rain-fed – Grazing	0.00	0.00	24.52	0.00	0.00	23.15	7.72	0.00	0.00	51.50
Rain-fed - Grazing – Tourism	0.00	0.00	0.00	0.00	0.00	0.00	8.59	0.00	0.00	8.22
Rain-fed – Tourism	0.00	0.00	15.06	0.00	0.00	0.00	0.00	0.00	2.12	21.52
Artisanal fisheries (river shrimp, tilapia)	0.00	16.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Artisanal fisheries (river shrimp, tilapia) - Swimming area in the river	0.00	4.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Artisanal fisheries (river shrimp, tilapia) – Tourism	0.00	36.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Artisanal fisheries (sea products)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	154.08	0.00	0.00
Tourism	0.00	0.00	0.00	11.39	0.00	0.00	0.00	0.00	0.00	1.71
Wood and fuel - Game hunting	4.25	0.00	0.00	0.00	0.00	9.29	0.55	0.00	530.83	0.00

Table 19 Input data matrix: area values (ha) shared between polygons of *land use* and *landform* classes

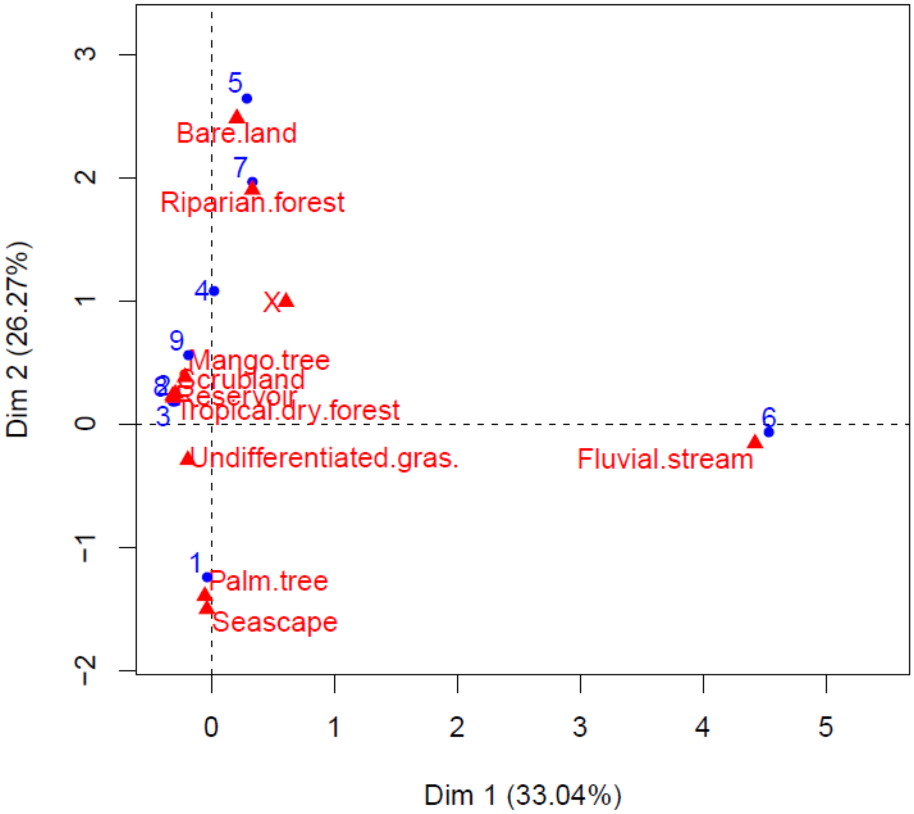
	Coastal Plain	Denudational slope	Footslope	Lower fluvial terrace	Major stream channel	Minor stream channel	Stream channel deposits	Summit Surface	Upper fluvial terrace
Barnyards	0.00	0.00	0.00	5.70	0.00	0.00	0.00	0.00	6.11
Swimming area in the ocean – Tourism	7.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Swimming area in the river	0.00	0.74	0.00	0.00	0.00	3.64	0.86	0.00	0.00
Brick production	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Building materials	2.98	17.58	1.02	8.92	0.42	16.05	0.00	0.00	0.97
Grazing - Wood and fuel - Game hunting	0.00	188.63	5.35	9.43	0.00	0.00	0.00	3.88	0.00
Localized irrigation	0.00	1.84	1.85	0.00	0.00	0.00	0.00	0.00	0.00
Localized irrigation - Barnyards - Brick production – Residential	0.00	5.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Localized irrigation – Grazing	0.00	0.00	0.00	1.79	0.00	0.00	0.00	0.00	0.00
Localized irrigation - Grazing – Tourism	0.00	0.00	0.00	0.00	0.00	0.00	13.97	0.00	0.00
Mixed irrigation systems	104.48	22.08	2.41	0.00	0.00	0.00	0.00	0.00	0.00
Mixed irrigation systems – Barnyards	0.00	1.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mixed irrigation systems – Grazing	0.67	0.00	2.71	0.00	0.00	0.00	0.00	0.00	0.00
Rain-fed	0.00	12.06	0.00	1.63	2.60	1.07	7.83	0.00	0.00
Rain-fed - Barnyards - Brick production - Residential	0.00	5.57	0.84	0.00	0.00	0.00	0.00	0.00	0.00
Rain-fed – Grazing	0.00	48.45	2.35	1.23	0.00	0.00	31.33	1.60	22.45
Rain-fed - Grazing – Tourism	6.25	8.40	2.26	0.00	0.00	0.00	0.00	0.00	0.00
Rain-fed – Tourism	19.51	11.08	8.37	0.00	0.00	0.00	0.00	0.00	0.00
Artisanal fisheries (river shrimp, tilapia)	2.08	0.00	0.00	0.00	14.75	0.00	0.00	0.00	0.00
Artisanal fisheries (river shrimp, tilapia) – Swimming area in the river	0.00	0.00	0.00	0.00	4.48	0.00	0.00	0.00	0.00
Artisanal fisheries (river shrimp, tilapia) - Tourism	2.54	0.00	0.00	0.00	32.93	0.00	0.86	0.00	0.00
Artisanal fisheries (sea products)	154.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tourism	12.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wood and fuel - Game hunting	3.93	478.13	26.08	13.99	0.00	3.22	0.00	20.37	0.00

3.3.1. DATA ORDINATION: CORRESPONDENCE ANALYSIS (CA)

When data are ordinated using correspondence analysis (CA), the results should arrange our classes in a low-dimensional space where the similar entities are close and dissimilar entities are far apart (Gauch, 1982). Correspondence Analysis will therefore arrange entities based on their correspondence between each other. In this case, the eigenvalues represent the values of variance, and percentage of variance, associated with each dimension (in this low-dimensional space). Thus, this eigenvalues explain how much variance in data is explained by each dimension (Husson *et al.,* 2010).

The first data set analyzed through CA was the one created by crossing *landform* and *land cover* attributes (Figure 5; Table 17). The first two dimensions explain a little more than half of total variance in data (59.3%); this value is quite high and reflects the existing correspondence between *landform* and *land cover*. Three groups are highlighted: a) the “fluvial stream” corresponds with the “major stream channel”; b) the “seascape” to “palm tree” attributed to “coastal plain”; c) “bare land” and “riparian forest” associated to “minor stream channel” and “stream channel deposits”. The fourth group is wider and establishes a correspondence between the following classes: “mango tree” to “lower fluvial terrace” and “upper fluvial terrace”; “scrubland”, “reservoir”, “tropical dry forest”, “grassland/cropland” all associated to “footslope”, “denudational slopes” and “summit surface”, all categories outside the valley bottom.

