Revista Mexicana de Ciencias Forestales Vol. 17 (94)
Marzo - Abril (2026)

DOI: 10.29298/rmcf.v17i94.1608

Research article

Land-use change and vegetation cover in the *San Pedro Mártir* River sub-basin, *Tabasco* state, Mexico

Cambio de uso del suelo y cobertura vegetal en la subcuenca del río San Pedro Mártir, Tabasco, México

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Fecha de recepción/Reception date: 7 de octubre de 2025.
Fecha de aceptación/Acceptance date: 6 de marzo de 2026.

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Abstract

The aim of this study was to analyze the dynamics of land-use and vegetation cover change in the *San Pedro Mártir* River sub-basin, *Tabasco* state, Mexico, for the 1984-2024 period using remote sensing techniques and geographic information systems. Landsat images corresponding to the 1984, 2000 and 2024 years were classified into eight land-use and vegetation cover categories. Based on these classifications, surface areas, vegetation cover transitions and annual rates of change were estimated for two analysis periods. The results reveal a territorial transformation characterized by the consolidation of pastures as the dominant vegetation cover, increasing from 33.7 % of the surface area in 1984 to 45.4 % in 2024. Secondary vegetation exhibited highly dynamic behavior, with phases of loss and partial recovery, confirming its role as a transitional cover within recurrent land-use cycles. Flooded lowland forest and ecosystems associated with inundated environments highlight a net reduction toward the end of the analyzed period. From 2000 onward, the emergence and rapid expansion of forest plantations were identified, mainly over agricultural areas, pastures, and secondary vegetation, reaching 6.2 % of the territory in 2024. The identified change trajectories reflect a productive reconfiguration of the landscape characterized by structural simplification and fragmentation of forest cover. The study provides a spatial and temporal baseline for analyzing territorial dynamics in humid tropical regions.

Keywords: Multitemporal analysis, land-use change, vegetation cover, landscape dynamics, tropical regions, remote sensing.

Resumen

El objetivo del estudio que se describe a continuación fue analizar la dinámica del cambio de uso del suelo y la cobertura vegetal en la subcuenca del río San Pedro Mártir, Tabasco, México durante el periodo 1984-2024 mediante técnicas de teledetección y sistemas de información geográfica. Se utilizaron imágenes *Landsat* correspondientes a los años 1984, 2000 y 2024, las cuales fueron clasificadas en ocho categorías de uso del suelo y cobertura vegetal. A partir de estas se estimaron superficies, transiciones entre coberturas y tasas de cambio anuales para dos periodos de análisis. Los resultados evidenciaron una transformación territorial caracterizada por la consolidación de los pastizales como la cobertura dominante del paisaje, al pasar de 33.7 % de la superficie en 1984 a 45.4 % en 2024. La vegetación secundaria presentó un comportamiento muy dinámico, con pérdidas y recuperaciones parciales, lo que confirmó su papel como cobertura transicional dentro de ciclos recurrentes de uso del suelo. La selva baja inundable y los ecosistemas asociados a ambientes inundables registraron una reducción neta hacia el final del periodo analizado. A partir del año 2000 se identificó la emergencia y rápida expansión de plantaciones forestales, principalmente sobre áreas agrícolas, pastizales y vegetación secundaria que alcanzó 6.2 % del territorio en 2024. Las trayectorias de cambio identificadas reflejan una reconfiguración productiva del paisaje caracterizada por la simplificación estructural y la fragmentación de las coberturas forestales. El estudio proporciona una línea base espacial y temporal para el análisis de la dinámica territorial en regiones tropicales húmedas.

Palabras clave: Análisis multitemporal, cambio de uso del suelo, cobertura vegetal, dinámica del paisaje, regiones tropicales, teledetección.

Introduction

The *San Pedro Mártir* River sub-basin, located in the *Ríos* Region of the state of *Tabasco*, Mexico, exhibits a high degree of environmental heterogeneity characteristic of humid tropical lowlands, where seasonally flooded lowland forest, secondary vegetation, wetlands, and areas transformed by agricultural activities coexist (Megia-Vera et al., 2025). This territory is of significant environmental and productive importance and includes protected natural areas of regional and national significance, such as the *Cascadas de Reforma* State Natural Area, the *Wanha'* Biosphere Reserve, and a portion of the *Cañón del Usumacinta* Flora and Fauna Protection Area (Gobierno del Estado de Tabasco, 2002; Secretaría de Gobernación, 2008, 2023).

Over the past few decades, the sub-basin has undergone a significant transformation in land use and vegetation cover, primarily associated with the expansion of extensive livestock farming, agriculture, and, more recently, the establishment of commercial forest plantations. These processes have modified the spatial distribution of native forest cover, secondary vegetation, and wetlands, resulting in a landscape dominated by productive uses and recurrent transitions between natural and human-modified

land cover (Gobierno del Estado de Tabasco, 2024; Manjarrez-Muñoz et al., 2007; Ramírez-García et al., 2022).

Globally, the conversion of tropical forests to agricultural uses and plantations is one of the main drivers of land-use change. Classic and recent studies agree that tropical forests have been the main source of new agricultural land since the late 20th century, particularly for the expansion of pastures and commercial crops, leading to permanent territorial transformations (Gibbs et al., 2010; Hansen et al., 2013). Global analyses based on Landsat imagery have shown that deforestation due to conversion to agricultural and forest activities accounts for a significant proportion of recent tree cover loss worldwide (Curtis et al., 2018).

