

# Conservation of the Tropical Rainforest in the Usumacinta Canyon Flora and Fauna Protection Area in Mexico

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## ABSTRACT

**Objective:** To study the conservation status of the tropical rainforest in the "Cañón del Usumacinta" Flora and Fauna Protection Area in Mexico, through an analysis of the change in land use and vegetation (1997, 2009 and 2016).

**Design/Methodology/Approach:** Vegetation and land use shapefiles at 1:250,000 scale (national continuum) corresponding to 1997 (series I), 2009 (series IV), and 2016 (series VI) were downloaded. Finally, a spatial analysis was generated with calculation of exchange rates, using the Land Change Modeler between 1997-2009 and 2009-2016.

**Results:** During 1997-2009, the tropical rainforest occupied 31.2% and the greatest impact of the period seen was a change rate of 7.4%. Subsequently, between 2009 and 2016 there was a great decrease in the land use change rate in the forest (0.8%), due to its decree as a federal Protected Area in 2008, as well as natural regeneration and the promotion of ecological restoration programs.

**Study Limitations/Implications:** Absence of geographic variables to analyze factors driving change in land use.

**Conclusions:** It is essential to promote the sustainable management of the Usumacinta Canyon based on what is established in the land use planning program and the management plan, and to redouble efforts to implement actions for restoring ecosystem services and the continuous monitoring of change in land use.

**Keywords:** Biological conservation; Protected areas; High Evergreen Forest; Territorial Ecological Planning.

## INTRODUCTION

The Usumacinta Canyon Flora and Fauna Protection Area contains unique biotic characteristics, as it is the entrance to the Petén department of Guatemala and to the Mesoamerican Biological Corridor, which spans from Mexico to Central America and constitutes the second most extensive mass of tropical rainforest after the Amazon (Arriaga *et al.*, 2000; DOF, 2008;

Mifsut and Castro, 2010; Hernández-López *et al.*, 2013, Mercedes Castillo, Barba-Álvarez, and Mayorga, 2018). One of its most characteristic traits is the presence of high evergreen rainforest, which is the most exuberant vegetation as well as the richest and most diverse of all the plant groups, according to Rzedowski and Huerta (1994). The most representative species of the reserve are chicozapote (*Manilkara zapota*), zapote (*Pouteria sapota*), breadnut (*Brosimum alicastrum*), guapaqué (*Dialium guianense*), and canxán (*Terminalia amazonia*) (Figure 1; DOF, 2008).

Until the 1960s, accessibility conditions kept the Usumacinta region practically unpopulated, registering during this period the establishment of the first population nuclei, with anthropic activities and devastating practices for the region's rainforest (Isaac-Márquez *et al.*, 2005; García and Soares, 2017). In this same decade, ecosystems in the Usumacinta and Chontalpa regions turned out to be the most impacted in the following watersheds: the Grijalva-Usumacinta due to the start of plans for directed colonization and productive modernization; the Chontalpa and Balancán-Tenosique, which influenced the dynamics of the population and territory (Isaac-Márquez *et al.*, 2005; Zavala and Castillo 2007; García-Morales *et al.*, 2014).

By 1970, the high evergreen rainforest represented 81.3% of the Usumacinta Canyon (Palomeque-de la Cruz, 2008). However, the livestock farming conversion process that was initiated in the previous decade arrived with particular strength for Tabasco in the mid-seventies. In this decade, the state of Tabasco became the top beef producer for Mexico City, which signified an increase in pastureland through the occupation of lands with high evergreen rainforest cover (Tudela, 1992; Manjarrez-Muñoz, 2007). The consolidation of traditional extensive cattle farming contributed to the deterioration of more than 95% of the high evergreen rainforest in all of the Grijalva-Usumacinta watershed territory (Isaac-Márquez *et al.*, 2005; Zavala and Castillo 2007; García-Morales *et al.*, 2014).

During the eighties, the government of Tabasco developed the first studies to

identify ecosystems in good state of conversion, as part of a strategy to mitigate the impact of the productive activities of the Chontalpa Plan and the Balancán-Tenosique Plan (SEMARNAT, 2015). It wasn't until 2005 that the Official Journal of the state published the Protected Area decree with state jurisdiction, designated as the Usumacinta Canyon State Park (Periódico Oficial del estado de Tabasco, 2005). Three years after the state decree, the federation released a decree that included the Usumacinta Canyon within the category of Flora and Fauna Protection Area (DOF, 2008).