Figure 5 *Landform* vs. *Land cover* data correspondence analysis (CA)



Code:

1 Coastal Plain
2 Denudational slope
3 Footslope
4 Lower fluvial terra*
5 Minor stream channel
6 Major stream channel
7 Stream channel deposits
8 Summit Surface
9 Upper fluvial terrace

Eigenvalues:

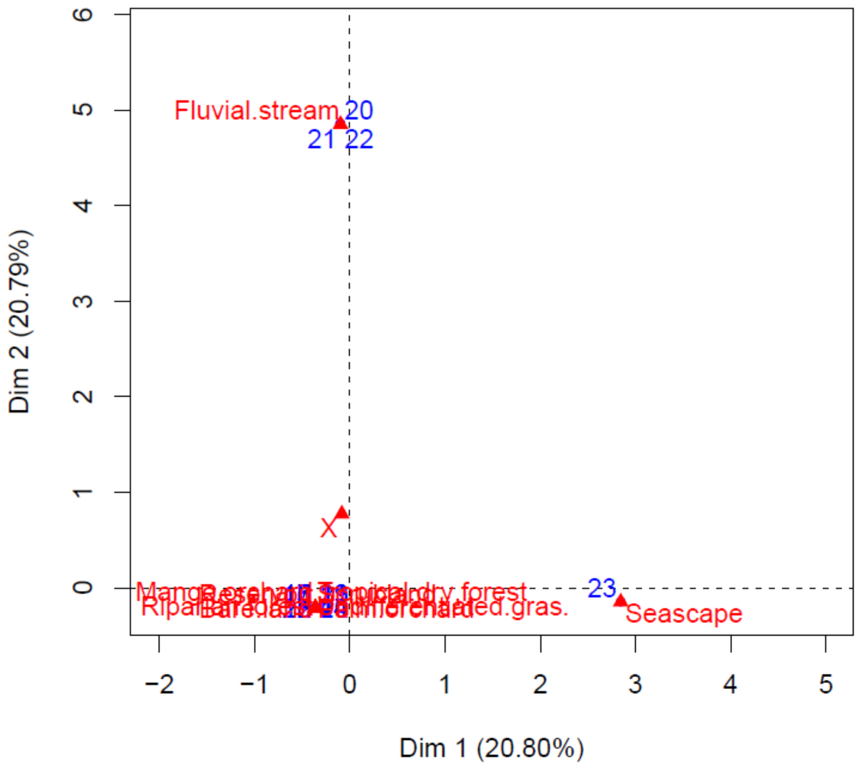
	Dim.1	Dim.2	Dim.3
Variance	0.865	0.688	0.633
% of var.	33.036	26.274	24.194
Cumulative % of var.	33.036	59.309	**83.504**

The results of CA confirm what was observed during field work, and may point to “the obvious”. However, these results are important because they describe spatial relationships in a quantitative manner, and above all they suggest that data are consistent and reliable.

What happens when *land cover* is analyzed along with *land use*? (Figure 6;

Table 18) As it was stated at the beginning of this proposal, we are assuming that both features are completely different as landscape attributes and that a *cover class* may be associated to many different *use classes*. The CA should help in the answer of this question.

Figure 6 *Land cover* vs. *Land use* data correspondence analysis (CA)



Code:

1	Barnyards	14	Mixed irrigation system - Grazing
2	Barnyards - Wood and fuel - Game hunting	15	Rain-fed
3	Swimming area in the ocean - Tourism	16	Rain-fed - Barnyards - Brick production - Reside
4	Swimming area in the river	17	Rain-fed - Grazing
5	Brick production	18	Rain-fed - Grazing - Tourism
6	Building materials	19	Rain-fed - Tourism
7	Grazing - Wood and fuel - Game hunting	20	Artisanal fisheries (river shrimp, tilapia)

8 Localized irrigation
9 Localized irrigation - Barnyards - Brick production - Residential
10 Localized irrigation - Grazing
11 Localized irrigation - Grazing - Tourism
12 Mixed irrigation system
13 Mixed irrigation system - Barnyards

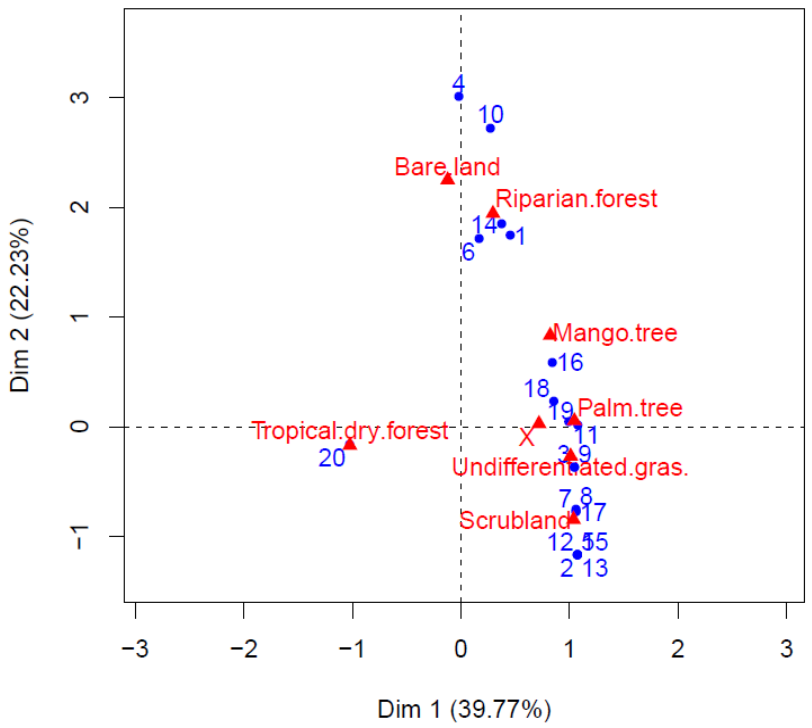
21 Artisanal fisheries (river shrimp, tilapia)- swimm area in the river
22 Artisanal fisheries (river shrimp, tilapia)- Touris
23 Artisanal fisheries (sea products)
24 Tourism
25 Wood and fuel - Game hunting

Eigenvalues:

	Dim.1	Dim.2	Dim.3
Variance	1.000	1.000	0.934
% of var.	20.795	20.794	19.429
Cumulative % of var.	20.795	41.589	**61.019**

This analysis poorly represents the variation in the data even when the first and second dimensions (Dim 1 and Dim 2) reasonably express 41.59% percent of total variability. The second axis is dominated by the fluvial stream class, along with the riverine land use and no perceptible data pattern can be interpreted. However, this analysis indicates that “seascape” is associated to “artisanal fishery (sea products)” and that the “fluvial stream” is associated to “artisanal fishery (river shrimp, tilapia and catfish)”, “swimming area in the river” and “tourism”. Nevertheless, “seascape” and “fluvial stream” are explaining most of the variance which is not very useful to explain other associations. Therefore, a second CA (Figure 7) was carried out excluding these two classes.

Figure 7 *Land cover* vs. *Land use* data correspondence analysis (CA). Second phase



Code:

1 Barnyards
2 Barnyards - Wood and fuel - Game hunting
3 Swimming area in the ocean – Tourism
4 Swimming area in river
5 Brick production
6 Building materials
7 Grazing - Wood and fuel - Game hunting
8 Localized irrigation - Barnyards - Brick production - Residential
9 Localized irrigation – Grazing
10 Localized irrigation - Grazing – Tourism
11 Mixed irrigation system
12 Mixed irrigation system – Barnyards
13 Mixed irrigation system - Grazing
14 Rain-fed
15 Rain-fed - Barnyards - Brick production - Reside
16 Rain-fed - Grazing
17 Rain-fed - Grazing - Tourism
18 Rain-fed - Tourism
19 Tourism
20 Wood and fuel - Game hunting

Eigenvalues:

	Dim.1	Dim.2	Dim.3
Variance	0.934	0.522	0.486
% of var.	39.774	22.233	20.696
Cumulative % of var.	39.774	62.007	**82.703**

The first two dimensions now explain 62% of variation and the relationships in the data are easier to see. The first dimension (x axis) explains that the most variable class, based on *use* affinities, is the "tropical dry forest". The second dimension (y axis) separates “bare land”, “riparian forest”, “mango tree”, “palm tree”, “grassland/cropland” and “scrubland”.

In terms of the correspondence with actual activities, the following patterns are observed: “tropical dry forest” is associated with “wood and fuel – game hunting”, while “mango” and “palm tree” are grouped together with “rain-fed” and “mixed irrigation system” agriculture, “grazing” and “swimming area in the ocean/tourism”. The “bare land” and “riparian forest” classes correspond to both “rain-fed” and “localized irrigation” agriculture[31], “swimming area in the river”, “grazing” and “building materials”. Finally, in the “grassland/cropland” and “scrubland” group, all types of agriculture (“rain-fed”, “localized” and “mixed irrigation”) were found as well as “barnyards” and “grazing”, “residential”, “brick production”, “wood and fuel extraction” and “game hunting”.

This analysis clearly represents the usual existence, at least in tropical countries, of *many-to-many* relationships between *cover* and *use*. It also suggests that assuming that only one kind of *activity* may be developed in only one *cover* type is misleading. This type of assumptions is common when using GIS and simple data overlying is accomplished among different maps. “Agriculture” and “cattle grazing” are clear examples of activities not developing necessarily in restricted *cover* types. Instead, we find “agriculture” and “cattle grazing” in almost all types of *covers*, although in different modalities. To establish a *one to many* relationship an extremely thorough analysis of these modalities needs to be done, but usually this calls for a study at a site level (farm, household, or slope catena).

