

Analysis and Modelling to Mapping Riparian Vegetation in the Usumacinta Watershed, Mexico

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ABSTRACT

Riparian vegetation of fluvial systems is a complex of vegetation units along the river network or water bodies. Despite covering a relatively small area, riparian vegetation provides many ecosystem services; however, these ecosystems experience multiple pressures because of land use change, timber harvesting, mining, deforestation. Managing for healthy native riparian vegetation and connected floodplains is a central part of river management, to carry it out this effort, a first step is to know the spatial distribution and the present state of such ecosystem. It is the objective of this study to illustrate how different elements of the geo-spatial information sciences, particularly remote sensing and spatial analysis and modeling, can contribute significantly in mapping the potential and present state of riparian ecosystem. In this study, to mapping riparian vegetation two approximations were conducted, the first one namely the valley bottom approximation, which was applied to the total area of Usumacinta watershed, and the other one the geomorphological mapping, which was applied in the low land area. The results show that most area of riparian vegetation has been destroyed, by introduction of grasslands and crops; only approximately 26 % of the area are in good conditions. An important conclusion is that mapping this special and important ecosystems is a first step to carry out a reclamation program, and establish a political measures to its conservation.

Keywords: Riparian vegetation, mapping, spatial analysis modelling

INTRODUCTION

Riparian vegetation of fluvial systems is a complex of vegetation units along the river network that is functionally related to the other components of the fluvial system and surrounding area [1]. Despite covering a relatively small area, riparian vegetation is of great importance in the management for the conservation of the habitat of various species and provides many ecosystem services related to river flow, sedimentary processes, biodiversity, water quality, cultural value [2]. However, riparian ecosystems experience multiple pressures (e.g., land use, water diversion, modified flood regime and have been severely altered in many regions of the world. Human activities have produced multiple interacting pressures on river ecosystems, including land-use intensification and hydro climatic alterations [3]

However, riparian vegetation is under significant pressure from a range of anthropogenic activities, such as alteration of disturbance regime, stream flow regulation by dams, pollution, land-use change, timber harvesting, water diversion, mining, deforestation, and from invasive species [4]

The severe degradation worldwide of freshwater ecosystems has posed a major threat to ES of riparian areas and their vegetation. This negative trend has continued to increase in centuries and most severely since 1950 even though the economic implications are serious (e.g., due flood damages), and in many places, this negative trend might even be intensified because of climate change [4]. Therefore, if a broader perspective on ES of riparian is included to help guide riparian management, the multi functionality of freshwater ecosystems can be protected and the provision of ES recovered or improved and the benefits to society enhanced [4]. On the other hand, riparian areas are one of the key elements in watershed management, since they connect the terrestrial and aquatic ecosystems, mitigating the impact of natural vegetation cover changes on rivers.

Managing for healthy native riparian vegetation and connected floodplains is a central part of river management and restoration because healthy riparian floodplains provide critical ecosystem services, such as reducing impacts of large flood events through nonstructural flood control, protecting water quality and terrestrial and aquatic habitat quality, maintaining habitat connectivity and movement corridors for fish and wildlife, and enhancing local and regional biodiversity [5].

Previous studies thus have documented that delineation of the areal extent of riparian woodland can aid understanding of the relative importance of its influences on different streams, thereby facilitating comparisons. Other land uses in the riparian zone also can be documented efficiently during the mapping of the riparian woodland, and often have been correlated with nutrient levels or biotic conditions in the streams [6]

It is the objective of this article to illustrate how different elements of the geospatial information sciences, particularly remote sensing and spatial analysis and modeling, can contribute significantly in mapping the potential and present state of riparian ecosystem. The result of this mapping effort is an important element that will contribute for the design of policies and programs related to the conservation of ecosystem services provided by this special ecosystem.