In the Usumacinta Canyon, there are still important high evergreen rainforest areas in corridors and fragments, but their full extent and current state of conservation are unknown. This information is essential to support ecological land use planning (Velasco-Tapia, 2010). Thus, Balvarena (2012) and Jiménez-Sierra *et al.* (2014) consider it necessary to study the dynamics of high evergreen rainforest covers due to the influence that they have on the presence or decrease of ecosystem services like climate regulation, carbon storage, water regulation (increase in infiltration and evapotranspiration), water quality, erosion, landslides, and flood control, among others.



**Figure 1.** Rainforests and wetlands in the Usumacinta Canyon Flora and Fauna Protection Area, Mexico. Source: System of Public Research Centers CONACyT (2017).

For this reason, the objective of this study was to evaluate the impact on natural vegetation as a result of livestock activities in the Usumacinta Canyon Flora and Fauna Protection Area, by analyzing the change in land use and vegetation in the periods between 1997-2009 and 2009-2016.

## MATERIALS AND METHODOLOGY

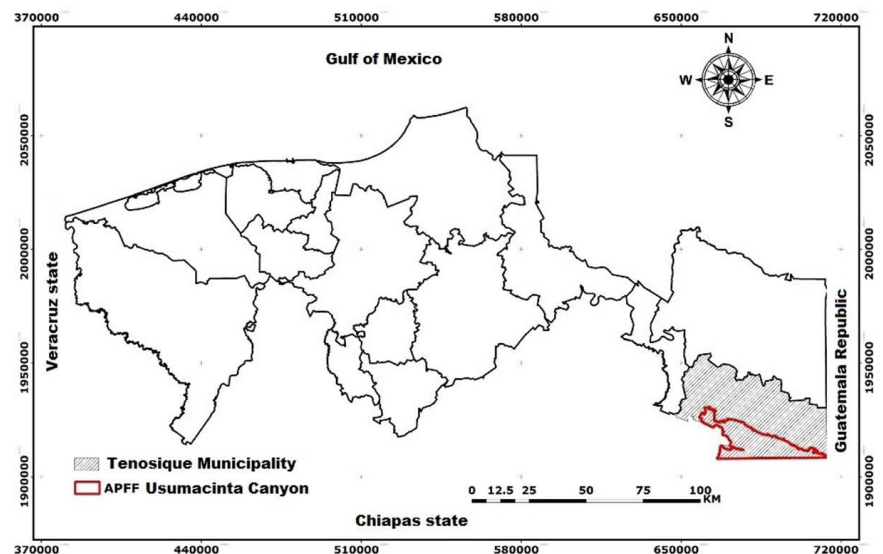
### Study Area

The Usumacinta Canyon Flora and Fauna Protection Area (Area de Protección de Fauna y Flora del Cañón del Sumidero, APFFCU) covers an area of 45,243 ha. The APFFCU is located between coordinates 17° 14' 00" and 17° 28' 00" North latitude, and 91° 32' 00" and 90° 56' 00" West longitude, in the southern part of the Tenosique municipality of Tabasco, bordering the Republic of Guatemala (Figure 2). It borders Chiapas to the west along the Usumacinta River for 33 kilometers; the Tenosique municipality to the north; and it borders Guatemala to the south in what is known as the physiographic province of the Sierra Madre de Chiapas and Guatemala, a sub-province of the El Petén lowlands (SEMARNAT, 2015). The predominant climate is warm-humid with year-round rain, and the average annual temperature is 26 °C with a precipitation range of 1,500 to 2,500 mm annually (INEGI, 2015).

### Database Procurement

Three shapefiles of vegetation and land use were downloaded at 1:250,000 scale (national continuum), corresponding to 1997 (series I), 2009 (series IV), and 2016 (series VI). The three shapefiles were obtained from the CONABIO geographic metadata catalogue with the geographic coordinate reference system UTM Zone 15 N, using the DATUM WGS84 parameters.