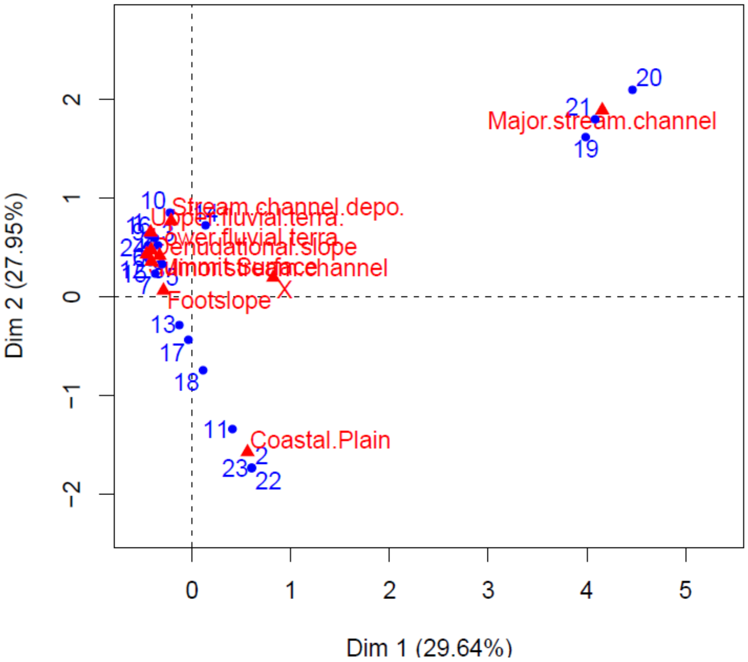
When all the *land use* and the *landform* records are ordinated in a CA (Figure 8; Table 19), the results tend to be unclear. Moreover, the analysis only suggests that the “major stream channel” associates, quite clearly, with “artisanal fishery (river shrimp, tilapia, and catfish)”, “swimming in the river” and “tourism”. On the other hand, the “coastal plain” corresponds to “mixed irrigation system”, “artisanal fisheries (sea products)”, “swimming in the ocean” and “tourism”. This is only logical but it does not

---

[31] Agriculture activities may be hard to associate to “bare land” and “riparian forest”. However, this association is due to the fact that very small parcels occur next to riparian vegetation which makes them hard to be differentiated at a 1:10,000 scale.

tell us much about the activity distribution over the valley, which is the priority area for analysis.

Figure 8 *Land use* vs. *Landform* data correspondence analysis (CA)



Code:

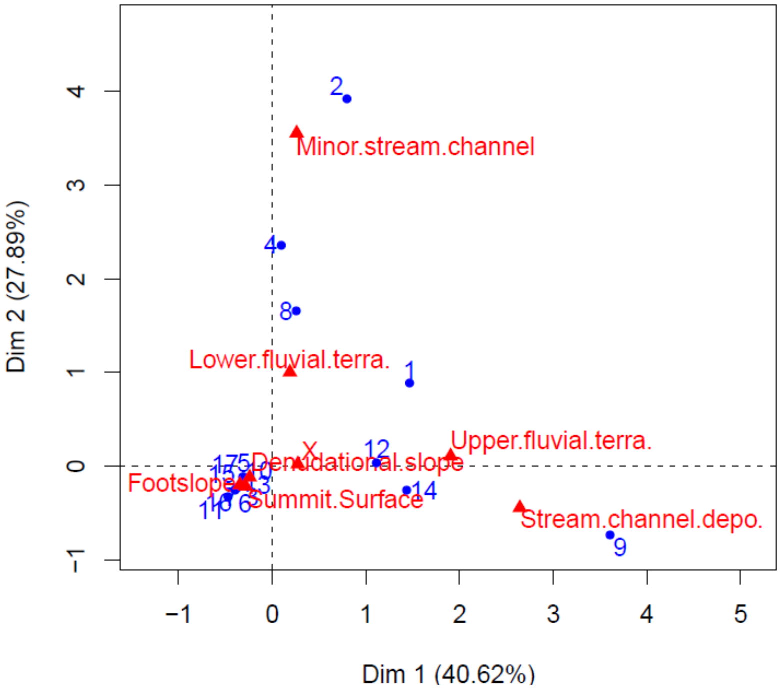
1	Barnyards	13	Mixed irrigation sy* - Grazing
2	Bath in the ocean - Tourism	14	Rain-fed
3	Bath in the river	15	Rain-fed - Barnyards - Brick production - Reside
4	Brick production	16	Rain-fed - Grazing
5	Building materials	17	Rain-fed - Grazing - Tourism
6	Grazing - Wood and fuel - Game hunting	18	Rain-fed - Tourism
7	Localized irrigation	19	River shrimp, tilap*
8	Localized irrigation - Barnyards - Brick production - Residential	20	River shrimp, tilap* - Bath in the river
9	Localized irrigation - Grazing	21	River shrimp, tilap* - Tourism
10	Localized irrigation - Grazing - Tourism	22	Sea products
11	Mixed irrigation sy*	23	Tourism
12	Mixed irrigation sy* - Barnyards	24	Wood and fuel - Game hunting

Eigenvalues:

	Dim.1	Dim.2	Dim.3
Variance	0.867	0.817	0.522
% of var.	29.638	27.953	17.866
Cumulative % of var.	29.638	57.591	**75.458**

As the “major stream channel” and “the coastal plain” groups are capturing too much variance in the data set, we have decided to run a CA without them:

Figure 9 *Land use* vs. *Landform* data correspondence analysis (CA). Second phase



Code:

1	Barnyards
2	Bath in the river
3	Brick production
4	Building materials
5	Grazing - Wood and fuel - Game hunting
6	Localized irrigation
7	Localized irrigation - Barnyards - Brick production - Residential
8	Localized irrigation – Grazing
9	Localized irrigation - Grazing – Tourism
10	Mixed irrigation sy* - Barnyards
11	Mixed irrigation sy* - Grazing
12	Rain-fed
13	Rain-fed - Barnyards - Brick production - Resider
14	Rain-fed - Grazing
15	Rain-fed - Grazing - Tourism
16	Rain-fed - Tourism
17	Wood and fuel - Game hunting

Eigenvalues:

	Dim.1	Dim.2	Dim.3
Variance	0.537	0.369	0.216
% of var.	40.617	27.892	16.297
Cumulative % of var.	40.617	68.509	**84.806**

In this case, the first two dimensions now explain 68.5% of the total variance, rather better than the 57.6% explained by the previous CA. The interpretation provides us with the following results: the first dimension (x axis) explains that the greatest values of variance are between the “stream channel deposits” and “upper fluvial terrace” with “footslope”, “denudational slope” and “summit surface”; on the other hand, the second dimension (y axis) explains the variance between “minor stream channel”, “lower fluvial terrace” with the “denudational slopes” and the “summit surface”.

In terms of the associations within features, the “stream channel deposits” are linked to “localized irrigation”, “grazing” and “tourism”, while the “upper fluvial terrace” is more linked to “rain-fed agriculture” and “grazing”. The “lower fluvial terrace” is associated with “building material extraction”, “localized irrigation” and “grazing”. The “footslope-denudational slopes- summit surface” triad shows, once again, a tangled pattern of activities, strongly associated with “grazing”, “wood and fuel extraction” and “game hunting”. Another interesting fact is that these activities are consistently distributed outside the “valley bottom” entities. This arrangement may suggest that the idea that fewer activities are being developed in steep and vegetated areas, as compared to plain and bare ones, is not correct.

CHAPTER 4

HURRICANE ‘MANUEL’: AN EXTREME EVENT IN NEXPA VALLEY

This chapter has been included to illustrate the importance of hazardous events, specifically hurricanes and tropical storms, as potential transformers of landscape features. For this purpose, ethnographic, meteorological and press material was collected in order to illustrate how places were affected by these extreme events.

The main objective is to complement our understanding of landscape dynamics that modify features such as *landforms*, *land cover* or *land use*. The question isn't why hazardous events occur but, what happens when they occur?

To pursue the answer, this section has been written regarding the following points: a) hurricanes and their spatial incidence on landscape, b) previous extreme event and c) approaches to damage control. Thus, in order to reinforce discussion, the data collection relies on different aspects such as visits to the field, local precipitation record analysis (from local weather stations), tropical storm survey (over the area) and a bibliographical review.

Recognition of the principal storms that have affected the area, their recurrence interval and the landscape transformations due to these events are expected in order to determine and understand better this kind of phenomenon and their repercussions at a local scale.

4.1 HURRICANES AND THEIR SPATIAL INCIDENCE ON LANDSCAPE: THE CASE OF "MANUEL"

On the of 13th September 2013, a tropical depression ('*TRECE-E*'), spotted 225 km south from Zihuatanejo, Guerrero was declared the seventh storm of the season coming from the Pacific Ocean. The atmospheric conditions associated with warm temperature of the ocean water turned out to be favorable for its development. By September 15th, the tropical depression had turned into a tropical storm and made landfall 20 km from Manzanillo, Colima (SAGARPA, 2013). By then, the recorded wind data increased from 75 km/h to 100 km/h, with a 15 km/h travel speed.