Riparian Vegetation, Ecosystems Services and Mapping

Given the scale, resolution and complexity of the analyses that can be conducted, in relation with riparian vegetation, one of the most important aspect to consider when interpreting the results, is the definition of such ecosystem, which has no universal definition and differs from one application to another [7]

“Riparian areas-Transitional between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect water bodies with their adjacent uplands. They include those portions of terrestrial ecosystems that significantly influence exchanges of

energy and matter with aquatic ecosystems (i.e., a zone of influence). Riparian areas are adjacent to perennial, intermittent, and ephemeral streams, lakes, and estuary-marine shorelines.” National Research Council [8]

“Riparian areas are ecosystems that occur along watercourses or water bodies. They are distinctly different from the surrounding lands because of unique soil and vegetation characteristics that are strongly influenced by free or unbound water in the soil. Riparian ecosystems occupy the transitional area between the terrestrial and aquatic ecosystems”. U.S. Department of Agriculture Natural Resource Conservation Service [9]

Riparian vegetation offers a variety of ecosystem services, which is a concept that has become an important model for linking the functioning of ecosystems to human welfare, and which is critical for a wide range of decision-making contexts [10]. This a concept, which introduced a new framework for analyzing social-ecological systems, has been advocated as a useful tool that provides a holistic and transparent assessment of impacts on human well-being [7]. According to [7] ecosystems services provided by Riparian ecosystems can be classified as: Provisioning services (biomass, genetic material), regulation and maintenance (transformation of biochemical or physical inputs, regulation of physical, chemical and biological conditions), cultural - biotic (Direct in situ and outdoor interactions with living systems, that depend on presence in the environmental setting).

Riparian zones are delineated in numerous ways [7, 11, 12, 13, 14]; their definition is usually dependent on the research approach or agency targets. Generally, they are described as the transition between terrestrial and freshwater ecosystems and defined by topographic, vegetation, and soil components. Riparian zones are dynamic regions with complex heterogeneous landscapes formed by frequent disturbances [7].

Study Area

The Usumacinta watershed (figure 1), an important trans-boundary basin, encompasses of 77.265 km², from which the 43.6% is located in Mexico (the study area considered in this study), 56.3% in Guatemala and 0.04% in Belice (Fig. 1). In Mexico is one of the most important watersheds and includes 5 municipalities of Tabasco State, 15 of Chiapas, and one of Campeche. The area has an average annual precipitation ranging from 1200 to 4000 mm; supports a population of about 1.000.000 inhabitants distributed in 5000 localities. The area includes 12 natural protected areas (8.500 km²).

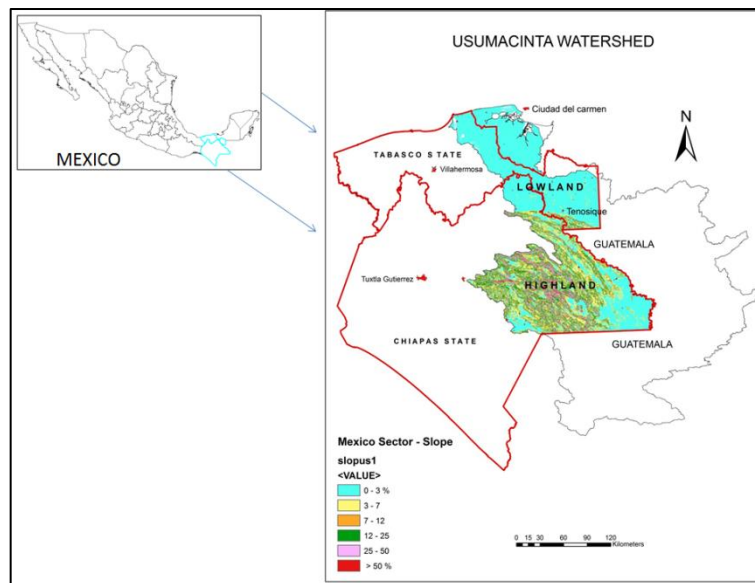


Figure 1: The study area, Usumacinta Watershed, Mexico

The Usumacinta watershed is constituted by two well defined sectors: Low land (low Usumacinta) and highland (Lacantun-Chijoy). The first sector includes eight municipalities. In this area the livestock is the principal activity (65%) and the crops 35%. The highland area (Lacantun-Chijoy) has 23.237 km², include 13 municipalities; more than 50% of population is native, in some municipalities the proportion of native population range from 73% to 100%.

METHODOLOGY

In this study, spatial analysis and modeling were used to mapping Riparian vegetation in the Usumacinta watershed. Fig. 2 shows a diagram of the methodological approximation used in this study.