The shapefiles were converted to raster format with a size of 10 meters per pixel, with 7280 columns and 7541 rows, using the RASTERVECTOR command of the IDRISI Terrset software. Later, they were reclassified using the RECLASS command of the IDRISI Terrset software with the following categories: (1) rainforest, (2) secondary vegetation, (3) wetland, (4) farmland, (5) pastureland, and (6) urban (Figure 3).



**Figure 2.** Geographic location of the Usumacinta Canyon Flora and Fauna Protection Area, Mexico. Source: self-made.

### Analysis of Changes 1997-2009-2016

With the Land Change Modeler module of the IDRISI Terrset software, a change matrix was generated with raster images that varied in the number of study dates; that is to say, in more than two periods of time (Pontius et al., 2004). In this analysis, cross-referencing of the raster images from 1997 and 2009 generated a matrix with a statistical  $\kappa=0.6444$ , while the images from 2009 and 2016 generated a matrix with a statistical  $\kappa=0.9088$ . These statistics that are close to 1.000 are reliable for the study of the spatial and temporal dynamics of the ecosystems in two time periods (Eastman, 2012).

### Calculation of Change Rate

The change rates were calculated using the Palacio-Prieto et al. (2004) formula:

$$Td = [(S2 / S1)(1 / n) - 1] * 100$$

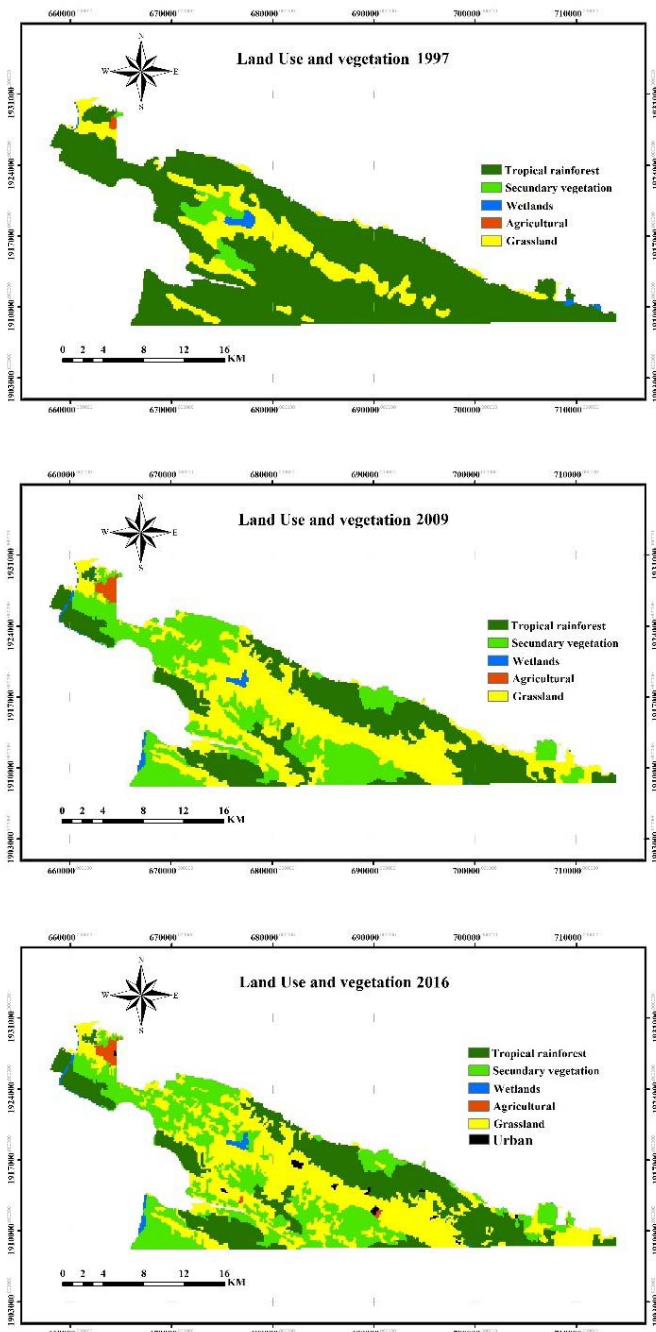
where:  $Td$ =annual change rate (%),  $S1$ =Covered area at start of period (ha),  $S2$ =Covered area at end of period (ha), and  $n$ =Number of years in period.

