Botanical Sciences 104 (2): 318-333. 2026
DOI: 10.17129/botsci.3785

Received: August 9, 2025, Accepted: November 24, 2025
On line first: March 11, 2026

Ecology / Ecología

Precipitation trends in areas sustaining populations of *Swietenia macrophylla* (Meliaceae): Implications for the future natural regeneration of an economically valuable tropical tree in Mexico

R. Iris Álvarez-Caballero* and Raúl Ernesto Alcalá

Centro de Investigación en Biodiversidad y Conservación. Universidad Autónoma del Estado de Morelos, Cuernavaca, Morelos, Mexico.
*Corresponding author: iris.alvarezcab@fcbiologicas.uaem.edu.mx

Abstract

Background: Climate change could have differential impacts on economically valuable tropical trees. Identification of statistical trends improves knowledge about how changes in rainfall are occurring in space and time.

Questions: Are distinct areas supporting *S. macrophylla* populations exposed to different patterns of rainfall that could differentially affect their future natural regeneration?

Studied species: *Swietenia macrophylla* King (Meliaceae)

Study site and dates: Southern Mexico during the period 1980-2011.

Methods: Databases from monthly precipitation and annual standardized precipitation index (SPI, used to detect hydrological droughts) were obtained and homogenized from 90 weather stations located throughout the distribution area of *S. macrophylla*. Mann-Kendall analyses (S) were performed on time series of both variables from the 1980–2011 period to statistically identify trends of change. Statistical significance of S was obtained using an approximation to the normal distribution (standardized Z value). Trends were interpreted at two levels, per weather station and per state.

Results: Fifty eighth of the 90 stations (64.4 %) showed climatic changes either for precipitation or SPI. Regarding the magnitude of Z, the number of stations (47) with negative trends for both variables doubled the number of stations (25) with positive trends. Reductions in precipitation and SPI indicate an overall trend toward drier climates in the most commercially important areas. Conversely, favorable conditions were found in Chiapas, Mexico.

Conclusions: Areas with higher commercial value experienced reductions in precipitation and increases in hydrological droughts. If these trends continue, the natural regeneration of *S. macrophylla* could be negatively impacted in the future.

Keywords: Big-leaf mahogany, climate change, Mann-Kendall climate trends, Sen's slope, SPI.

Resumen

Antecedentes: El cambio climático puede afectar de forma diferenciada a especies arbóreas tropicales de valor económico. El análisis de tendencias estadísticas permite comprender mejor las variaciones espaciales y temporales de la precipitación.

Pregunta: ¿Distintas áreas que sustentan poblaciones de *S. macrophylla* están expuestas a diferentes patrones de lluvia que podrían afectar de manera diferente su regeneración natural futura?

Especie de estudio: *Swietenia macrophylla* King (Meliaceae)

Sitio y años de estudio: Sur de México durante el período 1980-2011.

Métodos: Se homogeneizaron datos de precipitación mensual y del índice SPI anual de 90 estaciones dentro del área de distribución de *S. macrophylla*. Se aplicó el análisis de Mann-Kendall a las series 1980-2011 para detectar tendencias significativas mediante el valor Z estandarizado. Las tendencias se evaluaron por estación y por estado.

Resultados: Cincuenta y ocho de las 90 estaciones (64.4 %) mostraron cambios climáticos en precipitación o SPI. En cuanto a la magnitud de Z, el número de estaciones (47) con tendencias negativas para ambas variables duplicó el número de estaciones (25) con tendencias positivas. La reducción en precipitación y SPI indica una tendencia general hacia un clima más seco en las áreas de mayor importancia comercial. Por el contrario, se encontraron condiciones favorables en Chiapas, México.

Conclusiones: Las áreas con mayor valor comercial experimentaron una reducción en precipitación y un aumento en sequías hidrológicas. Si estas tendencias continúan, la regeneración natural de *S. macrophylla* podría verse negativamente afectada en el futuro.

Palabras clave: Caoba, cambio climático, tendencias climáticas de Mann-Kendall, pendiente de Sen, SPI.

Warming is the most evident and generalized effect of climate change (IPCC 2023). The monotonic increase in temperature scored from decades ago has been related with a myriad of effects on plants at different levels, from alterations of reproductive phenology of cultivated species to the displacement and fragmentation of the geographic distribution of tree species (Brodie *et al*. 2025, Dyderski *et al*. 2025, Terasaki *et al*. 2025). In contrast, studies addressing changes in precipitation anticipate a more complex scenario, as there is not a unique prediction. This is because empiric evidence often reveals spatially contrasting trends for precipitation with differences recorded at regional or even at local level (Jiang *et al*. 2007, Endo *et al*. 2009, Duhan & Pandey 2013, Salviano *et al*. 2016, Vu & Mishra 2016, Pendergrass *et al*. 2017, Onyutha 2018, Bartels *et al*. 2020, Carvalho 2020).

The analysis about how climate variables are changing, specifically for rainfall, is of particular interest for management of tropical tree species, which are often a cause for conservation concern because they contribute to human welfare as sources of food, medicine, logging, among others (Jhou *et al*. 2017, Seldon *et al*. 2021). There are few studies of tropical systems, as compared with those in temperate forests (Colwell & Feeley 2025). Research is needed because the response of tropical trees may not match the latitudinal or altitudinal patterns typically recorded for the tree temperate species (Körner 2004, Feeley 2012, Feeley *et al*. 2017, Boonman *et al*. 2021, Colwell & Feeley 2025, Dyderski *et al*. 2025). Tropical species are predicted to be especially sensitive because they generally have narrow niches due to climatic stability and specialization (Feeley 2012). In addition, tropical forests could be more sensitive to variability in rainfall than in temperature (Körner 2004, Esquivel-Muelbert *et al*. 2017). Knowledge of the occurrence of geographic variation in the amount and in the patterns of rainfall concentration, or the detection of physiological droughts, are also relevant for achieving a more comprehensive understanding of climate change. Therefore, increasing knowledge about rainfall trends on tropical vegetation is a fundamental action for conservation goals (Feeley *et al*. 2011, Santos-Hernández *et al*. 2021).

Swietenia macrophylla King. (Meliaceae) is a neotropical tree distributed from South America to southern Mexico. The big-leaf mahogany has high wood quality and it is considered as a precious wood tree species. The market income of *S. macrophylla* was valued at USD 1.8 billion in 2024 and is projected to reach USD 2.5 billion by 2033, growing at a compound annual growth rate of 4.5 % (https://www.verifiedmarketreports.com/product/mahogany-market/). Because of the high demand along its entire geographic distribution, it has been included in the in CITES Appendix II in 2003 (CITES Secretariat, 2003). In Mexico, the Yucatan Peninsula stands out for having the highest abundance of big-leaf mahogany. In this region, individuals of *S. macrophylla* usually are more frequent at medium stratum semi perennial forest in the states of Quintana Roo and Campeche (Navarro-Martínez *et al*. 2018) and, according to Comisión Nacional Forestal, it can be also found in the states of Veracruz and Chiapas (CONAFOR 2014). *Swietenia macrophylla* is subjected to sustainable logging in the forest massifs of southern Campeche and central Quintana Roo through an internationally recognized community forest management (Bray *et al*. 2005, Ellis *et al*. 2015, 2017).

A key factor for the success of forest management strategies based on natural regeneration is the assumption that some seedlings and saplings will survive to reach the cut diameter of about 55 cm (Hernández-Ramos *et al*. 2020). However, early stages of development are particularly sensitive to water scarcity due to the reduction in precipitation and the occurrence of droughts. For example, evidence obtained using different approaches shows that scarcity of water could negatively impact seed germination, as well as seedling growth and survivorship (Gerhardt 1996, Morris *et al*. 2000, Sneha *et al*. 2013, Negreros-Castillo *et al*. 2014, Bhuva *et al*. 2020). Other studies showed negative impacts of water shortage even in mature trees (Cabrales & Snook 2005, Jhou *et al*. 2017). Thus, a decreasing trend in rainfall could result in areas with unfavorable conditions, limiting the natural regeneration of the species and consequently compromising its future management. On other hand, areas with positive trends in rainfall could represent opportunities for future expansion of this tropical tree.

