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Agroclimatic Characterization of the Tropical Zone of Mexico

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Abstract

Mexico is considered a country with a predominantly tropical climate, since most of the country is generally located at 23˚27" north latitude, as part of the Tropic of Cancer. However, within this latitude there are temperate and semi-arid zones. The problem being faced is that the definition of *tropics* has been based just on *Latitude*, frequently ignoring the *Altitude* factor The above mentioned problem has led to an incomplete understanding of the real surface of the Mexican tropic and other methods employed in other countries are not applicable to the Mexican conditions. This work aimed to adequately delimit the tropical zone of the country in order to carry out programs able to trigger a sustainable development of both humid and subhumid tropics. The method was based on a detailed analysis of the physical environment. To process and determine the area covered by the tropical zone, the QGIS 3.22 Batioweiza software and the following databases were used: The digital elevation model from the National Institute of Statistic, Geography and Information (INEGI) with altitude values every 3 arc seconds (approximately a 90 × 90 m grid or 0.81 ha), climate database of the climatological normal of the National Meteorological System for the states of the Mexican Republic and the 1:250,000 scale map soils from the World Reference Base or WRB for its acronym in English. Two of the variables that determine the tropical climate are the temperature, which must be higher than 18˚C, and the average annual rainfall, higher than 600 mm. The images were reclassified according to altitude conditions, average annual temperature, average annual rainfall, soils, and agricultural and livestock areas. The regionalization of the tropical zone determined a total area of 70 million hectares, 18% (12.6 million has) considered as humid and most of the area 82% (57.4 million has) as sub-humid or dry tropics.

Subject Areas

Agricultural Engineering

Keywords

Regionalización, Geographic Informatio System, Physical Environment

1. Introduction

The tropics cover 40% of the total surface of the globe and are home to approximately 80% of the world's biological diversity and much of the linguistic and cultural diversity. 95% of the planet's mangrove area and 99% of mangrove species are found in tropical regions [1].

In the particular case of Latin America and the Caribbean, the region has resources and capacities to respond beyond its own needs and, therefore, can provide significant contributions to the rest of the world. The tropics are considered the region of the Earth between the parallels called the Tropic of Cancer, in the northern hemisphere, and the Tropic of Capricorn, in the southern hemisphere, equidistant from the Equator, located at 23˚27' north and south latitude respectively. [2], but this is not necessarily true. Although topography and other factors contribute to climatic variation, in general, we can say that tropical regions are warm and the seasons are little marked by changing temperatures. A characteristic of the areas closest to the Equator is the prevalence of rain.

Mexico is a country that has a long experience in the generation, classification and dissemination of primary information about the national territory, however, the cartographic and documentary information necessary for ecologically based regionalization studies is characterized by being dispersed [3].

In Mexico, the tropics covered 22% of the population, 70% of water resources, 99.5% of oil production, 79.5% of natural gas and 84% of the hydroelectric energy. Furthermore, the tropics are vital for carbon capture and climate regulation [4]. Tropical areas face various challenges that require special attention such as climate change, deforestation, logging exploitation, urbanization, soil pollution and demographic changes.

The problem being faced is that the definition of *tropics* has been based just on Latitude, frequently ignoring the *Altitude factor*. The foregoing has led to an incomplete understanding of the real surface of the Mexican tropic and other methods employed in other countries are not applicable to the Mexican conditions.

This work aimed to adequately delimit the tropical zone of the country in order to carry out programs able to trigger a sustainable development of both humid and subhumid tropics. This process will be based on a detailed analysis of the physical environment as an important part of this study.

2. Materials and Methods

2.1. Materials

The study area. The Mexican Republic is located in the Northern Hemisphere, between the parallels 14˚33' and 32˚44' north and between the meridians 85˚44' and 117˚07' west [5]. It borders to the north with the United States of America, to the southeast with Guatemala and Belize, to the south and west with the Pacific Ocean and to the east with the Gulf of Mexico and the Caribbean Sea. One part of the country (Southern portion) is located in the intertropical zone and the other (Northern portion) in the subtropical zone, because the Tropic of Cancer crosses the Republic in its middle part.