## RESULTS AND DISCUSSION

### Change in Land Use 1997-2009

During 1997 to 2009, losses of 21,870 ha of rainforest were detected, with a negative change rate of 7.4% (Table 1). This is very high compared to the deforestation rate at the regional level (0.90%) during 1993 and 2007 in the Grijalva-Usumacinta watershed (Kolb and Galicia, 2012).





**Figure 3.** Maps of land use and vegetation 1997a, 2009b and 2016c in the Usumacinta Canyon Flora and Fauna Protection Area, Mexico. Source: self-made.

Even though Tabasco is not a completely cattle-farming state, it sends large amounts of fattened livestock to the north of Mexico. Thus, cattle farming and agriculture are the dominant activities in the rural setting, both with a high degree of environmental deterioration. In the case at hand, deforestation of the high evergreen forest begins with the establishment of maize (*Zea mays*) plots that make up a significant part of the country’s diet, and which are then transformed into pastureland (Galindo-Alcántara *et al.*, 2006, Mifsut and Castro, 2010; Velasco-Tapia, 2010). The environmental impact generated by these farming systems is high; for cattle farming, because it is based on the transformation of natural vegetation with extensive grazing practices in pastures with low rates of summer pasture; and for agriculture, because the old slash-and-burn system continues to be maintained (Galindo-Alcantara, 1999).

The above shows that deforestation of the rainforest is not solely connected to population growth, but also to farming activities and external uses (Velasco-Tapia, 2010; Gallardo-Cruz *et al.*, 2019).

At the start of the new century, deforested areas were rising due to the creation of programs supporting livestock ranches, such as PROGAN. This program aided 2,126 projects in Balancán and Tenosique between 2003 and 2005. In contrast, the program for rainforest restoration (PRODEFOR) only benefitted between 17 and 28 projects during 2004 and 2005 (Manjarrez-Muñoz *et al.*, 2007). Notably, during 2000-2012, the municipality of Tenosique supplied between 20 and 40% of the total hectares of lost tree vegetation per year in the lower Usumacinta watershed (Gallardo-Cruz *et al.*, 2019).

Conversely, the areas of succession or secondary vegetation (acahuales) increased by 13,682 ha, with a growth rate of 19.5 % (Table 1). This increase is generally the result of a recovery process within abandoned

**Table 1.** Quantification of land use and vegetation change 1997-2009 in the Usumacinta Canyon Flora and Fauna Protection Area, Mexico.

| Category             | 1997   | %    | 2009   | %    | Losses  | Gains  | Net change | Exchange rate |
|----------------------|--------|------|--------|------|---------|--------|------------|---------------|
| Tropical Rain forest | 35,696 | 78.9 | 14,121 | 31.2 | -21,870 | 295    | -21,575    | -74           |
| Secondary vegetation | 1,611  | 3.6  | 13,682 | 30.2 | -929    | 13,001 | 12,071     | 19.5          |
| Wetlands             | 416    | 0.9  | 419    | 0.9  | -268    | 270    | 2          | 0.0           |
| Agricultural         | 81     | 0.2  | 374    | 0.8  | 0       | 293    | 293        | 13.6          |
| Grassland            | 7,439  | 16.4 | 16,648 | 36.8 | -1,490  | 10,699 | 9,209      | 6.9           |

farming and pasture zones due to loss in soil fertility in the case of farmland, or to meat market prices that push farmers to sell their animals (Galindo-Alcántara et al., 2006).

### Change in Land Use 2009-2016

In the 2009-2016 period, rainforests showed losses of 1,163 ha, therefore the negative change rate was at 0.8%, less than that registered during 1997-2009 (Table 2). This decrease in the rate of deforestation is attributed to the high evergreen rainforest and fragmented rainforest having undergone reversal processes in their vegetation cover (Arreola-Muñoz et al., 2011). In Tabasco, the reversal of tree vegetation has occurred naturally and induced: naturally as a result of abandoned farming activities, and induced due to the growth in the number of reforestation programs for forestry activities and payment for ecosystem services (Alejandro-Montiel et al., 2010; Gallardo-Cruz et al., 2019). Particularly, the conservation of high evergreen rainforest during 2009-2016 coincides with the decree of the Usumacinta Canyon as a Federally Protected Area in 2008 (DOF, 2008).