Some studies have forecasted the potential distribution of *S. macrophylla* considering scenarios of climate change. Regarding Mexican populations, there are contrasting conclusions predicting either positive (Ramírez-Magil *et al*. 2020, Sampayo-Maldonado *et al*. 2021) or negative effects on their future distribution (Garza-López *et al*. 2016). The results of these studies are discussed mainly considering the increase in temperature but, as far as we are aware, no prior study has analyzed current changes in the pattern of rainfall occurring in recent decades, emphasizing on their impact on Mexican tropical valuable tree species, such as *S. macrophylla.*

In this study we analyzed variables describing the rainfall patterns in areas that maintain big-leaf mahogany populations in Mexico. The period we selected, from 1980 to 2011, is significant because the 1980 decade corresponds to the implementation of the community management strategy of tropical forests in the states of Quintana Roo and Campeche (Rebollar Domínguez *et al*. 2002), while the end of this period covers the sampling implemented in the National Forest and Soil Inventory (CONAFOR 2014). The geographic variation (state and local) in annual mean precipitation and in standardized precipitation index (SPI; used to identify hydrological droughts) was analyzed to: i) assess whether distinct areas supporting *S. macrophylla* populations are exposed to different patterns of rainfall, and ii) identify areas where *S. macrophylla* could expand or contract its geographic range in the future based on the recognized dependence of its natural regeneration potential on water availability. This knowledge is useful because climate change is occurring at an unprecedented speed, and changes at a regional or local level could be uncoupled, particularly for precipitation. Positive or negative trends in the rainfall patterns derived from climate change could represent contrasting implications for the conservation of this tropical and economically important tree species. Furthermore, climate analysis focusing on current patterns of rainfall could contribute to improving the predictive power of ecological niche modeling for this species.

Materials and methods

Study area. The study area was delimited considering the geographic distribution of *S. macrophylla.* Sites with occurrence records of *S. macrophylla* were obtained from the National Forest and Soil Inventory (CONAFOR 2014). The inventory is based on a systematically stratified sampling of equidistant conglomerates. Each conglomerate is comprised of a circular area (10,000 m^2; radius = 56.42 m) containing four rectangular (40 × 10 m) sampling plots. The inventory includes 560 conglomerates throughout the entire Yucatan Peninsula, containing 518 records of mahogany trees: 265 in Campeche, 238 in Quintana Roo and 15 in Yucatan. In addition, we included 46 records of trees in the state of Chiapas, and 15 additional records from the state of Veracruz. The coordinate of each conglomerate was converted into a vector point using ArcMap v10.8 with the WGS84 datum to display the area of distribution of *S. macrophylla* in Mexico (Figure 1A).

Weather stations. Weather stations were selected from the map available in the National Meteorological System (smn.conagua.gob.mx). Initially, we obtained information of the monthly values of mean annual precipitation from a total of 380 weather stations, covering the whole distribution range of *S. macrophylla*. According to the World Meteorological Organization guidelines (WMO 2017), the data from each station throughout the selected period must be at least 70 % complete to be included in the analysis. A quality control procedure searching for inconsistencies (missing information, outliers), as well as homogenization tests, were performed for each weather station.

Homogenization tests are needed to guarantee that precipitation oscillations exclusively respond to climatic factors, eliminating potential biases derived from other undesirable sources of variation (Yan *et al*. 2014, Domonkos *et al*. 2022). The Kolmogorov Smirnov homogeneity test was performed because the fulfillment of normality assumptions is not required due to its non-parametric nature (Razali & Wah 2011). The revision of data and homogenization tests were performed in Clic-MD v2.01, as this software was specifically developed to perform comprehensive analyses in the framework of climate change (Bautista *et al*. 2014). After the quality control and homogenization tests, only 90 weather stations were retained for subsequent analyses (Figure 1B).

Regarding weather variables, annual average precipitation time series were created from monthly precipitation data, whereas the standardized precipitation index (SPI) was obtained at the annual base. When calculated at the annual base, the SPI provides information about hydrological droughts (Bautista *et al*. 2014). Overall, SPI estimates probability of occurrence of given values of precipitation along specific time periods, which are compared against a base line. SPI ranges from 4 to -4, in which positive and negative values higher than |2| indicate extremely wetter or drier conditions, respectively. It can be interpreted as the number of times that a specific value of accumulated precipitation in a period is separated from the mean value of the time series, measured in units of standard deviation (Mishra & Singh 2010, Lin *et al*. 2020).

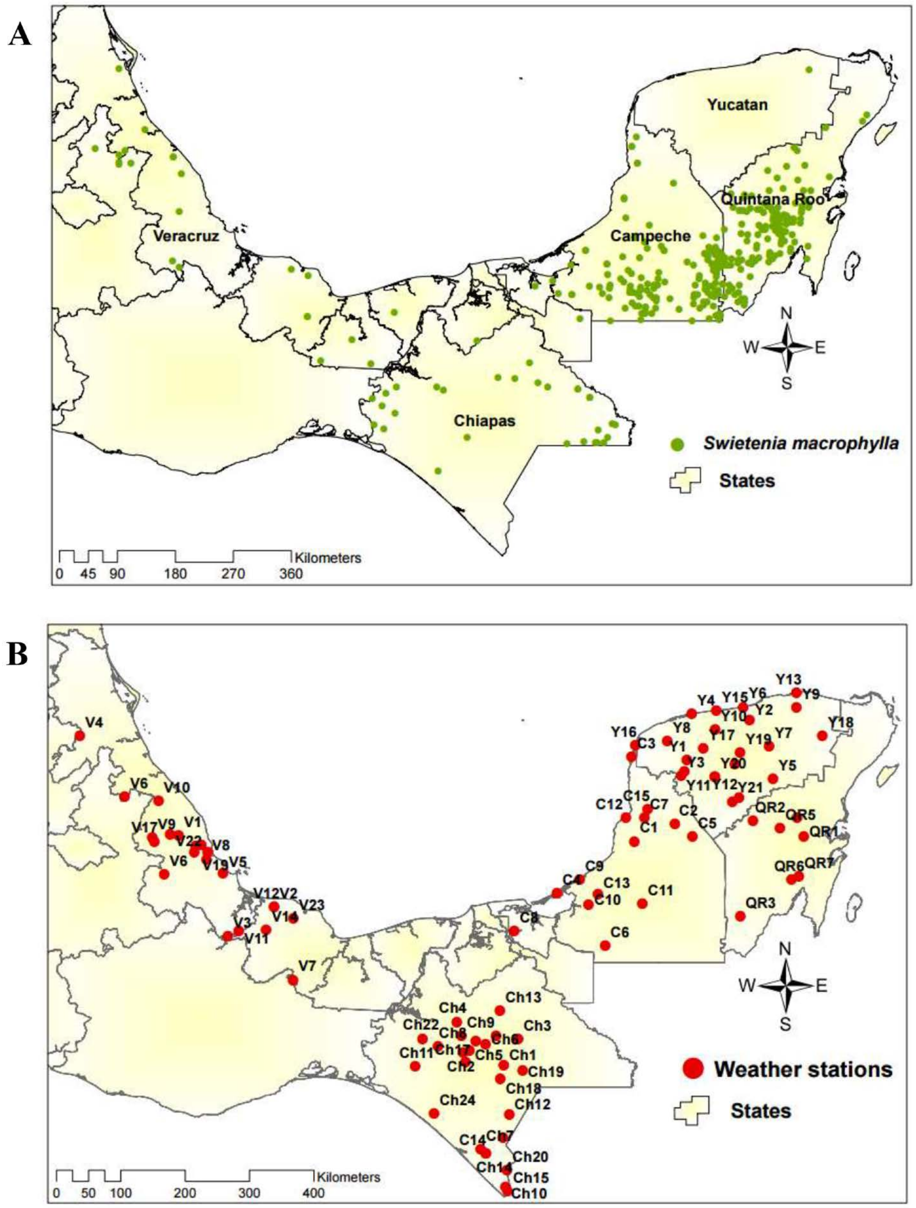

Figure 1. A) Distribution of *Swietenia macrophylla* trees in Mexico according to CONAFOR (2014). B) Available weather stations for analysis after the homogenization test.