Database: The data base used in this study include:

- A digital elevation model, spatial resolution 15 meters [15]. From this data a convergence index was calculated.
- Drainage net work, Usumacinta Watershed. From this layer streams less or equal to 3, according to Strahler order was used, and several buffers were calculated (< 50, 100, 200, 300 and 400 meters)
- Land use and land cover map, scale 1:50,000 [16]. This map was reclassified in eight categories, that include natural vegetation a land use, as follows: natural forest, arboreal vegetation, secondary vegetation, herbaceous vegetation, hydrophilic vegetation, grasslands, crops, settlement and water bodies.
- Geomorphological low land map, Usumacinta Watersehd. [17]. From this map Geophorm units was mapped as flood plain and valley, in the lowland of Usumacinta Watershed was used.

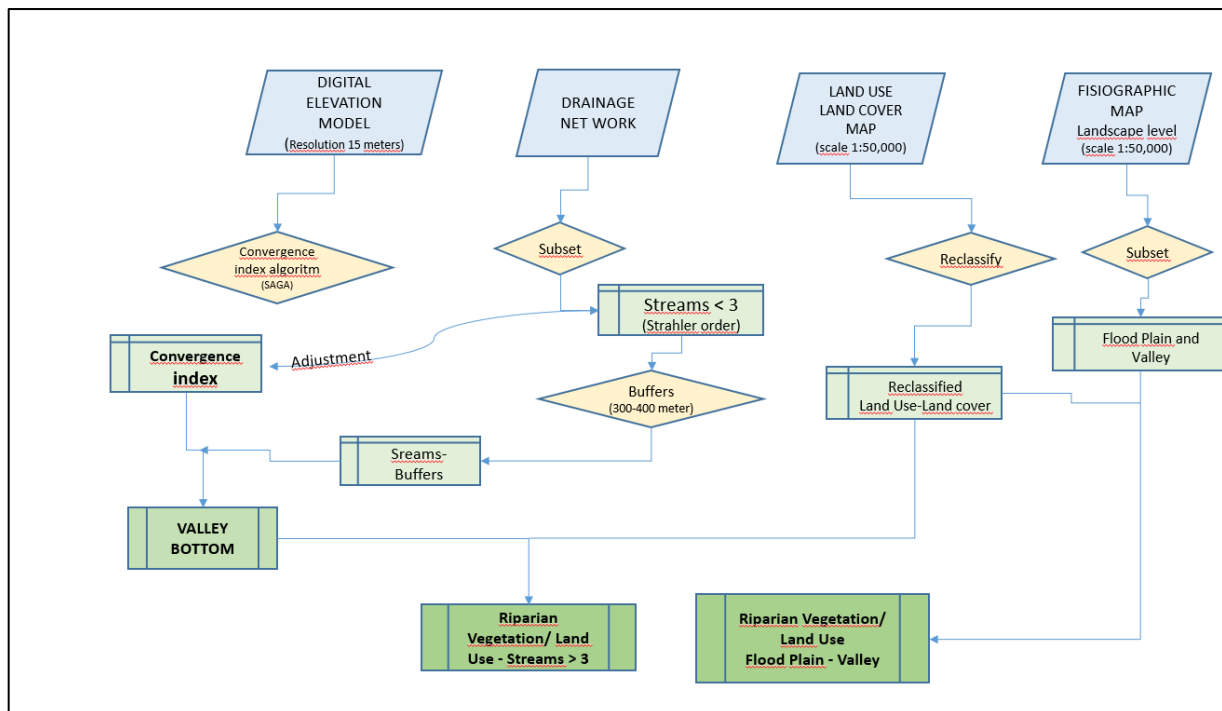


Figure 2: Metodological approach

Fixed buffers along streams have been broadly employed in delineating riparian zones; however, they do not capture temporal or spatial fluctuations of wet soils and vegetation. The potential maximum extent of riparian zones can be captured by identifying its' geomorphology (Paul et al., 2018). Based on these assumptions, in this study the concept of valley bottom, which capture the geo-morphological feature of riparian vegetation, was used. To define the valley bottom, we use the convergence index, adjusted with buffer of 300 meter for streams order 3 (Strahler order), and a buffer of 400 meters for streams less than 3. We use the buffers to exclude the foot of slope which are mapped in the convergence index. Another approximation to mapping riparian vegetation was used in the low land of watershed, where the hydro-logical process define a flood plain, in this case, we use the fisiographic map where this unit is mapped; several fisiographic sub-units that conform the flood plain were mapped, namely: shorelines, dykes, basins, indifferenciate flood plain and valley. In both cases (the valley bottom and flood plain approach) the geo-morphological unit were overaly with the land use and land cover map, defining so, the riparian vegetation or Land use that conform these geo-morphological units.