Currently, the federal program Sembrando Vida ("Planting Life") could be a catalyst for environmental conservation, as it is driving agroforestry projects and Tabasco is one of the benefitted states (De la Barrera et al., 2019, Secretaría de Bienestar, 2020).

During the 2000 to 2016 period, the lower basin of the Usumacinta River has been the region with the lowest rainforest deforestation rates, compared to the middle and higher region. This condition could be influenced by the extension of the protected areas in the middle and lower basin. For example, the extension of Montes Azules is much greater than the area of the Usumacinta Canyon, so that by volume the area lost in the former is greater than in the latter (DOF, 2008; Gallardo-Cruz et al., 2019).

During 2009-2016, the deforestation rate notably decreased. Despite this, farming activities in the APFFCU continue to be unsustainable because they are organized in a traditional extensive farming system that combines agriculture and cattle ranching with low economic reinvestment and high use of local natural resources, resulting in significant pressure on the high evergreen rainforest (Nuncio et al., 2001). However, there are currently other strategies that are contributing to the reforestation of these spaces. Such is the case with the Sembrando Vida program, which fosters recovery through the introduction of timber-yielding and fruit trees to the natural forests that include recently abandoned parcels (De la Barrera et al., 2019).

To restore and conserve the last remnants of high evergreen rainforest and control the impact of farming activities, proposals have been elaborated with a focus on land zoning that consider at least two premises: the incorporation of tree cover into cattle ranching surface areas using silvopastoral systems, and the use of species and technologies in the cattle farming units that decrease the use of natural resources (Manjarrez-Muñoz et al., 2007). Also available is an ecological zoning model where land use designation is based on the condition and vocation of the natural resources, and which integrates socioeconomic, productive, environmental, legal, and administrative aspects in order to face existing environmental conflicts and induce the integral management of the Usumacinta Canyon, organized in Environmental Management Units (Unidades de Gestión Ambiental, UGA) (Arreola-Muñoz et al., 2011) (Table 3).

Among other actions, implementing monitoring of the principal patterns in land use and vegetation change is recommended, by way of current remote sensing techniques and Geographic Information Systems, in order to identify the chief conditioning factors of these impacts and to map future scenarios. Studies measuring ecosystem services are also important, with the objective

**Table 2.** Quantification of land use and vegetation change 2009-2016 in the Usumacinta Canyon Flora and Fauna Protection Area, Mexico.

| Category             | 2009  | %    | 2016  | %    | Losses | Gains | Net change | Exchange rate |
|----------------------|-------|------|-------|------|--------|-------|------------|---------------|
| Tropical rainforest  | 14121 | 31.2 | 13322 | 29.4 | -1163  | 365   | -799.0     | -0.8          |
| Secondary vegetation | 13682 | 30.2 | 13817 | 30.5 | -2365  | 2500  | 135.0      | 0.1           |
| Wetlands             | 419   | 0.9  | 420.8 | 0.93 | -11    | 14    | 2.0        | 0.1           |
| Agricultural         | 374   | 0.8  | 432   | 0.95 | -16    | 74    | 59.0       | 2.1           |
| Grassland            | 16648 | 36.8 | 16990 | 37.6 | -2734  | 3076  | 342.0      | 0.3           |

**Table 3.** Environmental Management Units (UGA) for the Usumacinta Canyon Flora and Fauna Protection Area, Mexico.

| Land use                          | area (ha) |
|-----------------------------------|-----------|
| Rural human settlements           | 963,79    |
| Rainfed agriculture               | 445,14    |
| Fruit tree                        | 83,28     |
| Holistic Semi-Intensive Livestock | 7.750,21  |
| Plantaciones Forestales           | 7.364,10  |
| Productive restoration            | 1.654,33  |
| Agroforestry systems              | 1.362,76  |
| Silvopastoral System              | 9.790,17  |
| Environmental Rehabilitation      | 14.232,16 |
| Ecoturism                         | 360,3     |
| Xate and Motusay plantations      | 11,04     |
| Research work                     | 11.966,89 |

Source: Arreola-Muñoz *et al.* (2011).

of avoiding or reverting disturbance and conserving the original remains of the high rainforest, soil, and natural water flows that all maximize the provision of ecosystem services, since it is recognized that the Usumacinta rainforests are carbon sinks with relevance in America (Mifsut and Castro, 2010).