Analysis of current precipitation and SPI trends. Mann-Kendall analyses were performed to statistically identify trends along the period we evaluated. The Mann-Kendall is a non-parametric analysis and it is considered as a robust option to analyze climate trends because the statistical distribution of variables is not a limiting factor (Mann 1945, Kendall 1948). The statistical significance of S was obtained using an approximation to the normal distribution with the standardized value of Z. Therefore, Z values $\geq |1.96|$ are statistically significant ($P \leq 0.05$). The positive or negative sign of S indicates an increasing or decreasing trend, respectively. The Mann-Kendall S statistics were used to verify the existence of trends in precipitation and SPI at a local and regional level. In the first case, analyses were performed for each weather station. In the second case, analyses were performed for each of the five states included in this study. In addition, for each significant trend, the Sen slope was calculated to estimate the rate of change of the focal variable (Sen 1968).

Results

Weather station level. From the 90 weather stations analyzed, 58 of them showed significant trends for at least one of the two variables (precipitation or SPI) along the three-decade period analyzed. In other words, more than half of the stations (64.4 %) reported changes in the rainfall pattern. Differences were detected between the two variables. For precipitation, only two *Z* values were higher than |3.0| (*i.e.*, 3.22, 3.87), while for SPI, 15 *Z* values were higher than |3.0| and two of them reached magnitudes higher than |4.0|. Considering the two variables simultaneously (precipitation and SPI), 25 weather stations showed significant positive trends, whereas negative trends were observed at 47 stations (Appendix 1, Figure 4 and 5). Of the 90 stations analyzed for precipitation, 16 showed significant trends, representing 17.7 % of the total. From these, nine stations showed positive trends, while negative trends were observed in seven stations. The number of stations showing trends in SPI (N = 42, 46.6 %) was almost three times greater, as compared to precipitation. In this case, 18 stations showed a positive trend, and 24 stations showed a negative trend (Appendix 1).

State level. In the case of precipitation, the stations with positive or negative trends were not distributed homogeneously across the geographic space (Figure 2, Table 1). For example, most of the negative trends occurred in the states of Campeche, Quintana Roo and Veracruz, in which only one station showed a positive trend. In Chiapas, the opposite trend was observed, as six stations showed an increase in precipitation, and this was the state with the greatest number of positive trends. In Yucatan, the situation was more heterogeneous because two stations showed a positive trend, and a single station showed a negative trend (Figure 2, Table 1).

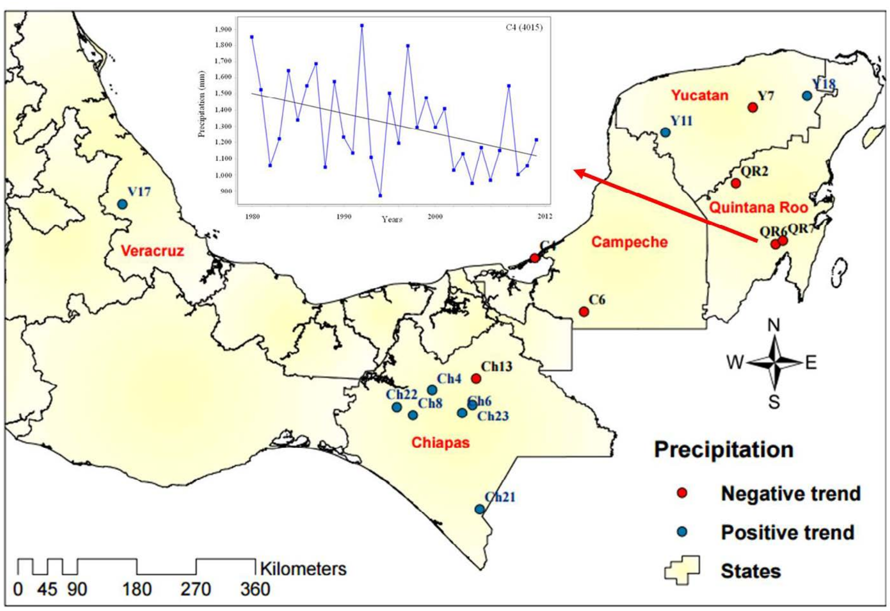

Figure 2. Weather stations that showed statistical trends for monthly values of precipitation during the period 1980-2011. Blue circles = positive trends; red circles = negative trends. An example of a statistically significant Mann-Kendall trend is also shown.

For the SPI, spatial variation was also observed. Negative trends were observed in areas where *S. macrophylla* is commercially managed. In the case of Campeche, three stations had a significant effect, two of them with negative trends. Quintana Roo showed negative trends in five stations. Veracruz also obtained negative trends in 10 stations, whereas Yucatan had nine stations with positive trends and four with negative trends. In Chiapas, positive trends were found in eight stations and three had negative trends (Figure 3, Table 1).

Table 1. Number of weather stations in each state exhibiting at least one statistically positive (+) or negative (-) trend for precipitation (PP) and for the standardized precipitation index (SPI).

State	N	PP	PP	SPI	SPI
		+	-	+	-
Campeche	5	0	2	1	2
Chiapas	18	6	1	8	3
Quintana Roo	8	0	3	0	5
Veracruz	10	1	0	0	9
Yucatan	16	2	1	9	4
Total	58	9	7	18	24

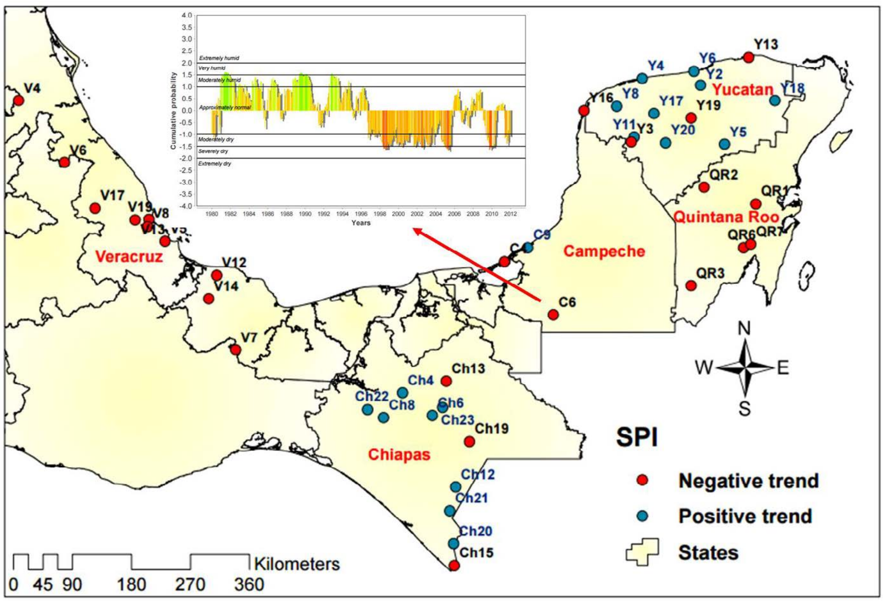

Figure 3. Weather stations that showed statistical trends for the Standardized Precipitation Index during the period 1980-2011. Blue circles = positive trends; red circles = negative trends. The graph shows the accumulated drought over the years (hydrological droughts). An example of a statistically significant Mann-Kendall trend is also shown. Bars with negative values indicate dry periods in recent years.