RESULTS AND ANALYSIS

The riparian vegetation considered in this study base on the two approach used (valley bottom and flood plain) include natural vegetation without alteration (natural forest, manglar, hydrophilic vegetation) or vegetation with some grade of alteration due to human intervention (arboreal vegetation, secondary vegetation, herbaceous vegetation).The land use refers to areas where the natural vegetation have been change, to introduce grassland and crops mainly, and to a lesser extent settlements.

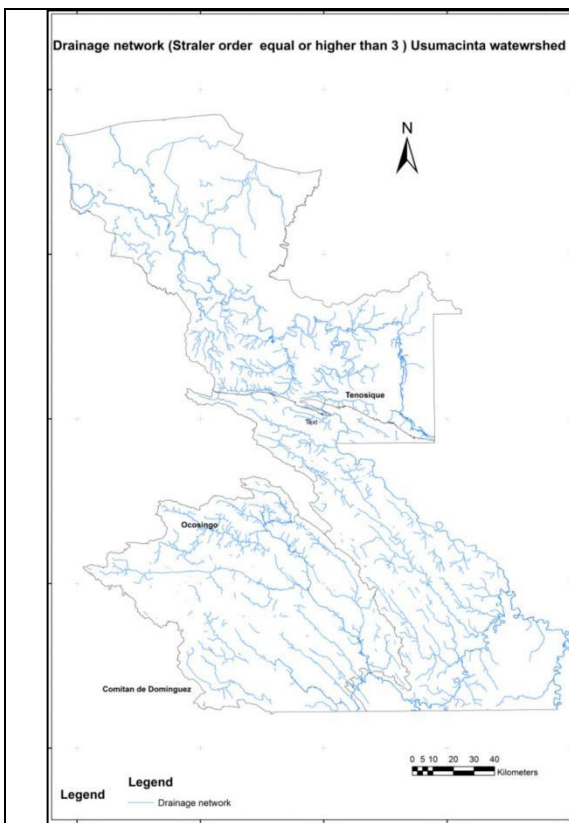


Figure 3: Usumacinta drainage net work, streams order less or equal to 3 (Strahler order)

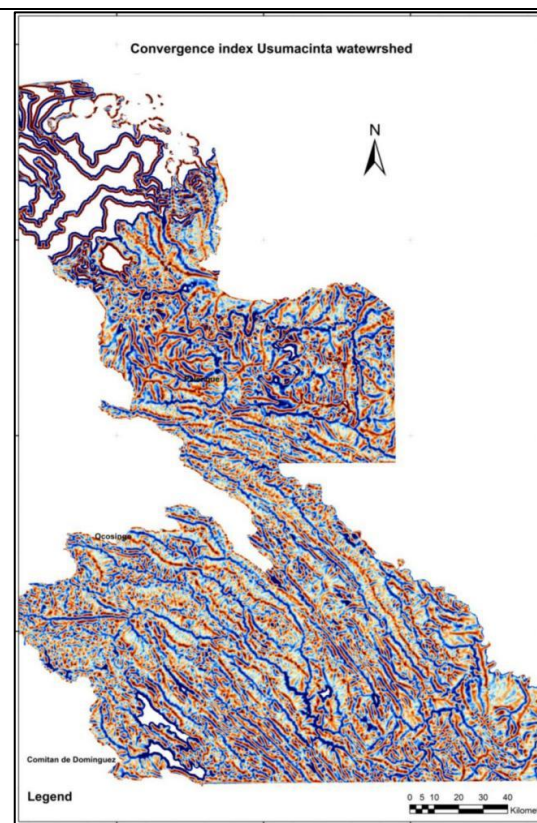


Figure 4: Convergence index (Saga, algoritm). The blue color refers to streams and foot of slope.

The figures 3 and 4 show the the drainage net work (adjusted with valley bottom) and the convergence index, the two main feature used to define the valley bottom, one of the approximation used here to mapping riparian vegetation.