### CONCLUSIONS

The study of the state of conservation in the high evergreen rainforest of the Usumacinta Canyon Flora and Fauna Protection Area determined that between 1997 and 2016, a total of 23,033 ha of rainforest were lost. Notably, the greatest negative change rate of rainforest was recorded in the period from 1997 to 2009, which it decreased in 2016 possibly as a result of the decree of the Protected Area and the implementation of programs driving ecological restoration. Since the decrease in natural cover entails the loss of other organisms from habitat loss, including silvopastoral systems in farming units is recommended, as well as the use of new technologies that lower the use of natural resources. Even the Sembrando Vida program could play a fundamental role in the development and conservation of the area. In addition, execution and follow-up of the policies established in the land zoning model is recommended, as well as the promotion of permanent monitoring of changes in land use and of ecosystem services.

### REFERENCES

Alejandro-Montiel, C., Galmiche-Tejeda, Á., Domínguez-Domínguez, M., & Rincón-Ramírez, A. (2010). Cambios en la cubierta forestal del área ecoturística de la Reserva ecológica de Agua

Selva, México. *Tropical and Subtropical Agroecosystems* 12 (3): 605-617.

Arreola-Muñoz, A., Reyes-Barrón, M.C., Segura-Bertollini, E.C., Hernández-Zárate, L.O., & Llergo-Juárez, J.G. (2011). Ordenamiento Territorial de la Microrregión Cañón del Usumacinta, Municipio de Tenosique, Tabasco. Villahermosa, México: SERNAPAM.

Arriaga, L.J., Espinoza, J.C., Aguilar, C., & Martínez, E. (2000). Regiones terrestres prioritarias de México. Ciudad de México: CONABIO.

De la Barrera, P. (2012). Los servicios ecosistémicos que ofrecen los bosques tropicales. *Revista Ecosistemas*, 21(1-2): 136-147.

De la Barrera, E., Villalvazo-Figueroa, E.A., Díaz-Álvarez E. A. *et al.* (2019). 4T don't stand for tacos: An analysis of food and environmental security considerations in the new Mexican government's agricultural agenda. *Food Research* 8:1768.

Diario Oficial de la Federación. (2008). Decreto por el que se declara área natural protegida con la categoría de área de protección de flora y fauna, la región conocida como Cañón del Usumacinta, localizada en el Municipio de Tenosique, en el Estado de Tabasco. Ciudad de México: Congreso de la Unión

Eastman, J.R. 2012. IDRISI Selva GIS and image processing software version 17.0. Clark Labs. Massachusetts, USA. 321 p

Gallardo-Cruz, A., Fernández-Montes de Oca, A., & Rives, C. (2019). Detección de amenazas y oportunidades para la conservación en la cuenca baja del Usumacinta a partir de técnicas de percepción remota. *Revista Ecosistemas* 28 (2): 82-99. doi: 10.7818/ECOS.1611

Galindo-Alcántara, A., Gama-Campillo, L. M., Ruiz-Acosta, S., & Morales-Hernández, A. (2006). Programa de conservación y manejo del Parque Estatal Cañón del Usumacinta. Villahermosa, México: SEDESPA

García-Morales, R., Gordillo-Chávez, E. J., Valdez-Leal, J. D. D. y Pacheco-Figueroa, C. (2014). Las áreas naturales protegidas y su papel en la conservación de los murciélagos del estado de Tabasco, México. *Therya* 5(3): 725-736.

García, G. D., & Soares, D. (2017). Introducción. En D. Soares y A. García (Eds.), *En La cuenca del río Usumacinta desde la perspectiva del cambio climático*. Ciudad de México: CONACYT-SEMARNAT-IMTA

Hernández-López, A., López-Alamilla, E., Ramírez, A. R., & Aquino-Bravata, V. (2013). Diagnóstico del uso de la fauna silvestre, en el área de protección de flora y fauna. *Ra Ximhai* 9 (1): 1-14.

Instituto Nacional de Estadística, Geografía e Informática (INEGI). (2015). *Prontuario de información geográfica municipal de los Estados Unidos Mexicanos*. Tenosique, Tenosique, Tabasco. Clave geoestadística 27017. INEGI. México.