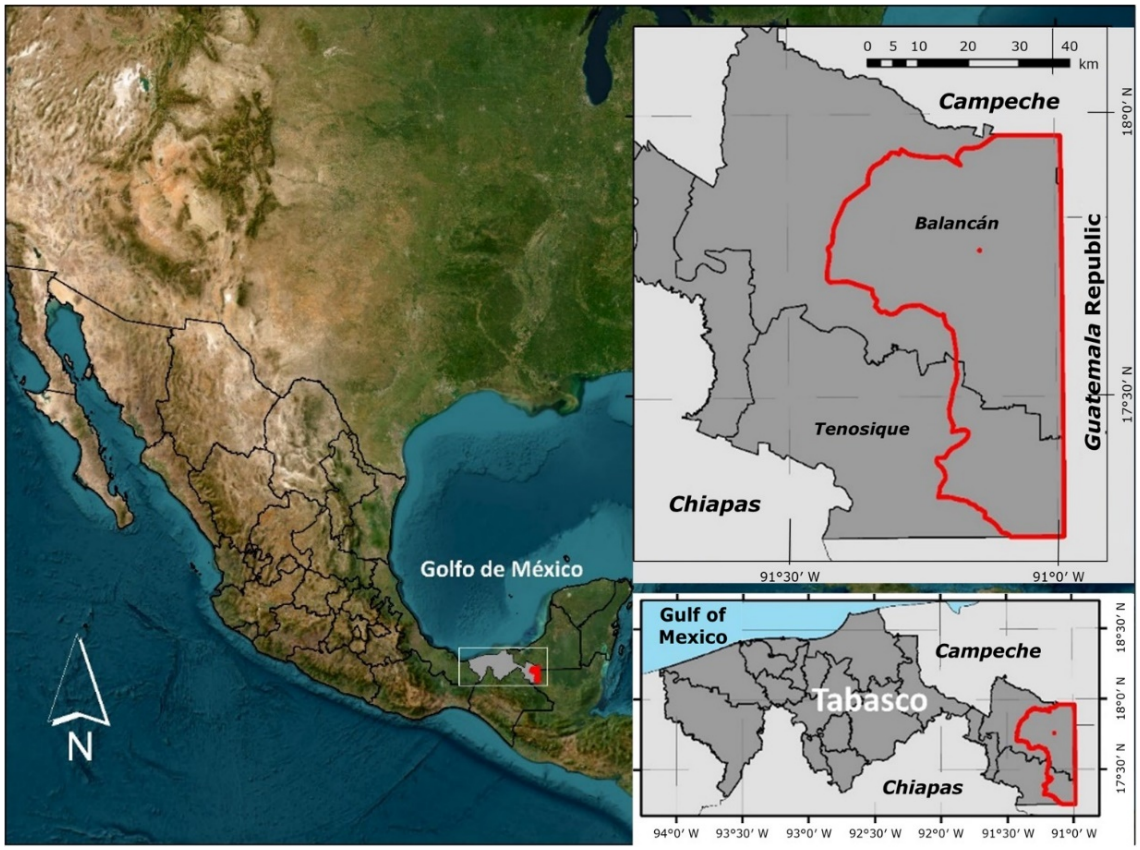
In this context, the expansion of forest plantations in tropical regions represents a distinct process that, while increasing tree cover, is not functionally equivalent to native forests. Several studies have indicated that these plantations exhibit simplified ecological structures and distinct environmental effects, making their interpretation as forest restoration potentially misleading when analyzing landscape dynamics, biodiversity, and ecosystem processes (Fagan et al., 2022; Kotowska et al., 2023).

Multitemporal land-use change analysis using remote sensing techniques and geographic information systems has proven to be a robust tool for identifying spatial patterns, quantifying transitions between land cover types, and estimating rates of land gain and loss over different periods (Agudelo-Hz et al., 2023; Eastman, 2012). In tropical regions such as Southeastern Mexico, where floodplain forests, wetlands, and agricultural landscapes converge, this approach is particularly useful for documenting the replacement of native forest cover, the dynamics of secondary vegetation as transitional land cover, and the emergence of new productive uses.

In this regard, the present study aimed to analyze the dynamics of land use change and vegetation cover in the *San Pedro Mártir* River sub-basin, *Tabasco*, Mexico, during the period 1984-2024, using remote sensing techniques and geographic information systems. This approach allows for the identification not only of surface changes but also of landscape transformation trajectories, understood as the sequences of land cover conversion that shape territorial dynamics over time.

Materials and Methods

The *San Pedro Mártir* River sub-basin is located in the *Ríos* Region of the state of *Tabasco*, Mexico, and is part of the *Usumacinta* River basin (Figure 1). Physiographically, it belongs to the Southern Gulf Coastal Plain province, characterized by the predominance of alluvial and fluvio-palustrine plains with flat to gently rolling surfaces and altitudes generally below 30 masl (Instituto Nacional de Estadística, Geografía e Informática [INEGI], 1986). These geomorphological conditions favor the presence of floodplains, wetlands, and interfluvial depressions. The climate is warm and humid with summer rains (Am), which contributes to the development of tropical ecosystems and extensive wetland systems characteristic of the *Tabasco* plains (INEGI, 1986).



Golfo de México = Gulf of Mexico; *Tabasco* = State of *Tabasco*.

Figure 1. Location of the study area.

Land use and vegetation cover change analysis was performed using a multi-temporal approach for the 1984, 2000 and 2024 years, using Landsat 5 TM and Landsat 8 OLI images with a spatial resolution of 30 m, obtained from the United States Geological Survey (USGS, 2024).