Discussion

At the weather station level, changes in the pattern of rainfall along the three-decade period were detected in a high percentage (64.4 %) of the stations examined. This indicates that extensive areas of southern Mexico are currently experiencing changes in rainfall, as it has been observed in other studies (Méndez-González *et al*. 2008, Márdero *et al*. 2012, Estrada-Medina *et al*. 2016, De la Barreda *et al*. 2020). We also observed that, in most cases, both precipitation and SPI showed the same direction, revealing either negative or positive trends. Negative trends in both precipitation and SPI could have negative consequences for *S. macrophylla,* as they point to reduction in humidity that would lead to drier climates. Considering this issue, we detected more consistent trends toward drier climates, as the number of weather stations exhibiting negative trends (47) almost doubled the number of stations with positive trends (25). It is more important to note that the evidence for trends signaling an increase in hydrological droughts was more evident than those observed for precipitation (Table 1). This means that, while the number of stations with negative trends for precipitation was 0.77 times lower than the stations with positive trends, the number of stations that showed negative trends for the SPI was 1.3 times higher than the number of stations with positive trends. Overall, at this level

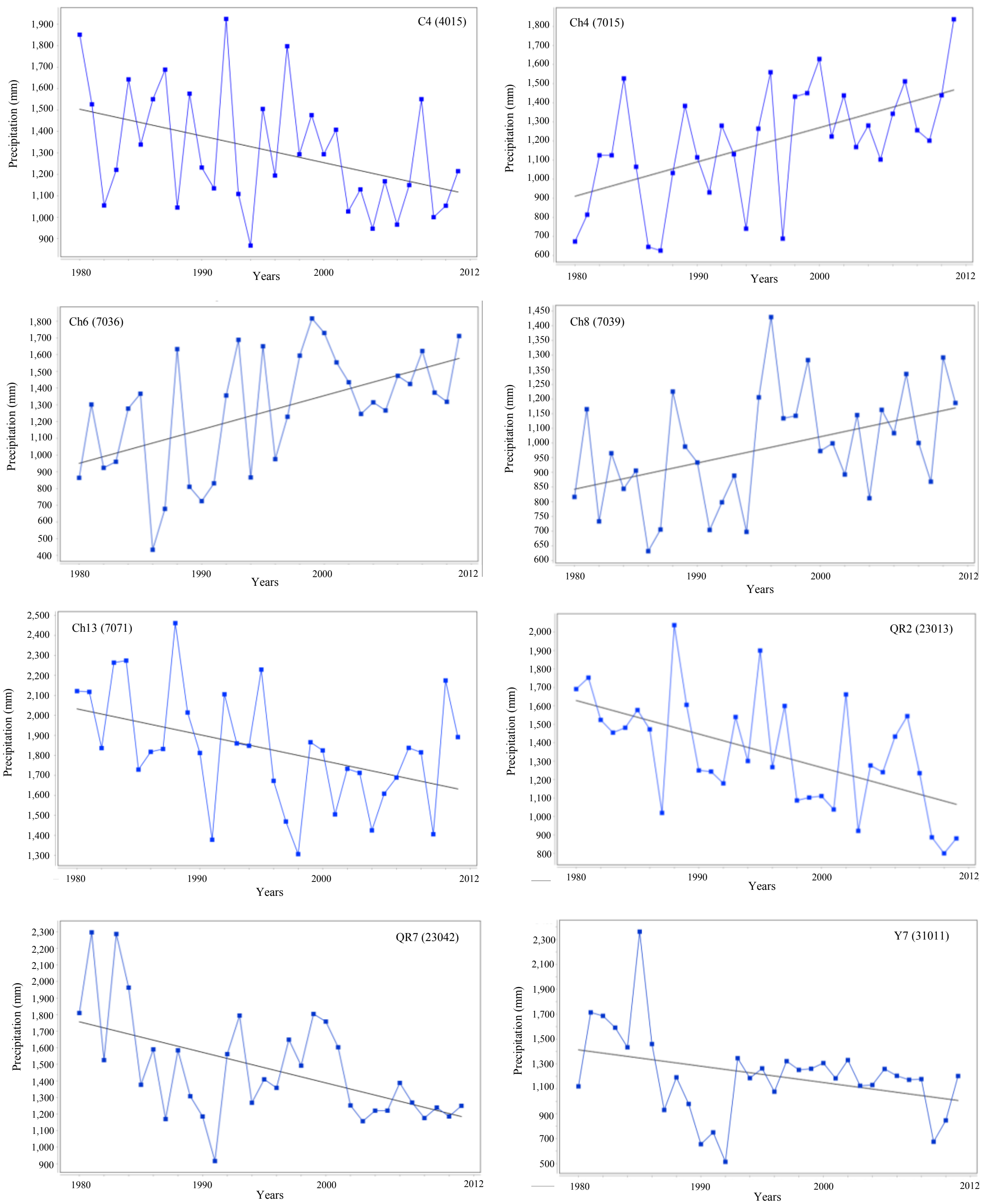

Figure 4. Precipitation graphs from some of the analyzed stations show significant trends.

of analysis, our results indicate that climate change measured throughout the three decades could conduce to negative impacts for the management of *S. macrophylla* whenever the trends detected continue to the future.

At the state level, our results indicate geographic variation in the rainfall patterns, suggesting that regions supporting populations of *S. macrophylla* face different weather conditions according to the contrasting (negative vs. positive) trends observed (Figures 2, 3). Our results indicate a statistical trend toward drier climates, coinciding with the most important areas sustaining commercial populations of *S. macrophylla* (Pennington & Sarukhán 2005). For example, in Quintana Roo, the eight weather stations with statistical effects show negative trends, three for estimated the change along time in precipitation and SPI for these stations. For precipitation, the estimated decrease in mm was 43.09. The SPI showed a mean reduction of 1.41 standard deviations, indicating an increase in hydrological droughts. These negative trends in both precipitation and SPI have already been reported in other studies, both regionally and locally (Prieto González *et al.* 2011, Magallanes-Quintanar *et al.* 2019). Therefore, if the negative trends of the past three decades continue, this could represent a complicated scenario for the natural regeneration of *S. macrophylla*. According to the available evidence, this species requires abundant soil moisture for its germination, survival and establishment, showing elevated mortality rates of seedlings under water shortage (Gerhardt 1996, Vieira *et al*. 2008, Sneha *et al*. 2013, Negreros-Castillo *et al*. 2014, Herrera Feijoo & Shiguango Shiguango 2019, Bhuva *et al*. 2020). For example, conditions of water scarcity and high illumination were reported to reduce germination by one order of magnitude (Morris *et al*. 2000). The reduction of daily to weekly irrigation reduced shoot length, total number of leaves and total plant weight in 35.5, 18.8 and 50.2 %, respectively (Bhuva *et al*. 2020). Seedling survival was around 90 % in the wet season, but fell down to zero at the end of the dry season in a deciduous forest (Gerhardt 1996).

The decreasing trend in precipitation could have negative effects on plant growth in the area sustaining commercial populations. For example, in Quintana Roo, diameter growth of *S. macrophylla* was 0.65 ± 0.08 cm in the wettest year (1,750 mm) and of only 0.20 ± 0.06 in the driest year (750 mm), which corresponds to a reduction of 30 % (Whigham *et al*. 1998). In Quintana Roo, most trees of *S. macrophylla* do not reach the desired commercial diameter of 55 cm in diameter at breast height (Snook 2005). Therefore, if these negative trends continue in the future and management programs do not consider the response of *S. macrophylla* to water availability, this situation could worsen. A study conducted in the Maya Biosphere Reserve in Guatemala estimated a mean annual increment in diameter of 0.43 mm yr^{-1} and found a positive relationship between previous-year precipitation and the growth of *S. macrophylla.* This pattern was not observed in a species from the same family, *Cedrela odorata*, revealing the sensitivity of big-leaf mahogany to water resource decline, even at more mature life stages (Martínez Prera 2016). Thus, increased droughts may not only affect the early stages of *S. macrophylla*, but the growth of adult trees too, which could complicate the commercial management in the area with the currently most abundant populations in Mexico (Navarro-Martínez *et al*. 2018). Within Mexican populations, those located at this area are relevant for conservation as retain intermediate levels of heterozygosity and could maintain connectivity with populations located at north Central America (Alcalá *et al*. 2014).

We also showed an overall signal toward drier climates along large areas of the state of Veracruz, as ten of the eleven weather stations exhibited a negative trend for SPI, and this means an increased probability of hydrological droughts (Figure 3). In this state, *S. macrophylla* distributes from its southern border (near the limits with the state of Chiapas) to the municipalities of Zozocolco and Coxquihui in the northern state areas. At this northern zone, *S. macrophylla* has low abundance, with some isolated trees that have the lowest levels of genetic diversity and a potentially lower adaptive response, among Mexican populations (Alcalá *et al*. 2014). Thus, the negative trend in rainfall could limit the development of *S. macrophylla* along large areas and could increase the probability of local extinction of the isolated, northernmost populations in Mexico.