On the Altantic side, hurricane 'Ingrid' (categorized 1 in the Saffir-Simpson scale) impacted the Veracruz coast on September 14th and proceeded north with a wind speed between 110 km/h to 140 km/h. The combination of 'Manuel' and 'Ingrid' caused torrential precipitation over a large portion of the Mexican territory (basically the states of *Veracruz*, *Tamaulipas, San Luis Potosí, Hidalgo, Puebla, Chiapas, Oaxaca, Guerrero, Michoacán, Morelos, Tabasco* and *Estado de México*) (CONAGUA, 2013).

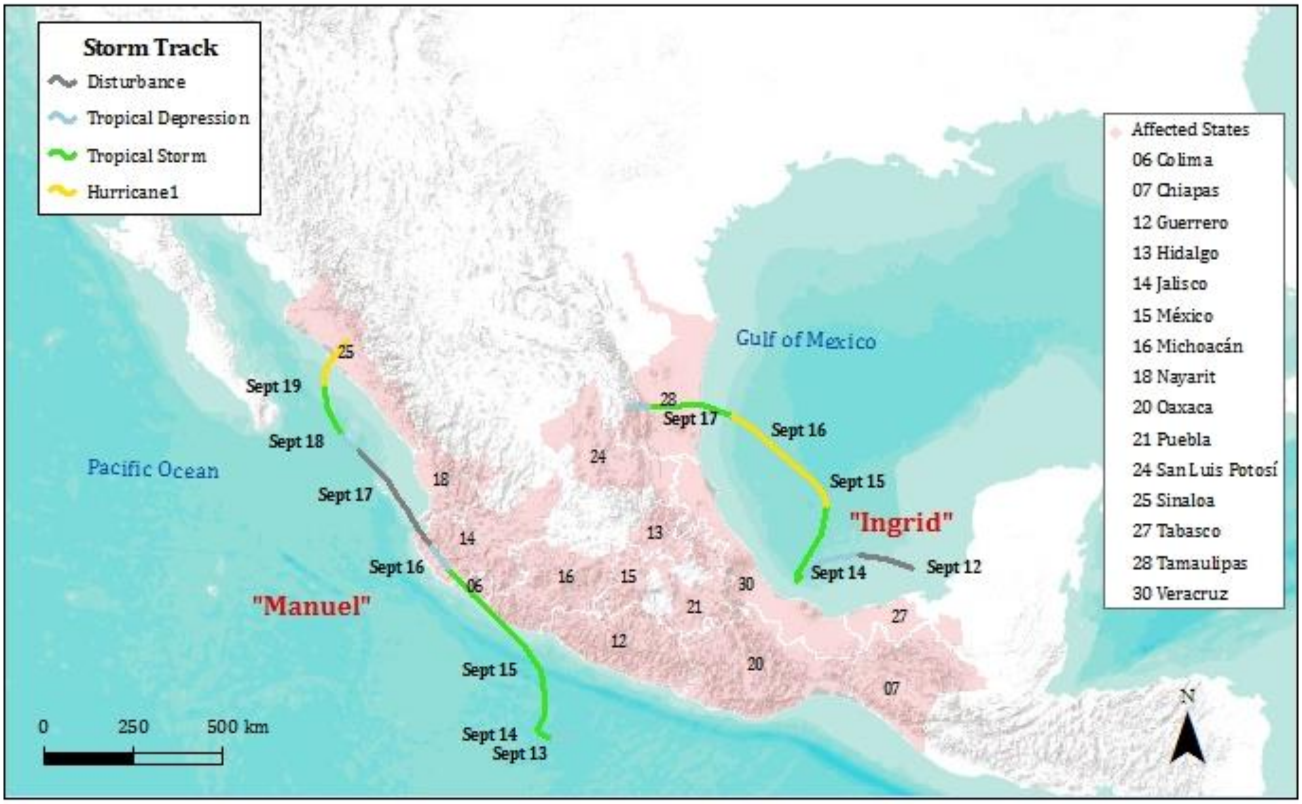
As 'Ingrid' developed as a hurricane, 'Manuel' prevailed as a tropical storm, because the Sierra Madre Occidental (a *ca.* 3,000 masl volcanic massif deployed parallel to the Pacific coast) acted as a barrier; wind speed however increased to 130km/h. Intense rainfall, strong winds and high waves threatened the coastal population from Jalisco to Oaxaca.

Eventually, 'Manuel' also reached sustained winds up to 120km/h and was classified as a category 1 hurricane in the Saffir-Simpson scale. This happened while it hit the Sinaloan coasts on September 18th. By September 19th, 'Manuel' dissipated gradually while moving at a much lower wind speed towards northwestern Mexico (Figure 10).

As Manuel impacted our study area, a question emerged: which would be the effects on the fluvial *landforms* of the Nexpa Valley? Would there be any transformations on *land use* and *land cover*? As a result, a visit to the field was set up ten days after the hazardous event.

In fact, landscape had been transformed: some places remained unchanged, while others were hard to recognize or impossible to recognize at all. The national road linking Michoacan and Colima was badly damaged; traffic was not possible for at least one week. The southern portion of the bridge on the Nexpa River collapsed during the flood (Image 1).

Figure 10 “Manuel” and “Ingrid” tracks over the Pacific Ocean and Gulf of Mexico (NOAA National Weather Service, GIS Datasets 2013)



However, one positive aspect emerged from this disaster: informants were willing to talk about this particular incident. This was helpful for the further understanding of storm repercussions on landscape and was useful for creating a starting point in the interviews: what had just happened? How did the event impact on the peasants´ property, crops and animal husbandry? A thorough revision of local and national newspapers also provided useful information for tracing ‘Manuel’ effects.

Over 50 people from different states of Mexico[32]. lost their lives due to the impact of hurricanes ‘Ingrid’ and ‘Manuel’ The national press estimated 1.2 million people were affected directly or indirectly by both storms, as well as substantial damage to infrastructure and property (Revista Proceso, September 16, 2013). Landslides were

---

[32] Most of the victims occurred in Guerrero (22) at the Pacific coast and in Veracruz (12) at the Gulf of Mexico (La Jornada, September 17, 2013)

common on many slopes and flooding affected most valley bottoms (La Jornada, September 17, 2013).

Image 1 The Nexpa River, Michoacan:

1. Before tropical storm "Manuel" (March 7, 2013; dry season); 2. During tropical storm "Manuel" (September 16, 2013); 3. After tropical storm "Manuel" (September 27, 2013)

In the State of Michoacan, over seven thousand farmers lost 29,000 hectares of cropland (Quadratin, September 15, 2013); nine national roads suffered substantial damage and seven bridges collapsed. The local government recognized that approximately 8,000 people in 21 municipalities were affected.

The consequences of the tropical storm 'Manuel' in the Nexpa basin were quite unfortunate. Although no residents in the study area died, two corpses that had been dragged downhill from the *Sierra* were found. Furthermore, important economic losses occurred: "I lost everything and the government won't look at us. I lost my mango orchard, I lost my land, I lost my irrigation pump, I lost my wire fence", (Mr. Francisco, September 2013)[33].

People lost livestock (mostly cows and goats dragged away by the flash-flood), good quality alluvial lands and crops, and irrigation infrastructure. Temporarily, roads and other communication means collapsed. The most alarming fact was the lack of an early warning to the population despite the fact that the local government was in possession of that information. People were completely uninformed about the intensity of the storm. They were aware of the weather conditions but not of the seriousness of the hazard.

Field observations indicated (Image 2) that the valley bottom had changed completely after the flash flood in a matter of hours and during the following few days. Within less than a week, fluvial terraces and meanders had disappeared and the river channel modified completely its course. Landowners would have to drop activities such as farming and fishing, at least for several weeks, until the river would occupy its new channel.

---

[33] -*"Yo perdí todo y el gobierno ni nos voltea a ver. Perdí toda la huerta de mango, perdí el terreno, perdí la bomba de riego, perdí la cerca de alambre"-.*

Image 2 Nexpa's valley bottom after "Manuel" tropical storm (September, 2013)

4.2 RECORDING PREVIOUS EXTREME EVENTS IN NEXPA

Several questions remained: What was the periodicity of this kind of phenomenon? Did inhabitants witness and experience events of this nature before? According to the people interviewed: "Each year, the river floods or grows but not with the intensity and strength of this event" (Mr. Selerino during the interview, September 2013)[34]. Furthermore, a couple of informants mentioned the 1966 hurricane suggesting that the event had analogous strength and impacts. They said they did not quite remember it but that they had heard of it from their parents: "There hadn't been an event of this magnitude since the 1966 storm", the informant then added that he did not personally remember it [the cyclone] very well, but that his father used to talk about it. Then he mentioned that his

---

[34] "*Cada año se inunda o crece el río, pero no con la intensidad y fuerza como el evento de ahora".*

family first started to grow mango tree after that event" (Mr. Francisco, September 2013)[35].