For preprocessing, the Semi-Automatic Classification Plugin (SCP) by Congedo (2023) was used in QGIS version 3.36 (QGIS Development Team, 2024). Radiometric and atmospheric correction was performed on the Landsat 5 TM and Landsat 8 OLI images, along with conversion to surface reflectance, cloud masking, and spatial standardization to ensure temporal comparability. The delimitation of the study area was carried out using the polygon available in the Water Flow Simulator of Hydrographic Basinsof the National Institute of Statistics and Geography (Instituto Nacional de Estadística y Geografía [Inegi], 2021).

Supervised classification was performed using the Maximum Likelihood algorithm (Congedo, 2023), defining eight land use and vegetation categories: flooded lowland forest, hydrophytic vegetation, secondary vegetation, water bodies, agricultural areas, grassland, forest plantations, and human settlements. Training samples were selected through visual interpretation of the images, supported by thematic maps and secondary information.

Field verification was carried out through reconnaissance walks in representative sites, used to support the interpretation and validation of the classes. Classification accuracy was evaluated using confusion matrices, comparing independent reference points obtained from field verification and visual interpretation of the images with the assigned classes. From this matrix, overall accuracy and the Kappa coefficient were estimated.

Land-use change dynamics were analyzed using the Land Change Modeler module of TerrSet 2020® (Center for Geospatial Analytics, 2020), estimating gains, losses, net changes, and rates of change for the periods 1984-2000 and 2000-2024. The rate of change was calculated using the following formula:

$$TC = \left(\left[\frac{S_2}{S_1} \right]^{\frac{1}{n}} - 1 \right) \times 100$$

Where:

TC = Annual rate of change (%)

S_1 = Area covered at the beginning of the period (ha)

S_2 = Area covered at the end of the period (ha)

n = Number of years in the period (Palacio-Prieto et al., 2004)

Results

Multitemporal analysis of land use and vegetation cover in the *San Pedro Mártir* River sub-basin showed significant changes in landscape composition and configuration between 1984 and 2000 (Kappa=0.6044, Accuracy≈88) and 2000-2024 (Kappa=0.5127, Accuracy≈84). Variations in the area of the main land cover types were identified, as well as distinct spatial transitions between forest, semi-natural, and productive land uses.

General changes in land use and vegetation cover (1984-2024)

In 1984, the landscape was dominated by secondary vegetation (36.4 %) and grassland (33.7 %), followed by agricultural areas (13.0 %), hydrophytic vegetation (8.0 %), and flooded lowland forest (6.2 %). Water bodies and human settlements represented less than 3 % of the total area (Table 1; Figure 2).

Table 1. Area and proportion of land use and vegetation cover categories in the *San Pedro Mártir* River sub-basin for the 1984, 2000, and 2024 years.

Categories	1984		2000		2024	
	ha	%	ha	%	ha	%
Flooded lowland forest	13 063	6.2	17 946.0	8.5	11 494.2	5.5
Hydrophytic vegetation	16 734	8.0	17 803.7	8.5	15 135.0	7.2
Secondary vegetation	76 588	36.4	55 669.1	26.5	57 582.2	27.4
Water bodies	4 748	2.3	5 386.5	2.6	2 894.5	1.4
Agricultural areas	27 357	13.0	50 010.2	23.8	8 998.5	4.3
Grasslands	70 772	33.7	61 655.2	29.3	95 476.6	45.4
Forest plantations	0	0.0	99.5	0.04	13 052.4	6.2
Human settlements	899	0.4	1 591.0	0.8	5 527.6	2.6
Total	210 161	100.0	210 161	100.0	210 161	100.0