2.2. Methods

Regionalization of the Tropical Zone. The spatial determination to define the agroecological characteristics of the tropical zone of Mexico was carried out by using map algebra, taking as input variables: the main climatic conditions, the digital elevation, slope and type of soils. The use of Geographic Information Systems (GIS), has been a successful method to spatially delimit the agroecological regions [6].

Spatial Information. Several geospatial databases were considered. The edaphic information was taken from the World Soil Resource Reference Base, known by its acronym in English as WRB, in vector format. Climatic data were taken from the World Clim version 2.0 database, specifically average temperature and precipitation during the crop cycle.

The Digital Elevation Model was obtained from the National Institute of Statistics, Geography and Informatics, in raster format with a resolution of 500 m^2. The map of slopes, bodies of water, mangrove, urban and rural areas as well as protected natural areas, were taken from the Geoportal of the National Information System for Biodiversity of the National Commission for the Knowledge and Use of Biodiversity.

Data processing. Map algebra is understood as the set of techniques and procedures that, operating on one or several layers in raster and/or vector format, allow us to obtain derived information, generally in the form of new data layers. For this case, the procedures basically consisted on classifying the climatic and edaphic attributes in the agroecological ranges established for the tropical area.

Vector data are entities associated with each attribute, and have their own spatial characteristics, and the geometry that defines each attribute serves by itself to carry out some geo-processes such as cuts and intersections. These geometric operations on vector data consisted of intercepting the edaphic and climatic layers to properly characterize the tropical zone. All information processing and reclassification was carried out in the free QGIS 3.22 Biatowieza software.

3. Results

3.1. Location of the Mexican Tropic

The Mexican Republic is crossed by the Tropic of Cancer (23˚27') so the country extends across two thermal zones: the northern temperate zone and the Torrid Zone. However, due to the mountain ranges and places at high altitudes, the climate prevailing in the so call *Tropics* is not necessarily warm due to the fact that there are temperate zones influenced by the high altitudes.

Based on this condition, the first assertion, necessary in this work, goes against the stereotypical idea that Mexico is a predominant tropical country.

The humid and rainiest tropical zone of Mexico is located on the declines of the Gulf of Mexico and the extreme southeast of Chiapas; On the other hand, the sub-humid or drier tropical zone is located in the pacific region, prevailing a rainy season in the summer (**Figure 1**).

3.2. Surface of the Mexican Tropic

Regarding the Tropcal surface, there are more than 70 million hectares, of which 18% are considered as humid tropics and the remaining 82% as subhumid or dry tropics. This classification is mainly influenced by two variables: the average annual temperature (higher than 18˚C) and the average annual precipitation. The Humid tropics are located in areas where rainfall is higher than 2000 mm whereas the Subhumid and Dry tropics are scattered in regions of less than 2000 mm and more than 600 mm.

3.3. Height above Sea Level as Related to the Surface

In terms of altitude, the plains of the Gulf of Mexico and the Pacific showed altitudes ranging from 0 to 200 m (43% of the surface) and from 0 to 500 m (17%). In a much smaller area, there are altitudes between 500 to 1000 m (13%), 1000 to 1500 m (13%), 1500 to 2000 m (12%), 2000 to 2500 m (1.5%) and 2500 to 3000 m (0.5%) (**Figure 2**).

3.4. Average Annual Temperature and Surface Distribution

In the case of the average annual temperature, 26˚C is considered very warm, 22˚C to 26˚C warm and 18˚C to 22˚C semi-warm. The very warm temperature, is distributed in 0.52% of the Mexican tropic whilst the warm temperature is the predominant one with 71.01% of the tropical area and 28.46% is semi-warm (**Figure 3**).