Younger informants specified that they had never seen the river that close to their houses. They suggested that a storm similar to 'Manuel' had not occurred recently; more precisely, it had not occurred in the past 47 years.

To validate this information we decided to examine precipitation data from the past decades. The first step was to examine precipitation data from a local weather station ('016217 *Caleta de Campos*'), located 5km east from Nexpa and 116 masl. The goal was to identify maximum daily and monthly rainfall events, assuming that they would trigger similar impacts at the Nexpa valley bottom.Unfortunately, the data from *Caleta* encompassed only the period from 1961 to 1985, so data had to be gathered from another weather station in the area. For the second period of time '016239 *Mexcalhuacan*' (30 masl) was chosen, because it had available data from 1981 to 2007 and was 15km (9.3 mi) away from Nexpa.

In addition, the NOAA Historical Hurricane Tracker[36] was used to identify the hurricanes that matched the local extreme precipitation values. Six hurricanes were found to have affected the area, one of them, as expected, in 1966 (Hurricane Adele). The other four were identified as: 'Lilian' in 1963, 'Eileen' in 1970, 'Bridget' in 1971, 'Ignacio' in 1979 and 'Norman' in 2006 (Figure 11).

However, as there are a lot of missing data in the local meteorological station data, were there more hurricane events that affected the area but that were not registered by local weather stations? In addition, there is another question: Why would informants only mention Adele in 1966 but not 'Lilian' in 1963 that, according to data register, was a more intense phenomenon? In this case, the answer may be related to the damage perceived, and this suggests that other events did not represent a great hazard as compared to 'Adele' and 'Manuel'.

---

[35] "*No había un evento de esta magnitud desde el ciclón de 1966*", he then added that he did not personally remember it very well but that his father used to talk about it. Then he mentioned that they first started to grow mango tree after that event.

[36] Available on: http://csc.noaa.gov/hurricanes/#

In any event, records suggest that the local population is highly vulnerable to hurricane activity, flash-floods, landslides and subsequent damage to life and property. A recurrence interval estimation (T), based on the probability of the events was estimated in order to answer the question: how often is the population vulnerable to hurricane activity? According to Aparicio (2007), a basic equation to estimate the likelihood that the maximum event in the data set could recur given a certain period of time is:

$$\mathbf{T = (n+1)/m}$$

Where:

T: recurrence interval.

n: the number of records

m: the maximum/minimum event recorded

In this case, our maximum values correspond to the day when the highest precipitation was recorded per year. The maximum precipitation value over the 21 year record, which is known to be associated with 'Lilian', has a recurrence interval of 22 years (Table 20) [37]. Of course, the minimum precipitation record has a recurrence interval of one year.

Table 20 Recurrence interval calculation

Number of event	Event	Year	Precipitation value (mm)	T (years)
1	'Lillian'	1963	322.0	22.0
2	'Ignacio'	1979	289.0	11.0
3	'Adele'	1966	240.0	7.3
4	No record	1969	202.0	5.5
5	No record	1968	198.0	4.4
6	'Bridget'	1971	196.5	3.7
7	No record	1978	194.0	3.1
8	'Eileen'	1970	188.0	2.8
9	No record	1980	185.0	2.4

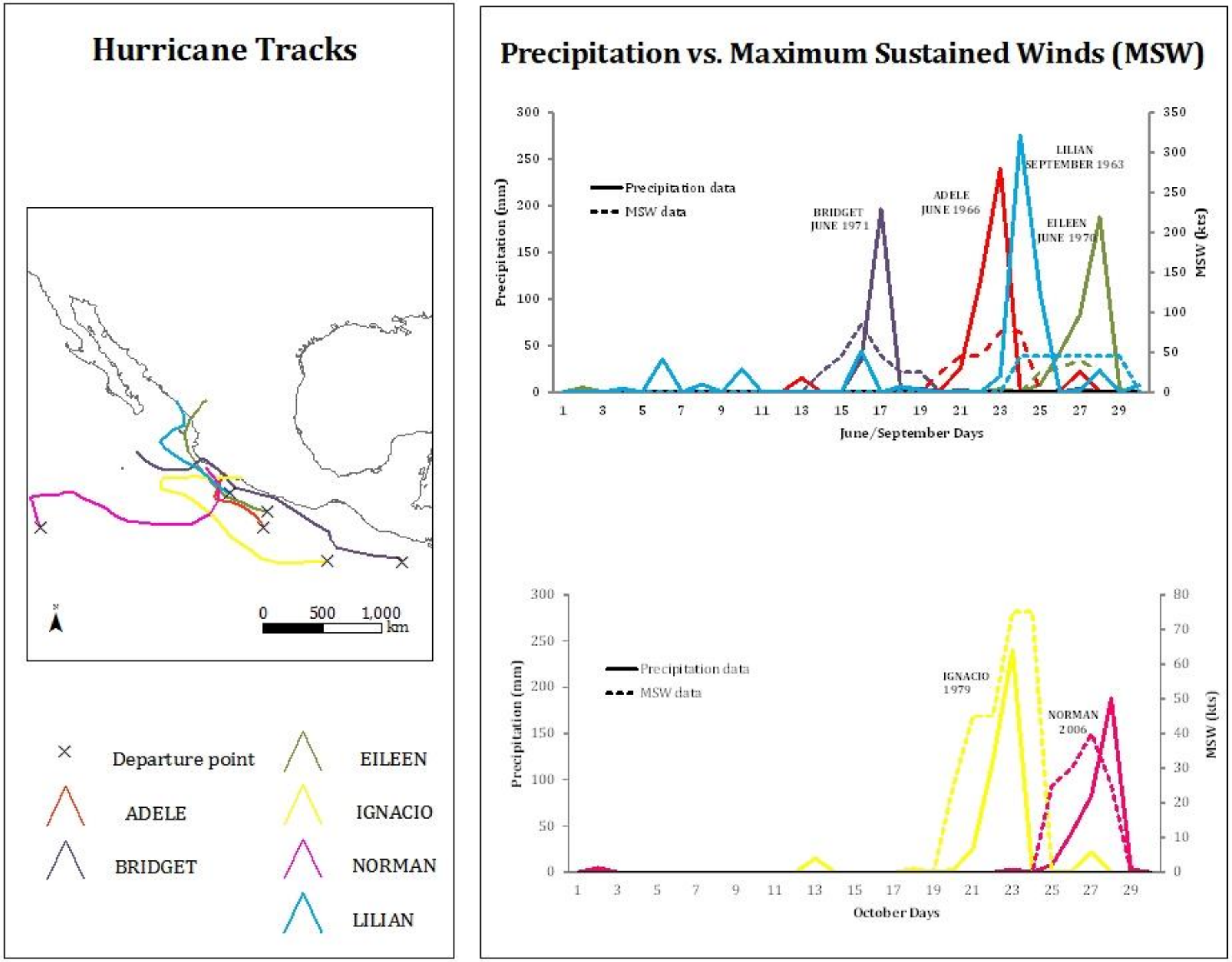
---

[37] To respect geodata consistency, only data from weather station '016217 *Caleta de Campos*', available from 1963 to 1983, was used for recurrence interval estimation.

10	No record	1967	160.0	2.2
11	No record	1977	149.5	2.0
12	No record	1974	136.5	1.8
13	No record	1983	133.0	1.7
14	No record	1975	129.5	1.6
15	No record	1964	126.5	1.5
16	No record	1981	104.0	1.4
17	No record	1972	97.0	1.3
18	No record	1973	95.5	1.2
19	No record	1982	85.0	1.2
20	No record	1976	84.5	1.1
21	No record	1965	61.5	1.0

* This matches the daily records that are associated witha particular storm event. This was verified through NOAA’s Historical Hurricane Tracks

Figure 11 Registered tracks, precipitation and maximum sustained wind data (MSW) of the Hurricanes that hit the study area from 1961 to 2007. The data was obtained from local weather stations (CONAGUA: 016 217 Caleta de Campos, 016 239 Mexcalhuacan) and the Historical Hurricane Tracker of the National Oceanic Atmospheric Administration (NOAA).