In Yucatan, we detected more weather stations exhibiting positive trends for precipitation and SPI. However, the scenario for range expansion is limited because this state exhibits the lowest average precipitation. From our database, the average precipitation across the three decades is only 86.57 mm. Thus, despite the positive trends, the amount of precipitation will also be low in the future. In contrast with the median semiperennial forests of Quintana Roo and Campeche, vegetation in Yucatan majorly corresponds to seasonally tropical dry forest, in which *Swietenia humilis* Zucc. shows higher abundance due to its affinity for drier conditions (Pennington &

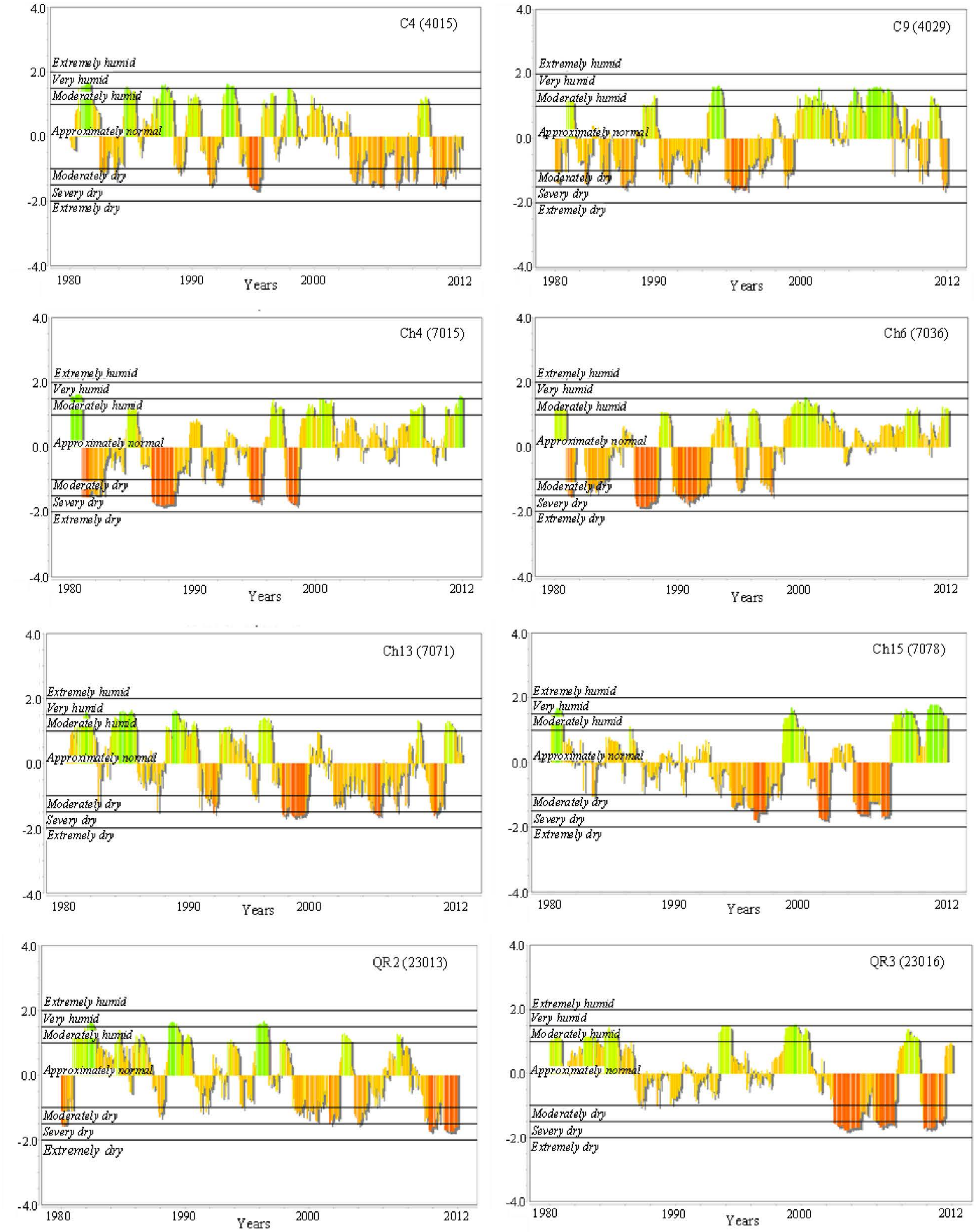

Figure 5. Standardized Precipitation Index graphs from some of the analyzed stations also show significant trends.

Sarukhán 2005), whereas *S. macrophylla* has been declared as locally extinct (Negreros-Castillo *et al*. 2014, Navarro-Martínez *et al*. 2018).

In Chiapas, we observed a clearer signal for positive trends in the rainfall pattern. From 18 weather stations exhibiting a significant signal, six showed positive trends and negative trends were observed in a single station. For SPI, eight stations showed positive trends and only three stations exhibited negative trends (Figure 3). Positive trends in rainfall were detected mainly along highland areas of Chiapas and in the southern area known as Soconusco. Currently, *S. macrophylla* is not present in these areas but it is more abundant in the Montes Azules Biosphere Reserve (Lacandon area), where it inhabits tropical rain forests and harbors the highest levels of heterozygosity within Mexican populations (Alcalá *et al*. 2014). However, both areas could be colonized in the future. Particularly, the highlands of Chiapas are becoming wetter and this could promote the upward migration of big-leaf mahogany. The southern area of Soconusco, could be considered suitable for populations of *S. macrophylla*, as it includes vegetation types such as high evergreen forest, medium sub-deciduous forest, low deciduous forest, among others, in addition to more humid climates (Flores-Verdugo *et al*. 2001). Our results, indicating a trend toward a higher amount of precipitation in conjunction with the characteristics of the present vegetation, suggest that Soconusco could be an interesting area for the government reforestation programs with tropical trees, being a particularly suitable area for the inclusion of *S. macrophylla*.

If the current decline in precipitation persists, *S. macrophylla* populations in Quintana Roo may gradually shift toward more humid regions, such as Petén, southern Belize, or the tropical forests of Chiapas. These areas could act as refugia under drier climatic conditions. Conservation efforts should therefore prioritize the maintenance of genetic diversity within existing protected areas, such as Calakmul in Campeche, while according to Garza-López *et al*. (2016) assisted regeneration is needed to promote habitat connectivity and facilitating natural migration of the species across suitable moisture gradients.

Different studies have forecasted the response of *S. macrophylla* under climate change scenarios. Some projections suggest severe contractions of its climatically suitable habitats across the Yucatán Peninsula, Guatemala, Belize, and eastern Honduras, with potential losses of up to 60 % by 2030 (Garza-López *et al.* 2016). By 2050 and 2070, habitat reductions of 39.8 and 47.6 % are expected, respectively, indicating a continued shrinkage of the species' ecological range and possible genetic fragmentation (Ramírez-Magil *et al*. 2020). The socioeconomic impacts would extend to rural communities that rely on mahogany harvests, potentially reducing their economic income and increasing its dependence on other resources (Ramírez-Magil *et al.* 2020). In contrast, the more optimistic scenarios for the period 2050-2070 show an increase in its future distribution across several Mexican states, including Campeche, Quintana Roo and Yucatan, either through analysis of the thermal niche of seed germination (Sampayo-Maldonado *et al*. 2021) or using ecological niche models (Herrera Feijoo & Shiguango Shiguango 2019). However, our results revealed a different scenario due to the generalized current trend toward the reduction in precipitation and the increase in hydrological droughts. Thus, if the trends we detected continue over the next decades, a future reduction in its original distribution can be expected, as *S. macrophylla* has been identified as low-tolerant species to drought due to elevated sensitivity of seeds to desiccation (Morris *et al*. 2000, Grogan *et al*. 2003, Negreros-Castillo *et al*. 2014, Sampayo-Maldonado *et al*. 2021). Populations of *S. macrophylla* with the highest current commercial value could increase their vulnerability to climate change because they are already facing drier conditions that could limit their future regeneration. According to our results, *S. macrophylla* could extend its geographic distribution towards higher elevation areas. Overall, the results derived from our study highlights the relevance of studying current precipitation trends to increase our knowledge about how climate change could impact economically valuable tropical tree species.

Acknowledgments

We are grateful to the National Forestry Commission for the mahogany records granted for carrying out this investigation. We are grateful to the editor section and the two anonymous reviewers for their insightful comments and valuable suggestions, which significantly improved the previous version of this manuscript.