The maps of figures 5 and 6 show the spatial distribution of riparian vegetation/land use mapped. In the table 1 and figures 7 -8, the areas for each one of the covers mapped is showed. As can be see in table 1, the most part of riparian areas have some grade of human intervention, only a small percentage (26.2%) which include natural forest and arboreal and hydrophilic vegetation (light intervention) are in good conditions. These areas are mainly located in two well defined sectors, the first one in the protected area, Montes Azules (highland area) and the other correspond to flood plain of rio San Pedro (low land). About 13.4 % include areas with moderate grade of intervention (secondary and herbaceous vegetation). The most area (60.4 %) of riparian vegetation has been change to introduce grassland (30.7 %), crops (27.8%) and settlements (1.9 %). Important area of crops are located along of flood plain of main rivers (Usumacinta, Lacantun, Santo Domingo and Jatate).

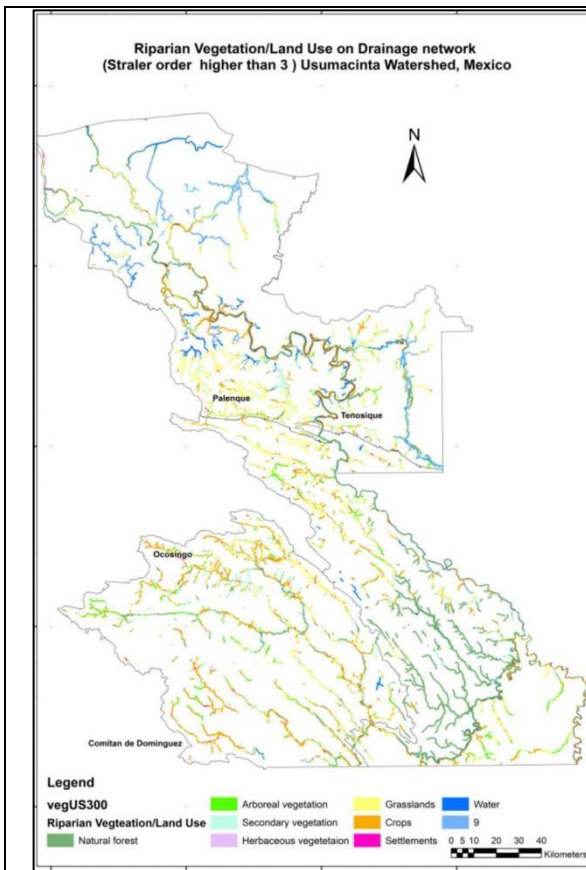


Figure 5: Riparian Vegetation/Land use

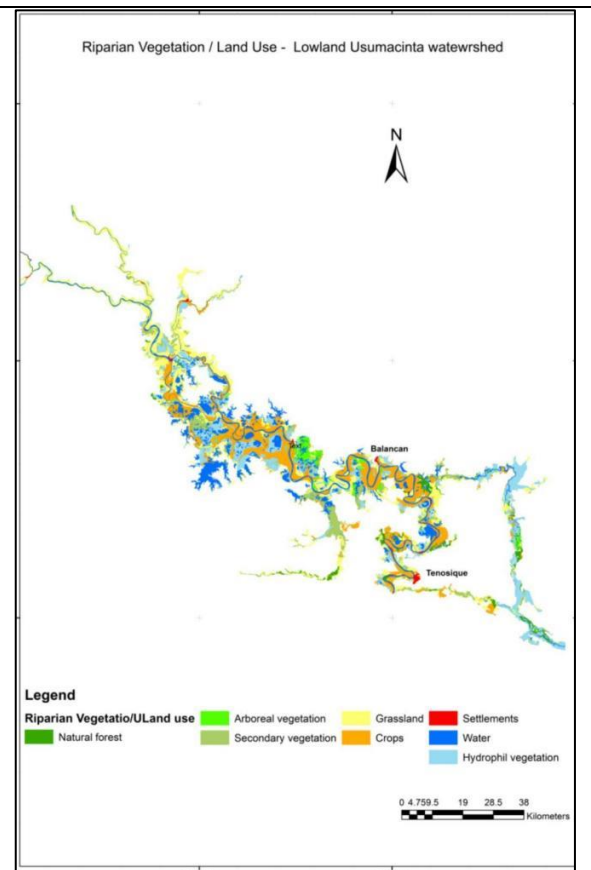


Figure 6: Riparian vegetation /Land use, low land Usumacinta watershed

From Geo-morphological point of view, in the high land the mapped valley bottom (mainly when de streams order 3 is considered) correspond to narrow valleys (v-shaped), and in some cases canyons (valleys with very steep slopes). The characteristics of this vegetation is different from that found in flat-bottomed U-shaped valleys, or in flood of the low land areas, where the surface and subsurface drainage conditions are different. In the highland the vegetation located in the narrow valleys play an important role in erosion control as well as interception of chemical elements from fertilization weed control, or plant protection. In the low land, one the most important function of the riparian vegetation is regulating surface runoff from the upper parts of the catchment.