4.3 APPROACHES FOR DAMAGE CONTROL: SOCIAL VULNERABILITY

¨Manuel´ was a clear example of how a sudden event, lasting hours, can affect a population and modify the landscape completely. In order to put this disaster into perspective, we could record damage in terms of material loss, blame climatic change over hazard contingency or discuss the incident in terms of population vulnerability. Each approach to disaster certainly has something important to highlight, but which can contribute the most to the deeper understanding of social costs at the local scale? A premise to this reasoning is the fact that hydro-meteorological events cannot be controlled. Management of vulnerability, instead, can be analyzed towards the proposal of sound damage control and management of social vulnerability.

O'Hare (2002) discusses the different approaches commonly used when facing disaster. An important point is the fact that climate change is not neglected but neither emphasized. Instead, the argument centers on the fact that these phenomena occur and affect population and that the real concern should be around the local strategies that are (or are not) being adopted. According to this analysis, there are two main tendencies for mitigation strategies: 1) a traditional approach using technological solutions[38] and 2) a modern view including self-empowerment and community action[39]. No doubt, these two may be combined, but they reflect actual contrasting viewpoints.

---

[38] This perspective emphasizes a 'top down' approach to the disaster problem, and (since the Industrial Revolution and more particularly since the 1950s) sees solutions through the application of physical measuring and monitoring techniques, and the use of structural management programs involving large engineering works and architectural design. Such dominant technocratic/techno-fix approaches have been transferred to developing countries, often through aid/development schemes. However, from the late 1970s they have come in for increasing criticism for being inappropriate (environmentally, socially, economically) in many development contexts, and for reinforcing the dependency contexts, and for reinforcing the dependency of recipient upon donor, leading to underdevelopment (Hewitt, 1983). One of the main reasons why externally imposed approaches to disaster management tend not to work is because nature and disasters are social constructions, in the sense that meaning given to them are different in different societies. People and communities develop their own view of the world and of nature, and their responses to disaster are governed by this"(O'Hare, 2002: 239-40)

[39] This more people-centered or 'bottom-up' perspective calls for greater community awareness and participation in vulnerability reduction. It claims that vulnerability and impacts should be considered more in terms of what people do, and greater consideration should be given to the effects of disasters on social and community groups (Comfort eta al., 1999) (…) In the face of global environmental change, societies are thus increasingly being encouraged to learn to live with nature rather than fight against it with ever bigger technology, necessitating a greater community awareness of , and involvement in, environmental processes and their mitigation. With this view, non-structural solutions to disasters are

Comfort *et al.* (1999) share O'Hare's viewpoint in the sense that disaster should not be seen as an "event that is beyond human control" or "the capricious hand of fate [that] moves against unsuspecting communities creating massive destruction and prompting victims to call for divine support as well as earthly assistance". Instead, these authors call "for an explicit analysis of the circumstances that make human communities vulnerable to unforeseen natural and technological events" (Comfort *et al,* 1999: 39). This approach has been widely discussed in the literature. As early as the beginning of the 90s, Degg (1992), for instance, highlighted the differences between the notions "disaster", "hazard" and "vulnerability", and pointed out that the term *natural* disaster is misleading [40]; conversely, it is society who provides meaning to it.

Additionally, authors such as Hugo Romero (2011) add the institutional and political factor as an element that plays a fundamental role in social vulnerability. This matter should not be disregarded as governmental institutions are responsible, for example, for alerting and preventing the population when they are in danger. In this particular case, some newspapers actually denounced that inhabitants had not been properly informed about the magnitude of this event because its strength had been underestimated (La Jornada, September 18, 2013). Furthermore, rural areas with no international touristic value were *invisible* to authorities and did not receive immediate attention from public institutions. Romero even suggests that instead of natural these events should be labeled as 'social disasters'. These questions call for a wide discussion that will certainly not be resolved here. Nevertheless, posing them is still useful for opening a panorama regarding these particular topics and concerns.

The issues exposed above are directly related to landscape and *man-land* bonding. In this study case, *landform*, *land cover* and *land use* are substantially modified "right in front of our eyes" giving us a chance to revalue and reinterpret our meaning of landscape.

---

recommended, including careful land use planning, risk assessment and management, and insurance" (O'Hare, 2002:241)

[40] Although in many occasions, this term could be validly used as opposed to an *unnatural* disaster like a war

SUMMARY

On September 15th 2013, the tropical storm ‘Manuel’ hit the Pacific shore affecting the study area (Nexpa). This brief review includes a technical report on the tropical storm ‘Manuel’ as well as the subsequent consequences at the local and regional scales. Furthermore, a short version of the informants’ perspective over ‘Manuel’, and past similar events, is included. Additionally, a precipitation and hurricane track data was consulted to recount previous storms that affected the area.

This section was included because of the need to expand our interpretations over the *man-land* associations, specifically due to extreme events. A rather simple discussion of the population’s vulnerability due to hazardous events is incorporated as an attempt to amplify our approach to other landscape relations.

CONCLUSIONS

The main purpose of this research project was to analyze associations between *landforms* (a major physical component of landscape), *land cover* (a hybrid attribute) and *land use* (the result of a social activity on land, in the words of Bibby & Shepherd, 2000), in a *man-land* frame of landscape studies. Remote sensing, GIS and multivariate statistic data analysis were used as the primary techniques for this purpose. In order to explore so-defined *man-land* relationships in this area, the Nexpa valley was chosen because it fulfills the geographic criteria needed for the type of analysis that we are willing to do at a local scale (1:10,000). In addition to the original thesis objectives, a 4th chapter was included to document the results of flooding on the landscape following a major storm during the study period.

The general question of the thesis must be developed in the following terms: how do man-land relationships occur in the lower Nexpa valley? More specifically, how do *landform, land cover* and *land use* intersect in space? The answers provided by this study follow.

The *landform-land cover* associations reveal that denudational slopes and hills, and flat lands (fluvial plains and costal area) fully differentiate. Conversely, the valley area shares similar cover entities. As indicated before, this depicts the logic of the spatial distribution of objects, and helps us validate the data consistency.

Land cover-land use data analysis points to the *many-to-many* kind of relationship that both landscape attributes share. This confirms the findings of previous studies (Cihlar & Jansen, 2001; Brown & Duh, 2004) that also seek to understand these types of relationships. Thus, it might be more accurate to refer to "associations of *cover*" that match "associations of *use*". Here, the term association would be used in a similar way as used in soils mapping.

Moreover, *land cover*, regardless of the scale and source of imagery, cannot be regarded as surrogates of *land use* patterns. The economic and cultural attributes trigger spatial arrangement of land uses types which in tropical areas intermingle and overlap among time, spaces and stakeholder.

A significant correspondence exists between *land use* and *landforms*. Still, the notion that productive activities are fully governed by the suitability of the terrain has to be taken with care. “Agriculture” and “cattle grazing” are better example of this in the study area, because they may be found either in steep or flat terrains. To further study this, a thorough study of *land use* is mandatory, information that is not provided by remotely-sensed data, or existing thematic cartographic data.

The most common type of agriculture in the area is the “rain-fed” agriculture, which confirms the “seasonal factor” that Sauer identified in the 1950’s: “… the frequent summer showers make possible also the growing of one summer, rain-season, or temporal crop on hill and mountain slopes” (Sauer, 1941:358). However, “rain-fed” agriculture is not only found on steep terrain but also on flat lands. This pattern of distribution may be explained, not by the characteristics of land *per se*, but rather by micro economic factors such as the wealth of the landowner or even by land tenancy factors. “Rain-fed” agriculture requires very little investment and sustains itself mostly by the *milieu’s* conditions.

The notion that the most important *uses* in the Mexican rural *milieu* are “agriculture” and “cattle grazing” needs further elaboration. In this particular case, both activities are distributed over the entire study area; nevertheless, a large portion of the area is devoted to other uses, including the conservation of the tropical dry forest. The “game hunting” and “wood and fuel extraction” are non-timber forest management activities. Moreover, the fact that these activities developed over a large proportion of the study highlight the importance of field survey, as they would remain “invisible” in a satellite image interpretation.

Regarding the spatial distribution of landscape components, specifically where *land uses* are more diverse, this research seems to provide a rather counterintuitive result. A large variety would be expected in fluvial or coastal plains, because of better accessibility as compared to hilly terrains. However, the areas where the activities were so tangled and difficult to interpret, due to a greater diversity, were either the steeper areas (footslope and denudational slope) or the less accessible areas, such as the summit surfaces. In any case, all of them were associated with “tropical dry forest” and “scrubland” *land covers*. Thus, different activities are being carried out in every portion of the landscape and, while they do differentiate in terms of terrain, it does not correspond to the traditional land suitability perspectives. It appears that the distribution of *land use* patterns could be better explained by the adaptative strategies developed by the population, rather than by the conditions of the terrain itself. These adaptive strategies also played a key role during the flooding experienced at the study area. This issue calls for a closer analysis, through modelling and projection, of the social vulnerability to which inhabitants are being continuously exposed.