Literature cited

Alcalá RE, Salazar H, Guitérrez-Granados G, Snook LK. 2014. Genetic structure and genetic diversity of *Swietenia macrophylla* (Meliaceae): implications for sustainable forest management in Mexico. *Journal of Tropical Forest Science* **26**: 142-152. DOI: http://www.jstor.org/stable/23617023

Bartels RJ, Black AW, Keim BD. 2020. Trends in precipitation days in the United States. *International Journal of Climatology* **40**: 1038-1048. DOI: https://doi.org/10.1002/joc.6254

Bautista F, Pacheco A, Bautista-Hernández DA. 2014. *Análisis del cambio climático con datos mensuales (Clic-MD*). México. Skiu: Centro de Investigaciones en Geografía Ambiental-Universidad Nacional Autónoma de México. ISBN: 978-607-96883-4-9

Bhuva DC, Prajapati VM, Amlani MH, Tandel MB. 2020. Effect of irrigation interval on growth and biomass of mahogany (*Swietenia macrophylla* King, Meliaceae) seedlings. *International Journal of Chemical Studies* **8**: 260-26.

Boonman CC, Huijbregts MA, Benítez-López A, Schipper AM, Thuiller W, Santini L. 2021. Trait-based projections of climate change effects on global biome distributions. *Diversity and Distributions* **28**: 25-37. DOI: https://doi.org/10.1111/ddi.13431

Bray DB, Merino-Pérez L, Barry D. 2005. Community managed in the strong sense of the phrase: The community forest enterprises of Mexico. *In:* Bray DB, Merino-Pérez L, Barry D, eds. *The Community Forests of Mexico: Managing for Sustainable Landscapes*. Austin: University of Texas Press, pp. 1-26. DOI: https://doi.org/10.7560/706378-003

Brodie JF, Freeman BG, Mannion PD, Hargreaves AL. 2025. Shifting, expanding, or contracting? Range movement consequences for biodiversity. *Trends in Ecology & Evolution*. **5**: 439-448. DOI: https://doi.org/10.1016/j.tree.2025.02.001

Cabrales LC, Snook LK. 2005. Producción de semillas de caoba en México Patrones de variación e implicaciones para la sostenibilidad. *Recursos Naturales y Ambiente* **44**: 60-67.

Carvalho LM. 2020. Assessing precipitation trends in the Americas with historical data: A review. *Wiley Interdisciplinary Reviews: Climate Change* **11**: e627. DOI: https://doi.org/10.1002/wcc.627

CITES Secretariat. 2003. Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora. Geneva, Switzerland: CITES Secretariat.

Colwell RK, Feeley KJ. 2025. Still little evidence of poleward range shifts in the tropics, but lowland biotic attrition may be underway. *Biotropica* **57**: e13358. DOI: https://doi.org/10.1111/btp.13358

CONAFOR [Comisión Nacional Forestal]. 2014. *Inventario Nacional Forestal y de Suelos. Procedimientos de muestreo*. Guadalajara, Jalisco, México: CONAFOR. https://www.conafor.gob.mx/apoyos/docs/externos/2022/DocumentosMetodologicos/2014/Anexo_procedimientos_muestreo_2014.pdf (accessed September 2, 2023)

De la Barreda B, Metcalfe SE, Boyd DS. 2020. Precipitation regionalization, anomalies and drought occurrence in the Yucatan Peninsula, Mexico. *International Journal of Climatology* **40**: 4541-4555. DOI: https://doi.org/10.1002/joc.6474

Dyderski MK, Paź-Dyderska, S, Jagodziński AM & Puchałka R. 2025. Shifts in native tree species distributions in Europe under climate change. *Journal of Environmental Management* **373**: 123504. DOI: https://doi.org/10.1016/j.jenvman.2024.123504

Domonkos P, Tóth R, Nyitrai L. 2022. *Climate observations: Data Quality Control and Time Series Homogenization*. Amsterdam, The Netherlands: Elsevier / Royal Meteorological Society. ISBN: 978-0-323-90487-2

Duhan D, Pandey A. 2013. Statistical analysis of long term spatial and temporal trends of precipitation during 1901-2002 at Madhya Pradesh, India. *Atmospheric Research* **122**: 136-149. DOI: https://doi.org/10.1016/j.atmosres.2012.10.010

Ellis EA, Kainer K, Sierra-Huelsz J, Negreros-Castillo P, Rodriguez-Ward D, DiGiano M. 2015. Endurance and adaptation of community forest management in Quintana Roo, Mexico. Forests 6: 4295-4327. DOI: https://doi.org/10.3390/f6114295

Ellis EA, Romero Montero JA, Hernández Gómez IU. 2017 Deforestation processes in the state of Quintana Roo, Mexico: The role of land use and community forestry. *Tropical Conservation Science* **10**: 1-12. DOI: https://doi.org/10.1177/1940082917697259

Endo N, Matsumoto J, Lwin T. 2009. Trends in precipitation extremes over Southeast Asia. *Sola* **5**: 168-171. DOI: https://doi.org/10.2151/sola.2009-043

Esquivel-Muelbert A, Galbraith D, Dexter KG, Baker TR, Lewis SL, Meir P, Rowland L, Lola da Costa AC, Nepstad D, Phillips OL. 2017. Biogeographic distributions of neotropical trees reflect their directly measured drought tolerances. *Scientific Reports* **7:** 1-11. DOI: https://doi.org/10.1038/s41598-017-08105-8

Esri. 2016. *ArcGIS Desktop: ArcMap 10.8.* Redlands, CA: Environmental Systems Research Institute. Software downloaded 2019.

Estrada-Medina H, Cobos-Gasca V, Acosta-Rodríguez JL, Peña Fierro S, Castilla-Martínez M, Castillo-Carrillo, C, Franco-Brito S, López-Castillo D, López-Díaz, M, Luna-Flores W, Maldonado-Repetto A, Álvarez-Rivera O, Cámara-Romero JL, Morales-Guadarrama A, Moreno-Arjona, AM, Pérez-Niño B, Rodríguez-Lara P, Zapata-Luna RL. 2016. La sequía de la península de Yucatán. *Tecnología y Ciencias del Agua* **7**: 151-165.

Feeley KJ. 2012. Distributional migrations, expansions, and contractions of tropical plant species as revealed in dated herbarium records. *Global Change Biology* **18**: 1335-1341. DOI: https://doi.org/10.1111/j.1365-2486.2011.02602.x

Feeley KJ, Silman, MR, Bush MB, Farfan W, Cabrera KG, Malhi Y, Meir P, Salinas-Revilla N, Raurau-Quisiyupanqui MN, Saatchi S. 2011. Upslope migration of Andean trees. *Journal of Biogeography* **38**: 783-791. DOI: https://doi.org/10.1111/j.1365-2699.2010.02444.x

Feeley KJ, Stroud JT, Perez TM. 2017. Most 'global' reviews of species' responses to climate change are not truly global. *Diversity and Distributions* **23**: 231-234. DOI: https://doi.org/10.1111/ddi.12517

Flores-Verdugo FJ, De la Lanza-Espino G, Espinosa FC, Agraz-Hernández CM. 2001. The tropical Pacific coast of Mexico. *In*: Seliger U, Kjerfv. eds. *Coastal Marine Ecosystems of Latin America*. Berlin: Springer, Heidelberg, pp. 307-314. DOI: https://doi.org/10.1016/C2009-0-02633-6

Garza-López M, Ortega-Rodríguez, JM, Zamudio-Sánchez FJ, López-Toledo, JF, Domínguez-Álvarez FA, Sáenz-Romero C. 2016. Calakmul como refugio de *Swietenia macrophylla* King ante el cambio climático. *Botanical Sciences* **94**: 43-50. DOI: https://doi.org/10.17129/botsci.500

Gerhardt K. 1996. Germination and development of sown mahogany (*Swietenia macrophylla* King) in secondary tropical dry forest habitats in Costa Rica. *Journal of Tropical Ecology* **12**: 275-289. DOI: https://doi.org/10.1017/S0266467400009457

Grogan J, Ashton MS, Galvao J. 2003. Big-leaf mahogany (*Swietenia macrophylla*) seedling survival and growth across a topographic gradient in southeast Pará, Brazil. *Forest Ecology and Management* **186**: 311-326. DOI: https://doi.org/10.1016/S0378-1127(03)00298-6

Hernández-Ramos J, Valdez-Hernández JI, García-Cuevas X, Tadeo-Noble AE, Reyes-Hernández VJ. 2020. Age estimation of *Swietenia macrophylla* (Meliaceae) from the normal diameter in populations of Southeastern Mexico. *Revista de Biología Tropical* **68**: 200-217. DOI: http://dx.doi.org/10.15517/rbt.v68i1.37725

Herrera Feijoo RJ, Shiguango Shiguango GJ. 2019. *Distribución potencial de Swietenia macrophylla King (Caoba) bajo condiciones climáticas actuales y futuras.* BSc Thesis. Puyo, Ecuador: Universidad Estatal Amazónica.