Table 1: Estadisticas for riparian vegetation/Land Use according two approximations (Valley bottom in the total area of watershed, and flood plain analysis in the low land)

Riparian vegetation/Land use	Low Land	%	Streams 1,2	Streams = 3	Streams <= 3	%
Natural forest	7664	4.4	20670	14463	35133	10.6
Arboreal vegetation	6050	3.4	0	20993	20993	6.3
Secondary vegetation	3802	2.2	9745	31740	41485	12.5
Herbageous vegetaion	0	0	407	2489	2896	0.9
Grasslands	61798	35.2	34485	67523	102008	30.7
Crops	49099	27.9	38529	53545	92074	27.8

Settlement	1798	1	2710	3653	6363	1.9
Hydrophilic vegetation	45487	25.9	13248	17640	30888	9.3
Total	175,698	100	119,794	212,046	331,840	100

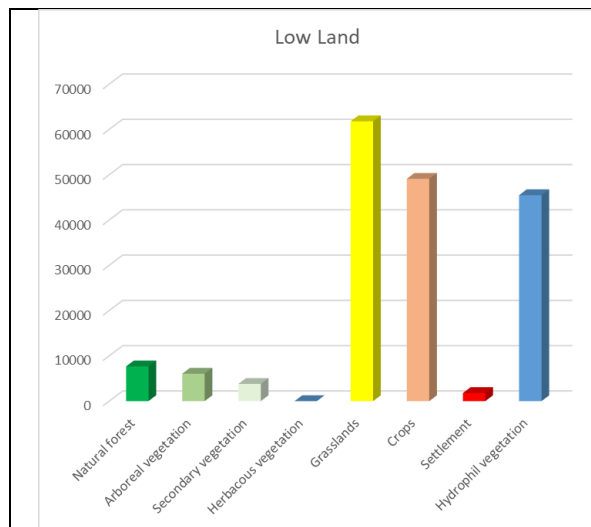


Figure 7: Riparian vegetation/Land use in the lowland (flood plain) Usumacinta Watershed

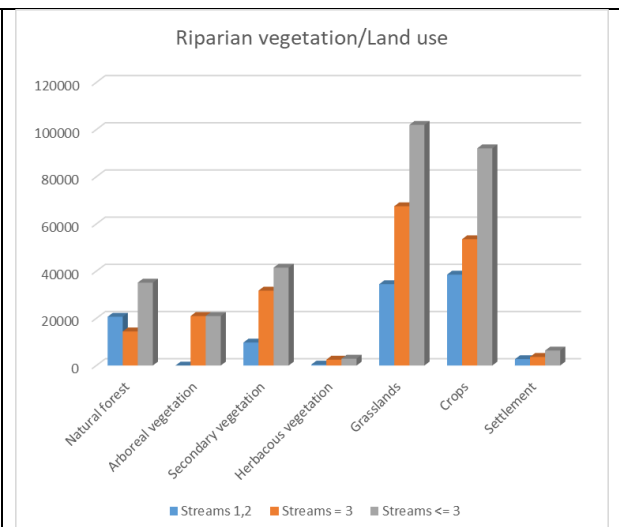


Figure 8: Riparian vegetation/Land use in the Usumacinta Watershed (Streams < or equal 3, of Strahler order)

CONCLUSION

- The valley bottom is considered a good approaching to mapping riparian vegetation in the high land, because by this geomorph the maximum extension of riparian areas can be captured.
- In the low land areas, where the hydrological process define a flood plain with its different sub units (dykes, basin), mapping riparian vegetation by using this geomorphological units is more straight forward and useful, because relationship between geomorphology and natural riparian cover and land use,
- In the Usumacinta watershed the most area of riparian vegetation has been destroyed by the introductions of grassland and crops.
- The mapping riparian vegetation can be useful in a reclamation program of this important ecosystem.

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