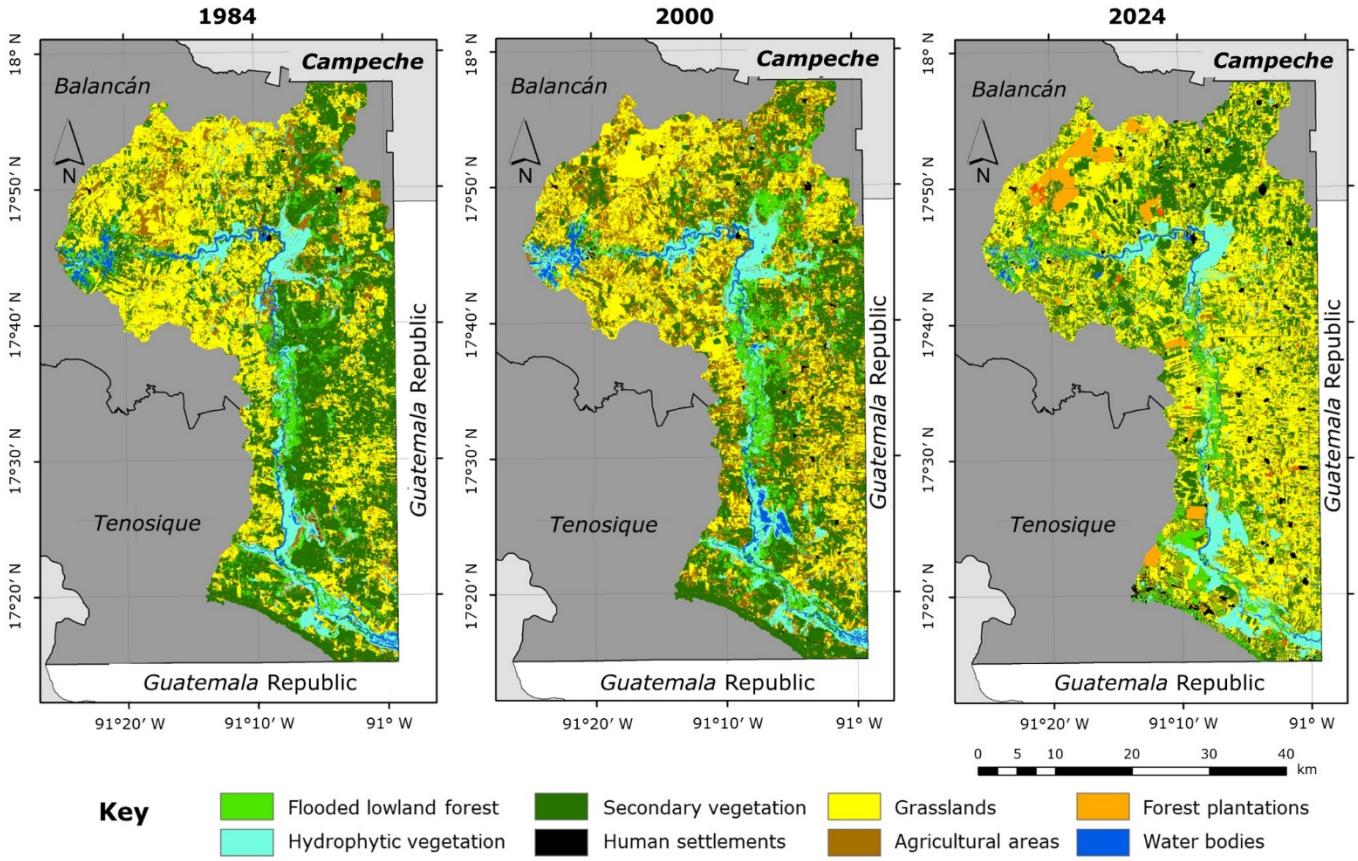


Figure 2. Spatial distribution of land use and vegetation cover categories in the *San Pedro Mártir* River sub-basin, *Tabasco*, Mexico, for the 1984, 2000 and 2024 years.

By the year 2000, changes in land cover distribution were observed. Agricultural land increased to 23.8 % of the territory, while secondary vegetation decreased to 26.5 % and grasslands to 29.3 %. Flooded lowland forest and hydrophytic vegetation increased in area, both reaching 8.5 % of the study area. During this period, forest plantations were identified for the first time, although their area was marginal (0.1 %).

In 2024, the spatial pattern of the landscape showed a new reconfiguration. Grasslands consolidated as the dominant land cover, occupying 45.4 % of the sub-basin, followed by secondary vegetation (27.4 %). Flooded lowland forest decreased to 5.5 %, hydrophytic vegetation to 7.2 %, and water bodies to 1.4 %. Forest plantations reached 6.2 % of the territory, while agricultural areas decreased to 4.3 % (Table 1).

Dynamics of land use transformations

Transition analysis identified the main land cover change trajectories for the periods 1984-2000 and 2000-2024 (Table 2). During the first period, the largest conversions were from secondary vegetation to agricultural areas and grasslands, as well as from grasslands to secondary vegetation and agricultural areas (Table 3).

Table 2. Gains and losses in land use change in the *San Pedro Mártir* River sub-basin (1984-2000 and 2000-2024).

Category	1984-2000			2000-2024			TC	
	G ha	P ha	GN ha	G ha	P ha	GN ha	1984-2000	2000-2024
Flooded lowland forest	11 966	7 083	4 883	7 259	13 711	-6 451	1.97	-1.87
Hydrophytic vegetation	7 020	5 950	1 069	5 662	8 331	-2 668	0.39	-0.68
Secondary vegetation	18 568	39 487	-20 918	37 031	35 118	1 913	-2.01	0.14
Water bodies	1 810	1 171	638	503	2 995	-2 491	0.79	-2.62
Agricultural areas	41 381	18 728	22 653	6 738	47 750	-41 011	3.70	-7.41
Grasslands	25 007	34 123	-9 116	58 349	24 527	33 821	-0.87	1.81
Forest plantations	99.5	0.0	99.5	13 038	85.8	12 953	100	18.39
Human settlements	692	0.0	692	4 098	0	4 098	3.50	5.06

G = Area that changed to the category; P = Area that transitioned from the category; GN = G−P; TC = Annual exchange rate, calculated from the net change and the duration of the period.

Table 3. Land use transitions in the *San Pedro Mártir* River sub-basin for the 1984-2000 and 2000-2024 periods.

	Land-use categories								
	1984–2000 period								
Category	**Sb**	**Vh**	**Vs**	**Ca**	**Ag**	**Pz**	**Pf**	**Ah**	**P**
Sb	0	1 829	2 634	238	1 538	842	0	0	7 083
Vh	1 759	0	472	1 120	1 601	997	0	0	5 950
Vs	7 980	1 268	0	133	16 575	13 123	99.5	307	39 487
Ca	225	855	90	0	0	0	0	0	1 171
Ag	1 430	2 559	4 267	317	0	10 043	0	108	18 728
Pz	570	508	11 103	0	21 666	0	0	275	34 123
Pf	0	0	0	0	0	0	0	0	0
Ah	0	0	0	0	0	0	0	0	0
G	11 966	7 020	18 568	1 810	41 381	25 007	99	692	
	2000–2024 period								
Category	**Sb**	**Vh**	**Vs**	**Ca**	**Ag**	**Pz**	**Pf**	**Ah**	**P**
Sb	0	1 364	5 109	97	513	5 553	917	155	13 711
Vh	1 095	0	1 783	267	572	4 050	354	206	8 331
Vs	3 966	822	0	87	2 248	22 341	4 336	1 316	35 118
Ca	263	2 113	226	0	65	245	80	0	2 995
Ag	1 301	890.6	14 764	0	0	25 996	3 613	1 183	47 750
Pz	633	470.9	15 061	50	3 337	0	3 736	1 236	24 527
Pf	0	0	85	0	0	0	0	0	85.8
Ah	0	0	0	0	0	0	0	0	0
G	7 259	5 662	37 031	503	6 738	58 187	13 038	4 098	