This *man-land* study of landscape also calls for a closer analysis of what Guttember & Nanetti (1974) have described as "The user" and "The use effect". In this sense the questions are, 'who are really the *land users*?', 'why they do what they do?', 'what is their history'? Other questions include, 'which repercussions bring *the uses* to the *users*?', 'Which are the environmental issues derived from *uses'*? 'What may be the alternatives'? These questions are left here as "mood breakers", that open a whole new panorama over *land use* as a forgotten geographical discipline.

Finally, it is important to return to Pattison's words referring to the misleading *man-land* interpretations such as 'environmentalism' where *man* is seen as "an independent agent, and land as a sufferer from action" (Pattison, 1964). In this sense, we hope to have overcome this simplistic conception with a more integrative notion of landscape.

BIBLIOGRAPHY

ABIZAID, C., COOMES, O. 2004. Land use and forest fallowing dynamics in seasonally dry tropical forests of the southern Yucatan Peninsula, Mexico, *Land Use Policy*, 21(1):71-84

APARICIO, J., 2007. *Fundamentos de Hidrología de Superficie,* Limusa eds., México, pc. 249-252

ASPINALL, R. 2010. A Century of Physical Geography Research in the Annals, *Annals of the Association of American Geographers*, 100(5): 1049-1059

BAKKER, M., VELDKAMP, A. 2012. Changing relationships between land use and environmental characteristics and their consequences for spatially explicit land-use change prediction, *Journal of Land Use Science*, 7(4), 407-424

BECKINSALE, R., CHORLEY, R. 1991. *The History of The Study of Landforms or The Development of Geomorphology* (vol. 3), Routledge, London/New York

BEH, E. 2004. Simple Correspondence Analysis: A Bibliographic Review*, International Statistical Review*, 72:2(257-284)

BIBBY, P., SHEPHERD, J. 2000. GIS, land use, and representation, *Environmental and Planning B: Planning and Design*, 27:583-598

BISHOP, M., JAMES, L., SHRODER, J., WALSH, S. 2012. Geospatial technologies and digital geomorphological mapping: Concepts, issues and research, *Geomorphology*, 137: 5-26

BOCCO, G. 2010 Geografía y Ciencias ambientales: ¿campos disciplinarios conexos o redundancia epistémica? *Investigación ambiental*, 2(2): 25-31

BOCCO, G. & P. URQUIJO. 2010. La geografía ambiental como ciencia social, In: A. Lindón and D. Hiernaux (eds.), *Los giros de la geografía,* Anthropos, UAM-1, Barcelona

BOCCO, G., URQUIJO, P., VIEYRA, A. 2011. *Geografía y ambiente en América Latina*, CIGA-INE-SEMARNAT, México

BONNEMAISON, J. 1981. Voyage autour du territoire*, L'espace géographique*, 4:249-262

BOWER, J., KOBUSIEWICZ, M. 1988. Late Quaternary Paleogeography of Middle Europe and the Northcentral United States: A Framework for Comparative Studies of Prehistoric Man-Land Relationships, *Geoarchaeology*, 3(2): 117-125

BRAND, D. 1957. Estudio Costero del Suroccidente de México, translated by: CIDEM-UNAM-Colegio de Michoacán, Morelia

BROWN, D., DUH, J. 2004. Spatial simulation for translating from land use to land cover, *International Journal of Geographic Information Science*, 18(1): 35-60

BURLEY, T. 1961. Land Use or Land Utilization, *The Professional Geographer*, 13(6):18-20

CAMPOS, M., VELÁZQUEZ, A., BOCCO, G., SKUTSCH, M., BOADA, M., PRIEGO, Á. 2012. An interdisciplinary approach to depict landscape change drivers: A case study of the Ticuiz agrarian community in Michoacan, Mexico, *Applied Geography*, 32: 409-419

CASTILLO, M., LÓPEZ, J., MUÑOZ, E. 2010. A geomorphologic GIS-multivariate analysis approach to delineate environmental units, a case study of La Malinche volcano (central México), *Applied Geography*, 30:629-638

CASTREE, N., DEMERITT, D., LIVERMAN, D., RHOADS, B. 2009. *A Companion to Environmental Geography*, Wiley-Blackwell, London

CHEN, Y., QI, J., ZHOU, J., LI, Y., XIAO, J. 2004 . Dynamic Modeling of a Man-Land System in Response to Environmental Catastrophe, *Human and Ecolgical Risk Assessment*, 10: 579-593

CHRISTIANSSON, C., KIKULA, I., ÖSTBERG, W. 1991. Man-Land Interrelations in Semiarid Tanzania: A Multidisciplinary Research Program, *Ambio*, 20(8):357-361

CIHLAR, J., JANSEN, L. 2001. From Land Cover to Land Use: A Methodology for Efficient Land Use Mapping over Large Areas, *The Professional Geographer*, 53(2): 275-289

COMBER, A. 2008. Land use or land cover? *Journal of Land Use Science*, 3(4):199-201

COMBER, A., WADSWORTH, R., FISHER, P. 2008. Using semantics to clarify the conceptual confusion between land cover and land use: the example of ‘forest’, *Journal of Land Use Science*, 3(2/3):185-198

COMFORT, L., WISNER, B., CUTTER, S., PULWARTY, R., HEWITT, K., OLIVER, A., WIENER, J., FORDHAM, M., PEACOCK, W., KRIMGOLD, F. 1999. Reframing disaster policy: the global evolution of vulnerable communities, *Environmental Hazards* 1:39-44

CONAGUA (Comisión Nacional del Agua). 2013. *Comunicados de Prensa* 2013:622-13/ 625-13/ 627-13. Online reference: http://www.conagua.gob.mx/BoletinesSalaPrensa.aspx?n1=Comunicados

CONAGUA (Comisión Nacional del Agua). 2013. *Normales climatológicas por estación.* Online reference: http://smn.cna.gob.mx/index.php?option=com_content&view=article&id=42&Itemid=28

CONAPO (Consejo Nacional de Población). 2010. *Índice de marginación por Entidad Federativa y Municipio.* Online reference: http://www.conapo.gob.mx/es/CONAPO/Indices_de_Marginacion_2010_por_entidad_federativa_y_municipio

CORNWALL COUNCIL, UK GOVERNMENT. 2012. *Landscape and Seascape,* Landscape and Seascape Issues Paper, January: 2-18. Available online: https://www.cornwall.gov.uk/media/3638105/Landscape-and-Seascape.pdf

CPLADE, 2010. *Programa de desarrollo 2010-2012 región IX "Sierra Costa" del estado de Michoacán.* Gobierno del Estado de Michoacán, pp. 120. *Michoacán*

CUEVAS, G. 2009. *Implicaciones socio-ambientales del cambio global y fortalecimiento de capacidades institucionales locales en regiones costeras del pacífico mexicano.* Informe Final, CIGA-UNAM, pp. 114

DEGG, M. 1992. Natural Disasters: Recent Trends and Future Prospects, *Geography*, 77(3):198-209

DEMERITT, D. 2009. Geography and the promise of integrative environmental research, *Geoforum*, 40(2): 127-129

DI GREGORIO, A. 2000. *Land Cover Classification System (LCCS): Classification Concepts and user Manual*. Environment and Natural Resources Service (SDRN), FAO-Rome, pp. 91

FOODY, G. 1996. Approaches for the production and evalutation of fuzzy land cover classifications from remotely-sensed data, *International Journal of Remote Sensing*, 17(7), 1317-1340

FRY, M. 2011. From Crops to Concrete: Urbanization, Deagriculturalization, and Construction Material Mining in Central Mexico*, Annals of American Geographers*, 101(6):1285-1306

GARCIA, M., ORTIZ, M., ZAMORANO, J., REYES, Y. 2007. Vegetation and landform relationships at Ajusco volcano Mexico, using a geographic information system (GIS), *Forest Ecology and Management*, 239: 1-12

GARCÍA, M. 2013 (21 de septiembre). Alrededor de 8 mil personas los afectados en Michoacán por 'Manuel', *Periódico Excelsior*

GAUCH, H. 1982. *Multivariate Analysis in Community Ecology.* Cambridge University Press, pp. 298

GITAS, I., KARYDAS, C., KAZAKIS, G. 2003. Land cover mapping of Mediterranean landscapes, using SPOT4-Xi and IKONOS imagery-A preliminary investigation, *Options Mediterraneennes, Series B*, 27-41

GOUDIE, A. 1994. The Nature of Physical Geography: A View from the Drylands, *Geography*, 79(3): 194-209

GRAIZBORD, B. 2002. Elementos para el ordenamiento territorial: el uso del suelo y recursos, *Estudios Demográficos y Urbanos*, 17(2): 411-423