Isaac-Márquez, R., De-Jong, B., Eastmond, A., Ochoa-Gaona, S., Hernández, S., & Kantún, M.D. (2005). Estrategias productivas campesinas: un análisis de los factores condicionantes del uso del suelo en el oriente de Tabasco, México. *Universidad y Ciencia* 21(42): 57-73.

Jiménez-Sierra, C.L., Sosa-Ramírez, J., Cortés-Calva, P., Breceda-Solía, C.A., Íñiguez Dávalos, L.I., & Ortega-Rubio, A. (2014). México país megadiverso y la relevancia de las áreas naturales protegidas. *Investigación y Ciencia* 22 (60): 16-22.

Kolb, M., & Galicia, L. (2012). Challenging the linear forestation narrative in the Neo-tropic: regional patterns and processes of deforestation and regeneration in southern Mexico. *The Geographical Journal* 178 (2): 147-161.

- Manjarrez-Muñoz, B., Hernández-Daumás, S., De-Jong, B., Nahed-Toral, J., Dios-Vallejo, O. O. D., & Salvatierra-Zaba, E. B. (2007). Configuración territorial y perspectivas de ordenamiento de la ganadería bovina en los municipios de Balancán y Tenosique, Tabasco. *Investigaciones Geográficas* (64): 90-115.
- Mifsut, I. M., & Castro, M. (2010). La cuenca del Río Usumacinta: perfil y perspectivas para su conservación y desarrollo sustentable. *Las cuencas hidrográficas de México. Diagnóstico y priorización*. Ciudad de México: SEMARNAT
- Nuncio-Ochoa, G., Nahed-Toral, J., Díaz-Hernández, B., Escobedo-Amezcuca, F. & Salvatierra-Izaba, B. (2001). Caracterización de los sistemas de producción ovina en el estado de Tabasco. *Agrociencia* 35(4): 469-477.
- Palacio-Prieto, J.L., Sánchez-Salazar, M.T., Casado, J.M., Propin, F.E., Delgado, C.J., Velázquez, M.A., & Camacho, R.C.G. (2004). Indicadores para la caracterización y el ordenamiento territorial. Ciudad de México: SEMARNAT.
- Palomeque de la Cruz, M. Á. (2008). Análisis del cambio de uso del suelo y las actividades productivas en el parque estatal Cañón del Usumacinta en Tenosique, Tabasco. Tesis de Maestría en Ciencias Ambientales. División Académica de Ciencias Biológicas, Universidad Juárez Autónoma de Tabasco. Villahermosa, México.
- Periódico Oficial del Estado de Tabasco. (2005). Decreto por el cual se declara Área Natural Protegida de Carácter estatal, el Parque Estatal Cañón del Usumacinta Tenosique Tabasco. Villahermosa, México: Oficialía Mayor de Gobierno.
- Pontius J., R.G., Huffaker, D., & Denman, K. (2004). Useful techniques of validation for spatially explicit land-change models. *Ecological Modelling* 179(4): 445-461.
- Rzedowski, J., & Huerta, L. (1994). *Vegetación de México*. Ciudad de México: Limusa, Noriega Editores.
- Sistema de Centros Públicos de Investigación CONACYT (2017). Explorando el Usumacinta. Conociendo Tenosique. Recuperado de <https://centrosconacyt.mx/objeto/usumacinta/>
- Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT). (2015). Programa de Manejo Área de Protección de Flora y Fauna Cañón del Usumacinta. Ciudad de México: SEMARNAT-CONANP
- Tudela, F. (1992). *La modernización forzada del trópico: el caso de Tabasco*. Ciudad de México: El Colegio de México
- Velasco-Tapia (2010). Identificación de cambios en el uso del suelo y vegetación, y cálculo de la tasa de transformación del hábitat en el periodo 2000-2010, Área de Protección de Flora y Fauna Cañón del Usumacinta. Ciudad de México: CONANP
- Zavala, J., & Castillo, A. O. (2007). Cambio de uso de la tierra en el estado de Tabasco. En D. J. Palma y A. Triano (Eds.), *Plan de uso sustentable de los suelos del estado de Tabasco* (vol, II, pp. 38-56). Villahermosa, México: Colegio de Posgraduados.