Sb = Flooded lowland forest; Vh = Hydrophytic vegetation; Vs = Secondary vegetation; Ca = Water bodies; Ag = Agricultural areas; Pz = Grasslands; Pf = Forest plantations; Ah = Human settlements; G = Gains by category; P = Losses by category.

Between 2000 and 2024, the predominant transitions were toward the expansion of grasslands and forest plantations. Agricultural areas and secondary vegetation were the main sources of conversion to these uses, while flooded lowland forest

and hydrophytic vegetation showed net losses associated with their transformation into productive land cover.

The details of the main land cover change trajectories are presented in Table 3. Outstanding among these are the changes from agricultural areas and secondary vegetation to grasslands, as well as the conversion of these land cover types to secondary vegetation during the 2000-2024 period.

Changes in the flooded lowland forest

Flooded lowland forest covered 13 063 ha (6.2 %) in 1984. By 2000, its area had increased to 17 946 ha (8.5 %), which means a net gain of 4 883 ha. The conversion to this land cover came primarily from secondary vegetation, hydrophytic vegetation, and agricultural areas.

In 2024, the area of flooded lowland forest had decreased to 11 494 ha (5.5 %), reflecting a net loss of 6 451 ha between 2000 and 2024, with an annual rate of change of -1.87 %. The main conversions resulting from this loss were to grassland and secondary vegetation.

Dynamics of secondary vegetation

In 1984, secondary vegetation was the dominant land cover, covering 76 588 ha (36.4 %). By 2000, its area had decreased to 55 669 ha, representing a net loss of 20 918 ha with an annual rate of change of -2.01 %. During this period, the

most significant transitions occurred toward agricultural areas, grasslands and flooded lowland forest.

In 2024, secondary vegetation reached 57 582 ha, a net gain of 1 913 ha compared to 2000. The changes toward this land cover came primarily from grasslands and agricultural areas, although losses exceeding 35 000 ha to other land uses were also recorded, resulting in a net rate of change close to zero (Table 2).

Grassland expansion

Grasslands covered 70 772 ha (33.7 %) in 1984. By 2000, their area had decreased to 61 655 ha (29.3 %), a net loss of 9 116 ha, primarily due to conversions to agricultural land and secondary vegetation.

Between 2000 and 2024, grasslands experienced the greatest expansion among all land cover types, reaching 95 476 ha (45.4 %) in 2024. The net gain was 33 821 ha, with conversions predominantly from agricultural land, secondary vegetation, flooded lowland forest and hydrophytic vegetation (Table 3).

Changes in agricultural land use

In 1984, agricultural land occupied 27 357 ha (13.0 %). By 2000, this land cover had increased to 50 010 ha (23.8 %), representing a net gain of 22 653 ha. The main conversions to agriculture came from grasslands and secondary vegetation.

In 2024, agricultural land use had decreased sharply to 8 998 ha (4.3 %), with a net loss of 41 011 ha between 2000 and 2024 and an annual rate of change of -7.41 % (Table 2). The conversions resulting from these losses were primarily to grassland, secondary vegetation, and forest plantations.

Dynamics of forest plantations

Forest plantations were absent in 1984 and were first identified in 2000, covering an area of 99.5 ha (0.04 % of the territory). By 2024, this coverage had increased to 13 052 ha (6.2 %), with a net gain of 12 953 ha and an annual rate of change of 18.39 %.

The main conversions to forest plantations resulted from secondary vegetation, agricultural areas, grasslands and flooded lowland forest, demonstrating their expansion over previously transformed land cover and, to a lesser extent, over native forest cover.

Changes in water bodies and hydrophytic vegetation

In 1984, water bodies covered 4 748 ha. By 2000, this coverage had increased to 5 386 ha, with a net gain of 638 ha. Between 2000 and 2024, water bodies decreased to 2 894 ha, recording a net loss of 2 491 ha.

Hydrophytic vegetation showed moderate temporal variations. Between 1984 and 2000, a net gain of 1 069 ha was recorded, while between 2000 and 2024 a net loss of 2 668 ha was observed, mainly associated with transitions to grassland and secondary vegetation (Table 3).

The annual rates of change for each category and period are presented in Table 2.

Discussion

The results obtained demonstrate a sustained territorial transformation in the *San Pedro Mártir* River sub-basin during the 1984-2024 period, characterized by the progressive replacement of native and semi-natural land cover with other productive uses, primarily grasslands and, more recently, forest plantations. In this sense, the observed dynamics represent not only a process of vegetation cover change, but also a productive reconfiguration of the landscape, in which different land uses compete and are spatially reorganized according to economic, environmental, and accessibility conditions. This pattern is consistent with processes documented in tropical regions, where agricultural and forestry expansion is one of the main drivers of land-use change (Curtis et al., 2018; Gibbs et al., 2010; Hansen et al., 2013).