HASCHENBURGER, J., SOUCH, C. 2004. Contributions to the Understanding of Geomorphic Landscapes Published in the Annals, *Annals of American Geographers*, 94(4): 771-793

HILL, R. 1984. Land Use Change, *Geoforum*, 15(3):457-461

HILHORST, D. 2003. Responding to Disasters: Diversity of Bureaucrats, Technocrats and Local People, *International Journal of Mass Emergencies and Disasters*, 21(1):37-55

HONGLIANG, F., GAOHUAN, L., KEARNEY, M. 2005. Georelational Analysis of Soil Type, Soil Salt Content, Landform, and Land Use in the Yellow River Delta, China, *Environmental Management*, 35(1):72-83

HUDSON, P., COLDITZ, R., AGUILAR, M. 2006. Spatial Relations Between Floodplain Environments and Land Use-Land Cover of a Large Lowland Tropical River Valley: Pánuco Basin, México, *Environmental Management*, 38(3): 487-503

HUPP, C., RINALDI, M. 2007. Riparian Vegetation Patterns in Relation to Fluvial Landforms and Channel Evolution along Selected Rivers of Tuscany (Central Italy), *Annals of the Association of American Geographers*, 97(1): 12-30

HUSSON, F., LE, S., PAGES, J. (2010). *Exploratory Multivariate Analysis by Example Using R*, Chapman and Hall/CRS

INEGI (Instituto Nacional de Estadística y Geografía). 2010. Censo de Población y Vivienda (2010). Online reference: http://www.inegi.org.mx/est/contenidos/proyectos/ccpv/cpv2010/Default.aspx

INKPEN, R. 2005. *Science, Philosophy and Physical Geography*, Routledge, London/New York

JOHNSTON, R., SIDAWAY, J. 1997. *Geography and geographers: Anglo-American geography since 1945,* John Wiley & Sons, New York

LANE, S. 2001. Constructive comments on D Massey 'Space-time, "science" and the relationship between physical geography and human geography', *Transactions of the Institute of British Geographers,* 26(2): 43-256

MASSEY, D. 1999. Space-time, 'science' and the relationship between physical geography and human geography, *Transactions of the Institute of British Geographers,* 24(3): 261-276

MATHEWSON, K. 2011. Sauer's Berkeley School Legacy: Foundation for An Emergent Environmental Geography? In: G. Bocco, P. Urquijo and A. Vieyra (eds.), *Geografía y ambiente en América Latina,* CIGA-UNAM, SEMARNAT, INE, Morelia, c.p: 51-82

MORENO, S., VILLAFUERTE, R. 1995. Traditional Management of Scrubland for the Conservation of Rabbits Oryctolagus cuniculus and their Predators in Doñana National Park, Spain, *Biological Conservation*, 73:81-85

MURPHY, P., LUGO, A. 1986. Ecology of Tropical Dry Forest, *Annual Review of Ecology and Systematics*, 17:67-88.

NICHOLSON, H. 1962. Coalcomán and Motines del Oro by Donald Brand (Review), *American Antrhopologist*, 64(2): 397-400

NOAA (National Weather Service), National Hurricane Center: GIS Archive- Tropical Cyclone Best Track (2013 Datasets). Online reference: http://www.nhc.noaa.gov/gis/archive_besttrack.php

NOAA (National Weather Service), Historical Hurricane Tracks. Online reference: http://csc.noaa.gov/hurricanes/#

O'HARE, G. 2001. Hurricane 07B in the Godavari Delta, Andhra Pradesh, India: Vulnerability, Mitigation and the Spatial Impact, *The Geographical Journal*, 167(1):23-38

O'HARE, G. 2002. Climate Change and the Temple of Sustainable Development, *Geography*, 87(3):234-246

PANEQUE, J., MAS, J., MORE, G., CRISTOBAL, J., ORTA, M., LUZ, A., GUEZE, M., MACIA, M., REYES, V. 2013. Enhanced land use/cover classification of heterogeneous tropical landscapes using support vector machines and textural homogeneity, *International Journal of Applied Earth Observation and Geoinformation*, 23:372-383

PARSONS, J. 1981. Carl Sauer's Fieldwork in Latin America by Robert C. West (Review), *The Hispanic American Historical Review*, 61(2): 346-347

PASCARELLA, J., AIDE, T., SERRANO, M., ZIMMERMAN, J. 2000. Land-Use History and Forest Regeneration in the Cayey Mountains, Puerto Rico, *Ecosystems*, 3:217-228

PASUTO, A., SOLDATI, M. 1999. The use of landslide units in geomorphological mapping: an example in the Italian Dolomites, *Geomorphology*, 30: 53-64

PATTISSON, W. 1964. The Four Traditions of Geography, *Journal of Geography*, 63(5): 211-216

PHINA (Padrón e Historial de Núcleos Agrarios). 2013. Registro Agrario Nacional, Online reference: http://phina.ran.gob.mx/phina2/Sessiones

PRESTON, N., BRIERLEY, G., FRYIRS, K. 2011. The Geographic Basis of Geomorphic Enquiry, *Geography Compass*, 5(1): 21-34

PRIEGO, Á., BOCCO, G., RIVAS, H., TROCHE, C., ACOSTA, A., MATHEWS, J., 2008. Bases para el ordenamiento ecológico de la Región Sierra-Costa de Michoacán. Informe Técnico, CIGA-UNAM/SUMA, pp. 160

QUIAO, J., LI, X., KONG, Y. 2006. Status and dynamic change of regional man-land system in view of micro-level quantitative aspect, *Chinese Geographical Science*, 16)1:9-17

RENWICK, W. 1992. Equilibrium, disequilibrium, and nonequilibrium landforms in the landscape, *Geomorphology*, 5(3-5):265-276

REYES, H., AGUILAR, M., AGUIRRE, J., FORTANELLI, J. 2008. Spatial Configuration of Land-use/Land-cover in the Pujal-Coy Project Area, Huasteca Potosina Region, Mexico. *A Journal of the Human Environment*, 37(5): 381-389

RHOADS, B. 1999. Beyond Pragmatism: The Value of Philosophical Discourse for Physical Geography, *Annals of the Association of American Geographers*, 89(4): 760-771

RICHARDSON, D., HOLMES, P., ELSER, K., GALATOWITSCH, S., STROMBERG, J., KIRKMAN, S., PYSEK, P., HOBBS, R. 2007. Riparian vegetation: degradation, alien plan invasions, and restoration prospects, *Diversity and Distributions,* 13:126-139

ROBINSON, J. 2007. A New Look at the Four Traditions of Geography, *Journal of Geography*, 75(9): 520-530

ROMERO, H. 2011. La Geografía de los riesgos "naturales" y el terremoto de Chile del 27 de febrero de 2010, In: G. Bocco, P. Urquijo and A. Vieyra (eds.), *Geografía y ambiente en América Latina,* CIGA-INE-SEMARNAT, México

ROSILES, L. 2013 (15 de noviembre). Entregarán 50 mdp a productores afectados por Manuel, *Quadratin*

SAGARPA (Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación). 2013. *Huracán Manuel: 13 septiembre 2013*, Temporada de Huracanes 2013:023, Consulta en línea: http://portal.sinavef.gob.mx/documentos/AlertaClimatica/H_Manuel.pdf

SAUER, C. 1941. The Personality of Mexico, *Geographical Review*, 31(3):353-364

S/AUTOR. 2013 (16 de septiembre). Golpean 'Ingrid' y 'Manuel' a gran parte del país y dejan 50 muertos, *Revista Proceso*

SHAPIRO, I. 1959. Urban Land Use Classification, *Land Economics*, 35(2):149-155

STANISVLAWSKI, D. 1950. La anatomía de los once pueblos, translated by: CIDEM-UNAM-Colegio de Michoacán, Morelia

THRIFT, N. 2002. The future of geography, *Geoforum*, 33: 291-298

TURNER, B. 2002. Contested Identities: Human-Environment Geography and Disciplinary Implications in a Restructuring Academy, *Annals of the Association of American Geographers*, 92(1):52-74

van ZUIDAM, R. 1986. *Aaerial Photo-interpretation in Terrain Analysis and Geomorphic Mapping,* Smits Publishers, The Hague, pp. 442.

VELASCO, E. 2013 (17 de septiembre). Gobernación declara zona de emergencia al menos 58 municipios, *La Jornada*

WARMAN, A., 1985. *Notas para una redefinición de la comunidad agraria.* Revista Mexicana de Sociología, 47(3): 5-20

WICKE, C. 1967. Coalcomán and Motines del Oro by Donald Brand (Review), *The Hispanic American Historical Review*, 47(2):267-268