IPCC. [Intergovernmental Panel of Climate Change]. 2023. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Chang*e. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, DOI: http://doi.org/10.1017/9781009157896

Jhou HC, Wang YN, Wu CS, Yu JC, Chen CI. 2017. Photosynthetic gas exchange responses of *Swietenia macrophylla* King and *Melia azedarach* L. plantations under drought conditions. *Botanical Studies* **58**: 1-11. DOI: https://doi.org/10.1186/s40529-017-0212-8

Jiang T, Su B, Hartmann H. 2007. Temporal and spatial trends of precipitation and river flow in the Yangtze River

Basin, 1961-2000. *Geomorphology* **85**: 143-154. DOI: https://doi.org/10.1016/j.geomorph.2006.03.015
Kendall MG. 1948. *Rank Correlation Methods*. Griffin, London: Universidad de Michigan.
Körner C. 2004. Through enhanced tree dynamics carbon dioxide enrichment may cause tropical forests to lose carbon. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences* **359**: 493-498. DOI: https://doi.org/10.1098/rstb.2003.1429
Lin H, Wang J, Li F, Xie Y, Jiang C, Sun L. 2020. Drought trends and the extreme drought frequency and characteristics under climate change based on SPI and HI in the Upper and Middle Reaches of the Huai River Basin, China. *Water* **12**: 1100. DOI: https://doi.org/10.3390/w12041100
Magallanes-Quintanar R, Blanco-Macías F, Galván-Tejada EC, Galván-Tejada J, Márquez-Madrid M, Valdez-Cepeda RD. 2019. Negative regional standardized precipitation index trends prevail in the Mexico's state of Zacatecas. *Terra Latinoamericana* **37**: 487-499.
Mann HB. 1945. Nonparametric tests against trend. *Econometrica* **13**: 245-259. DOI: https://doi.org/10.2307/1907187
Márdero S, Nickl E, Schmook B, Schneider L, Rogan J, Christman Z, Lawrence D. 2012. Sequías en el sur de la península de Yucatán: análisis de la variabilidad anual y estacional de la precipitación. *Investigaciones Geográficas* **78**: 19-33.
Martínez Prera AE. 2016. Interpretación dendroecológica y desarrollo de modelos de crecimiento en dos especies tropicales: *Swietenia macrophylla* y *Cedrela odorata* en la Reserva de Biosfera Maya, Petén, Guatemala. MSc Thesis. Centro Agronómico Tropical de Investigación y Enseñanza.
Méndez-González J, Návar Cháidez JDJ, González Ontiveros V. 2008. Analysis of rainfall trends (1920-2004) in Mexico. *Investigaciones Geográficas* **65**: 38-55.
Mishra AK, Singh VP. 2010. A review of drought concepts. Journal of Hydrology **391**: 202-216. DOI: https://doi.org/10.1016/j.jhydrol.2010.07.012
Morris MH, Negreros-Castillo P, Mize C. 2000. Sowing date, shade, and irrigation affect big-leaf mahogany (*Swietenia macrophylla* King). *Forest Ecology and Management* **132**: 173-181. DOI: https://doi.org/10.1016/S0378-1127(99)00224-8
Navarro-Martínez A, Ellis EA, Hernández-Gómez, I, Romero-Montero JA, Sánchez-Sánchez O. 2018. Distribution and abundance of big-leaf mahogany (*Swietenia macrophylla*) on the Yucatan Peninsula, Mexico. *Tropical Conservation Science* **11**: 1-17. DOI: https://doi.org/10.1177/1940082918766875
Negreros-Castillo P, Cámara-Cabrales L, Devall MS, Fajvan MA, Mendoza- Briseño MA, Mize CW, Navarro-Martínez A. 2014. *Silvicultura de las Selvas de Caoba en Quintana Roo, México: Criterios y Recomendaciones*. Comisión Nacional Forestal. https://www.fs.usda.gov/nrs/pubs/jrnl/2014/nrs_2014_negreros-castillo_ESP_001.pdf (accessed November 22, 2025)
Onyutha C. 2018. Trends and variability in African long-term precipitation. *Stochastic Environmental Research and Risk Assessment* **32**: 2721-2739. DOI: https://doi.org/10.1007/s00477-018-1587-0
Pendergrass AG, Knutti R, Lehner F, Deser C, Sanderson BM. 2017. Precipitation variability increases in a warmer climate. *Scientific Reports* **7**: 1-9 DOI: https://doi.org/10.1038/s41598-017-17966-y
Pennington TD, Sarukhán J. 2005. *Árboles tropicales de México: manual para la identificación de las principales especies*. México: Universidad Nacional Autónoma de México, ISBN: 970-32-1643-9
Prieto González R, Cortés Hernández V, Montero Martínez M. 2011. Variability of the standardized precipitation over Mexico under the A2 climate change scenario. *Atmósfera* **24**: 243-250
Ramírez-Magil G, Botello F, Navarro-Martínez A. 2020. Habitat suitability for *Swietenia macrophylla* in climate change scenarios in Mexico. *Madera y Bosques* **26**: 1-13. DOI: https://doi.org/10.21829/myb.2020.2631954
Razali NM, Wah YB. 2011. Power comparisons of Shapiro-Wilk, Kolmogorov-Smirnov, Lilliefors and Anderson-Darling tests. *Journal of Statistical Modeling and Analytics* **2**: 21-33.
Rebollar Domínguez S, Santos, JV. Sánchez ARL. 2002. Estrategias de recuperación de selvas en dos ejidos de Quintana Roo, México. *Maderas y Bosques* **8**: 19-38. DOI: https://doi.org/10.21829/myb.2002.811303
Sampayo-Maldonado S, Ordoñez-Salanueva CA, Mattana E, Way M, Castillo-Lorenzo E, Dávila-Aranda PD, Lira-

Saade R, Téllez-Valdés O, Rodríguez-Arévalo NI, Uliano T, Flores-Ortíz CM. 2021. Thermal niche for seed germination and species distribution modelling of *Swietenia macrophylla* King (mahogany) under climate change scenarios. *Plants* **10**: 2377. DOI: https://doi.org/10.3390/plants10112377

Salviano MF, Groppo JD, Pellegrino GQ. 2016. Trends analysis of precipitation and temperature data in Brazil. *Revista Brasileira de Meteorologia* **31**: 64-73. DOI: https://doi.org/10.1590/0102-778620150003

Santos-Hernández AF, Monterroso-Rivas AI, Granados-Sánchez D, Villanueva-Morales A, Santacruz-Carrillo M. 2021. Projections for Mexico's tropical rainforests considering ecological niche and climate change. *Forests* **12**: 119. DOI: https://doi.org/10.3390/f12020119

Seldon J, Snyder VA, Harmsen E, Van Bloem S. 2021. Water requirements for growth and survival of *Swietenia macrophylla* and *Tabebuia heterophyll*a juvenile trees in relation to water production capacity of dew condensers. *The Journal of Agriculture of the University of Puerto Rico* **105**: 143-162. DOI: https://doi.org/10.46429/jaupr.v105i2.20073

Sen PK. 1968. Estimates of the regression coefficient based on Kendall's tau. *Journal of the American Statistical Association* **63**: 1379-1389.

Sneha C, Santhoshkumar AV, Sunil KM. 2013. Quantifying water stress using crop water stress index in mahogany (*Swietenia macrophylla* King) seedlings. *Current Science* **104**: 348-351.