The consolidation of grasslands as the dominant land cover by 2024, with a net gain of over 33 000 ha and a positive annual rate of change of 1.81 % for the 2000-2024 period, reflects the persistence of extensive livestock farming as a landscape-structuring activity. This behavior has been widely documented in Latin America, where grasslands represent one of the most persistent land cover types following forest conversion, resulting in homogeneous landscapes with less structural complexity (Maza-Villalobos et al., 2023; Von Thaden et al., 2020).

In Southeastern Mexico, regional studies have described similar dynamics associated with livestock expansion, with rates of change comparable to those observed in the *San Pedro Mártir* River sub-basin (Hernández-Pérez et al., 2022; Manjarrez-Muñoz et al., 2007; Ramírez-García et al., 2022; Von Thaden et al., 2020). In this regard, the results confirm that extensive livestock farming continues to be a dominant driver of land-use change in humid tropical landscapes.

Secondary vegetation exhibited highly dynamic behavior, with contrasting annual rates of change between periods, confirming its role as transitional land cover within

recurring cycles of land use, abandonment, and conversion. The loss recorded between 1984 and 2000 (*TC*=-2.01 %) and the subsequent marginal recovery (*TC*=0.14 % between 2000 and 2024) indicate that its presence does not respond to a stable process of forest regeneration, but to fluctuations in productive activities, as has been documented in other highly transformed tropical landscapes (Estacio et al., 2022; Maza-Villalobos et al., 2023; Ramos-Reyes & Palomeque-de la Cruz, 2023).

Meanwhile, the net reduction of lowland floodplain forest, mainly associated with its conversion to grassland and forest plantations, with a negative annual rate of change of -1.87 % between 2000 and 2024, demonstrates the vulnerability of these ecosystems to the expansion of productive uses in lowland landscapes. Similar results have been described in tropical regions where floodplain ecosystems are highly susceptible to conversion due to their accessibility and agricultural potential (Alarcón-Aguirre et al., 2021; Osorio-Olvera et al., 2023).

The emergence and rapid expansion of forest plantations since 2000, with an annual growth rate of 18.39 % for the period 2000-2024, constitutes one of the most significant changes of the analyzed period. This growth reflects recent transformations in the territory's production strategies, driven by economic incentives and sectoral policies, a pattern observed in various tropical landscapes (Fagan et al., 2022).

However, several studies have indicated that forest plantations are not functionally equivalent to native forests. While they increase tree cover, they exhibit simplified ecological structures and lower biodiversity, limiting their capacity to replace the ecosystem services of natural forest cover (Kotowska et al., 2023; Maza-Villalobos et al., 2023). In this context, the expansion of forest plantations in the *San Pedro Mártir* River sub-basin represents a productive reconfiguration of the landscape, without reversing the overall trend of reduced native forest cover.

Overall, the identified change trajectories reflect a structural simplification of the landscape, characterized by the consolidation of a grassland-dominated matrix, the fragmentation of forest cover, and the coexistence of multiple productive uses. This type of configuration has been widely documented in tropical landscapes subjected to persistent agricultural pressures, where fragmentation arises as a

direct consequence of repeated land use conversions (Chan et al., 2025; Curtis et al., 2018; Mello et al., 2023).

Conclusions

The multi-temporal analysis of land use and vegetation cover change in the *San Pedro Mártir* River sub-basin, *Tabasco*, during the period 1984-2024 revealed a territorial transformation characterized by the progressive replacement of native and semi-natural forest cover with productive uses. During this period, grasslands consolidated as the dominant landscape cover, increasing from 70 772 ha (33.7 %) in 1984 to 95 476 ha (45.4 %) in 2024, with a net gain of 33 821 ha between 2000 and 2024 and an annual rate of change of 1.81 %, confirming the persistence of extensive livestock farming as a structuring activity of the territory. Simultaneously, the flooded lowland forest decreased from 17 946 ha (8.5 %) in 2000 to 11 494 ha (5.5 %) in 2024, registering a net loss of 6 451 ha and an annual rate of -1.87 %, reflecting the pressure exerted by productive land uses on ecosystems associated with floodplains.

Secondary vegetation exhibited highly dynamic behavior, decreasing from 76 588 ha in 1984 to 55 669 ha in 2000 (-20 918 ha) and partially recovering to 57 582 ha in 2024, confirming its role as transitional land cover within recurring cycles of land use, abandonment and conversion. From 2000 onward, forest plantations emerged as a significant land use in the sub-basin, increasing from 99.5 ha (0.04 % of the territory) to 13 052 ha in 2024 (6.2 %), with a net gain of 12 953 ha and an annual rate of change of 18.39 %. This is one of the fastest transformation processes of the analyzed period. Its growth occurred primarily on previously transformed areas —agricultural land, grasslands and secondary vegetation— demonstrating a recent reconfiguration of the territory's production strategies. However, this increase in tree cover does not

necessarily imply a recovery of native forest cover, as these plantations exhibit simplified ecological structures and lower biodiversity. Taken together, the identified change trajectories reveal a productive reconfiguration of the landscape characterized by the consolidation of a grassland-dominated matrix, the reduction of floodplain ecosystems, and the coexistence of multiple productive uses that contribute to the structural simplification and fragmentation of forest cover. These results underscore the importance of incorporating the historical dynamics of land-use change into land-use planning and landscape management processes in humid tropical regions of Southeastern Mexico.

Acknowledgments

The authors thank the Science and Technology Council of the State of *Tabasco* for funding the project "State of conservation and restoration in the area of influence of the *San Pedro* River (*Ríos* Region, *Tabasco*)"; grant number PRODECTI-2023-01/003, MODALITY "A", which made the development of this article possible.

Conflict of interest

The authors declare no conflict of interest.

Contribution by author

Miguel Ángel Palomeque De la Cruz: conceptualization and drafting of the first version; Silvia del Carmen Ruiz Acosta: conceptualization, writing, and analysis; Alex Ricardo Ramírez García: image classification and data verification; Manuel Fidel Domínguez Azueta: image classification and data verification; Tania Gudelia

Núñez Magaña: data verification; Adalberto Galindo Alcántara: conceptualization, writing, editing, and adaptation.

References

Agudelo-Hz, W. J., Castillo-Barrera, N. C., & Murcia-García, U. (2023). Scenarios of land use and land cover change in the Colombian Amazon to evaluate alternative post-conflict pathways. *Scientific Reports*, *13*, Article 2152. https://doi.org/10.1038/s41598-023-29243-2

Alarcón-Aguirre, G., Canahuire-Robles, R. R., Guevara-Duarez, F. M., Rodríguez-Achata, L., Gallegos-Chacón, L. E., & Garate-Quispe, J. (2021). Dinámica de la pérdida de bosques en el sureste de la Amazonia peruana. *Ecosistemas*, *30*(2), Artículo 2175. https://doi.org/10.7818/ECOS.2175

Center for Geospatial Analytics. (2020). *Land Change Modeler in TerrSet*. Clark University. https://clarklabs.org/terrset/land-change-modeler/

Chan, K. K. Y., Ren, Z., Liu, Y., Song, H., Bai, Y., & Xu, B. (2025). Land cover change and fragmentation within China's Ramsar sites. *Remote Sensing*, *17*(5), Article 896. https://doi.org/10.3390/rs17050896

Congedo, L. (2023, October 8). *Semi-Automatic Classification Plugin* (Versión 8.01) [Software]. QGIS Development Team. https://plugins.qgis.org/plugins/SemiAutomaticClassificationPlugin/?utm_source=chatgpt.com#plugin-versions

Curtis, P. G., Slay, C. M., Harris, N. L., Tyukavina, A., & Hansen, M. C. (2018). Classifying drivers of global forest loss. *Science*, *361*(6407), 1108-1111. https://doi.org/10.1126/science.aau3445

Eastman, J. R. (2012). *IDRISI Selva: Guide to GIS and image processing*. Clark University. https://clarklabs.org/wp-content/uploads/2016/10/IDRISI-Selva-Spanish-Manual.pdf

Estacio, I., Basu, M., Sianipar, C. P. M., Onitsuka, K., & Hoshino, S. (2022). Dynamics of land cover transitions and agricultural abandonment in a mountainous agricultural landscape: Case of Ifugao rice terraces, Philippines. *Landscape and Urban Planning*, *222*, Article 104394. https://doi.org/10.1016/j.landurbplan.2022.104394

Fagan, M. E., Kim, D.-H., Settle, W., Ferry, L., Drew, J., Carlson, H., Slaughter, J., Schaferbien, J., Tyukavina, A., Harris, N. L., Goldman, E., & Ordway, E. M. (2022). The expansion of tree plantations across tropical biomes. *Nature Sustainability*, *5*, 681-688. https://www.nature.com/articles/s41893-022-00904-w

Gibbs, H. K., Ruesch, A. S., Achard, F., Clayton, M. K., Holmgren, P., Ramankutty, N., & Foley, J. A. (2010). Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. *Proceedings of the National Academy of Sciences*, *107*(38), 16732-16737. https://doi.org/10.1073/pnas.0910275107

Gobierno del Estado de Tabasco. (2002). *Acuerdo en el que se declara Área Natural Protegida de Jurisdicción Estatal clasificada como Reserva Ecológica, en el municipio de Balancán, Tabasco y cuya denominación es «Cascadas de Reforma»*. Periódico Oficial del Estado de Tabasco [No. 17432]. https://tabasco.gob.mx/sites/default/files/users/sbstabasco/DRE-CR-Reserva%20Ecol%C3%B3gica%20Cascadas%20de%20Reforma.pdf

Gobierno del Estado de Tabasco. (2024, 15 de julio). *El sector forestal en el Estado de Tabasco*. Gobierno del Estado de Tabasco. https://tabasco.gob.mx/el-sector-forestal-en-el-estado-de-tabasco

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., Thau, D., Stehman, S. V., Goetz, S. J., Loveland, T. R., Kommareddy, A., Egorov, A., Chini, L., Justice, C. O., & Townshend, J. R. G. (2013). High-resolution global maps of 21st-century forest cover change. *Science*, *342*(6160), 850-853. https://www.science.org/doi/10.1126/science.1244693

Hernández-Pérez, E., García-Franco, J. G., Vázquez, G., & Cantellano-de Rosas, E. (2022). Cambio de uso de suelo y fragmentación del paisaje en el centro de Veracruz, México (1989-2015). *Madera y Bosques*, *28*(1), Artículo e2812294. https://doi.org/10.21829/myb.2022.2812294

Instituto Nacional de Estadística, Geografía e Informática. (1986). *Síntesis geográfica, nomenclátor y anexo cartográfico del estado de Tabasco. Síntesis Geográfica de Tabasco*. Instituto Nacional de Estadística, Geografía e Informática. https://www.inegi.org.mx/contenidos/productos/prod_serv/contenidos/espanol/bvinegi/productos/historicos/2104/702825221256/702825221256_1.pdf#[14,{%22name%22:%22Fit%22}