Snook LK. 2005. Aprovechamiento sostenido de caoba en la Selva Maya de México de la conservación fortuita al manejo sostenible. *Revista Forestal Centroamericana* **44**: 9-18.

Terasaki Hart DE, Bùi TN, Di Maggio L, Wang IJ. 2025. Global phenology maps reveal the drivers and effects of seasonal asynchrony. *Nature* **645**: 133-140. DOI: https://doi.org/10.1038/s41586-025-09410-3

Vieira DLM, de Lima VV, Sevilha AC, Scariot A. 2008. Consequences of dry-season seed dispersal on seedling establishment of dry forest trees: Should we store seeds until the rains? *Forest Ecology and Management* **256**: 471-481. DOI: https://doi.org/10.1016/j.foreco.2008.04.052

Vu TM, Mishra AK. 2016. Spatial and temporal variability of standardized precipitation index over Indochina peninsula. *Geographical Research Letters* **42**: 221-232. DOI: https://doi.org/10.18172/cig.2928

WMO [World Meteorological Organization]. 2017. WMO Guidelines on the Calculation of Climate Normals. Geneva, Switzerland: WMO. WMO-No. 1203. ISBN 978-92-63-11203-3.

Whigham DF, Lynch JF, Dickinson MB. 1998. Dynamics and ecology of natural and managed forests in Quintana Roo, Mexico. In: Primack RB, Bray DB, Galletti HA, Ponciano I, eds. *Timber, Tourists and Temples: Conservation and Development in the Maya Forests of Belize, Guatemala and Mexico.* Washington, DC: Island Press, pp. 267-281.Yan Z, Li Z, Xia J. 2014. Homogenization of climate series: The basis for assessing climate changes. *Science China Earth Sciences* **57**: 2891-2900. DOI: https://doi.org/10.1007/s11430-014-4945-x

---

Associate editor: Ernesto Iván Badano

Author contributions: IAC, wrote the first draft, compiled data base, performed the statistical analysis. REA, conceptualized the study design, critically revised the manuscript and contributed with writing of the final version.

Supporting agencies: Secretaría de Ciencia, Humanidades, Tecnología e Innovación (SECIHTI).

Conflict of interests: The authors declare that there is no conflict of interest, financial or personal, in the information, presentation of data and results of this article.

Appendix 1. Geographic coordinates of the weather stations. C = Campeche, Ch = Chiapas, QR = Quintana Roo, V = Veracruz and Y = Yucatan. The Mann-Kendall Z values, Sen's slopes derived from trend analysis are indicated. Significant *p* values are marked in boldface.

N° Weather Station	Clue	Latitude	Longitude	Altitude	Precipitation			SPI		
					Z	*p*	Sen's Slope	*Z*	*p*	Sen's Slope
4015	C4	19.58	-96.78	730	-2.27	**0.023**	-1.03	-2.77	**0.005**	-0.04
4021	C6	18.05	-90.82	100	-3.87	**< 0.001**	-2.17	-3.19	**0.001**	-0.06
4029	C9	18.97	-91.17	5	1.31	0.189	0.71	2.48	**0.013**	0.03
7015	Ch4	16.98	-92.89	1,200	2.98	**0.002**	1.44	2.51	**0.011**	0.05
7036	Ch6	16.67	-92.48	2,266	2.77	**0.005**	1.65	3.09	**0.001**	0.05
7038	Ch7	15.2	-92.55	63	1.57	0.116	0.97	1.5	0.131	0.02
7039	Ch8	16.64	-93.15	500	2.28	**0.022**	0.73	2.28	**0.022**	0.03
7070	Ch12	15.69	-92.16	630	0.6	0.548	0.38	2.87	**0.004**	0.02
7071	Ch13	17.14	-92.29	1,160	-2.18	**0.028**	-1.08	-3.06	**0.002**	-0.05
7077	Ch14	15.14	-92.48	40	1.73	0.082	1.82	1.63	0.101	0.02
7078	Ch15	14.61	-92.18	7	0.08	0.93	0.1	-3.94	**< 0.001**	-0.03
7104	Ch19	16.31	-91.97	1,512	-0.82	0.4	-0.34	-4.42	**< 0.001**	-0.02
7116	Ch20	14.91	-92.19	245	1.897	0.057	2.49	4.89	**< 0.001**	0.001
7119	Ch21	15.36	-92.24	1,260	3.22	**0.001**	1.87	3.81	**< 0.001**	0.07
7123	Ch22	16.75	-93.37	838	2.31	**0.02**	0.83	2.15	**0.031**	0.04
7125	Ch23	16.78	-92.34	1,987	2.64	**0.008**	1.88	2.09	**0.036**	0.04
23003	QR1	19.57	-88.04	17	-1.89	0.057	-1.19	-1.99	**0.046**	-0.03
23013	QR2	19.8	-88.75	16	-3.25	**0.001**	-1.71	-3.38	**< 0.001**	-0.05
23016	QR3	18.45	-88.93	109	-1.83	0.066	-1.54	-2.44	**0.014**	-0.05
23033	QR6	18.97	-88.21	15	-2.41	**0.015**	-1.06	-2.02	**0.042**	-0.04
23042	QR7	19.02	-88.11	9	-2.87	**0.004**	-1.27	-2.8	**0.005**	-0.05
30041	V4	20.99	-98.16	291	-1.63	0.101	-1.6	-2.53	**0.011**	-0.02
30056	V5	19.06	-96.15	10	0.29	0.77	0.26	-1.97	**0.047**	-0.02
30072	V6	20.14	-97.53	322	-0.4	0.685	-0.18	-3.77	**< 0.001**	-0.02
30081	V7	17.57	-95.18	109	-1.37	0.168	-0.8	-2.77	**0.005**	-0.01
30093	V8	19.26	-96.39	30	-0.38	0.697	-0.31	-3.9	**< 0.001**	-0.02
30132	V12	18.59	-95.44	50	0.12	0.896	0.1	-5.1	**< 0.001**	-0.02
30141	V13	19.35	-96.56	263	0.85	0.3901	0.47	-3.29	**< 0.001**	-0.03
30152	V14	18.27	-95.55	20	0.11	0.909	0.04	-2.35	**0.018**	-0.009
30175	V17	19.51	-97.11	3,102	2.06	**0.039**	1.1	-0.64	0.516	-0.005
30193	V19	19.36	-96.37	28	-1.8	0.071	-0.76	-1.96	**0.049**	-0.01
31003	Y2	21.2	-88.8	6	-0.08	0.935	-0.06	3.01	**0.002**	0.02
31005	Y3	20.42	-89.75	50	-0.6	0.548	-0.16	-2.93	**0.003**	-0.008
31007	Y4	21.29	-89.6	3	-0.27	0.782	-0.11	3.84	**< 0.001**	0.04
31008	Y5	20.39	-88.47	26	0.79	0.426	0.33	2.41	**0.015**	0.01
31010	Y6	21.39	-88.89	2	-0.5	0.615	-0.28	3.01	**0.002**	0.01
31011	Y7	20.83	-88.52	30	-2.02	**0.042**	-1	-1.18	0.236	-0.005
31016	Y8	20.91	-89.95	8	0.29	0.77	0.08	2.28	**0.022**	0.007

N° Weather Station	Clue	Latitude	Longitude	Altitude	Precipitation			SPI		
					Z	*p*	Sen's Slope	*Z*	*p*	Sen's Slope
31021	Y11	20.49	-89.71	29	2.44	**0.014**	0.9	3.68	**< 0.001**	0.03
31024	Y13	21.58	-88.14	4	-0.11	0.909	-0.06	-3.48	**< 0.001**	-0.02
31040	Y16	20.85	-90.4	3	-1.45	0.144	-0.45	-3.51	**< 0.001**	-0.02
31065	Y17	20.81	-89.44	14	1.63	0.101	0.62	2.22	**0.026**	0.02
31069	Y18	20.99	-87.78	8	2.03	**0.042**	1.23	2.35	**0.018**	0.02
31071	Y19	20.75	-88.93	22	0.58	0.559	0.37	-2.01	**0.044**	-0.01
31072	Y20	20.41	-89.28	26	1.34	0.178	0.8	3.05	**0.002**	0.03