Instituto Nacional de Estadística y Geografía. (2021). *SIATL v4, Simulador de Flujos de Agua de Cuencas Hidrográficas* [Mapa interactivo]. Instituto Nacional de Estadística y Geografía. https://antares.inegi.org.mx/analisis/red_hidro/siatl/

Kotowska, M. M., Samhita, S., Hertel, D., Triadiati, T., Beyer, F., Allen, K., Link, R. M., & Leuschner, C. (2023). Consequences of tropical rainforest conversion to tree plantations on fine root dynamics and functional traits. *Oikos*, *2023*(1), Article e08898. https://doi.org/10.1111/oik.08898

Manjarrez-Muñoz, B., Hernández-Daumás, S., De Jong, B., Nahed-Toral, J., de Dios-Vallejo, O. O., & 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, Boletín del Instituto de Geografía*, (64), 90-115. https://www.investigacionesgeograficas.unam.mx/index.php/rig/article/view/17968

Maza-Villalobos, S., Alvarado-Sosa, E., Arriaza-Rodríguez, A. D., Infante, F., & Castillo-Santiago, M. Á. (2023). Dinámica del uso de suelo y vegetación en paisajes altamente modificados por actividades agropecuarias en el sur de México. *Botanical Sciences*, *101*(2), 374-386. https://doi.org/10.17129/botsci.3148

Megia-Vera, H. J., Peralta-Carreta, C., Medrano-Pérez, O., Palomeque-De la Cruz, M. Á., Ramos-Reyes, R., & Galindo-Alcantara, A. (2025). Análisis de la cobertura y uso de suelo de la Cuenca Baja del Río Usumacinta mediante técnicas de teledetección. *Terra Latinoamericana*, *43*, 1-15. https://doi.org/10.28940/terralatinoamericana.v43i.2075

Mello, A. L., Lezama, F., & Baeza, S. (2023). Patrones y controles regionales de la fragmentación de pastizales naturales en Uruguay. *Ecosistemas*, *32*(2), Article 2534. https://doi.org/10.7818/ECOS.2534

Osorio-Olvera, L., Rioja-Nieto, R., Torres-Irineo, E., & Guerra-Martínez, F. (2023). Natural Protected Areas effect on the cover change rate of mangrove forests in the Yucatan Peninsula, Mexico. *Wetlands*, *43*, Article 52. https://doi.org/10.1007/s13157-023-01697-0

Palacio-Prieto, J. L., Sánchez-Salazar, M. T., Casado-Izquierdo, J. M., Propin-Frejomil, E., Delgado-Campos, J., Velázquez-Montes, A., Chias-Becerril, J., Ortiz-Álvarez, M. I., González-Sánchez, J., Negrete-Fernández, G., Gabriel-Morales, J., & Márquez-Huitzil, R. (Coord.). (2004). *Indicadores para la caracterización y ordenamiento del territorio*. Universidad Nacional Autónoma de México, Secretaría de Desarrollo Social, Secretaría de Medio Ambiente y Recursos Naturales e Instituto Nacional de Ecología. https://unidadesdepaisaje.unam.mx/sites/default/files/2022-06/Palacio%20et%20al%2C%202004_0.pdf

QGIS Development Team. (2024). *QGIS Geographic Information System* (Version 3.36) [Software]. QGIS Association. https://www.qgis.org/

Ramírez-García, A. R., Zavala-Cruz, J., Rincón-Ramírez, J. A., Guerrero-Peña, A., García-López, E., Sánchez-Hernández, R., Castillo-Acosta, O., Alfaro-Sánchez, G., & Ortiz-Pérez, M. A. (2022). Vegetation cover and land use change (1947-2019) in the region of Los Ríos, Tabasco, México. *Revista Chapingo Serie Ciencias Forestales y del Ambiente*, *28*(3), 465-481. http://doi.org/10.5154/r.rchscfa.2022.01.001

Ramos-Reyes, R., & Palomeque-de la Cruz, M. Á. (2023). Cambio de uso del suelo y escenarios prospectivos en el Estado de Tabasco (México). *Anales de Geografía de la Universidad Complutense*, *43*(1), 185-209. https://doi.org/10.5209/aguc.85944

Secretaría de Gobernación. (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*. Diario Oficial de la Federación. https://www.dof.gob.mx/nota_detalle.php?codigo=5060691&fecha=22/09/2008#gsc.tab=0

Secretaría de Gobernación. (2023). *DECRETO por el que se declara área natural protegida Wanha', con el carácter de reserva de la biosfera, la superficie de 38,255-64-17.76 hectáreas, ubicada en los municipios de Balancán y Tenosique, estado de Tabasco*. Diario Oficial de la Federación. https://www.dof.gob.mx/nota_detalle_popup.php?codigo=5700586

United States Geological Survey. (2024). *EarthExplorer* [Interactive compendium of maps]. United States Geological Survey. https://earthexplorer.usgs.gov/

Von Thaden, J. J., Laborde, J., Guevara, S., & Mokondoko-Delgadillo, P. (2020). Dinámica de los cambios en el uso del suelo y cobertura vegetal en la Reserva de la Biosfera Los Tuxtlas (2006-2016). *Revista Mexicana de Biodiversidad*, *91*, Artículo e913190. https://doi.org/10.22201/ib.20078706e.2020.91.3190