3.5. Average Annual Precipitation and Surface Distribution

The average annual precipitation in presents two well-differentiated seasons, one warm and humid from May to October and another less humid with the presence of "nortes" (cold fronts). Generally, 80% of the precipitation occurs from May to October and the other 20% from November to April. Regarding the

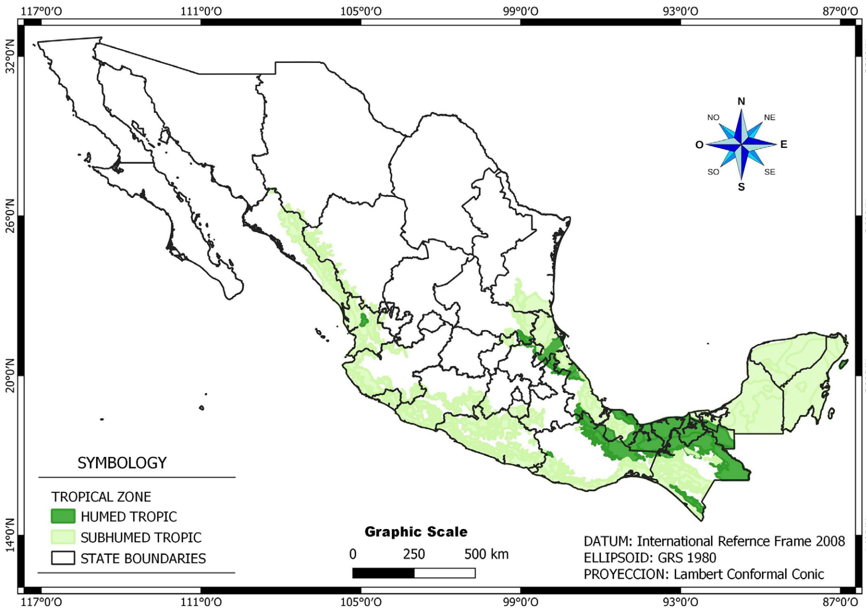

Figure 1. Geographic distribution of the Tropic of Mexico.

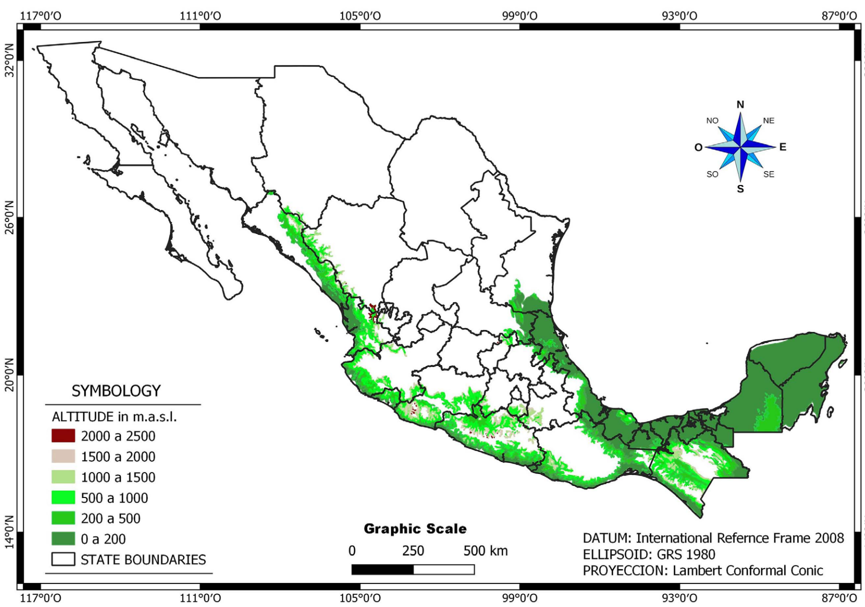

Figure 2. Geographic distribution of altitude in the Tropic of Mexico.

ranges of average annual precipitation, 16% of the total area has more than 2000 mm, 75% from 800 to 2000 mm and 9% from 400 to 800 mm (Figure 4).

3.6. Predominant Soils and Its Surface Distribution

In whole Mexico, there are 26 of the 32 soil groups recognized by the International World Reference Base System for Soil Resources. *Leptosols* (28.3% of the territory), R*egosols* (13.7%), *Phaeozems* (11.7%), *Calcisols* (10.4%), *Luvisols* (9%) and *Vertisols* (8.6%) are the predominant soils, occupying 81.7% of the national surface.

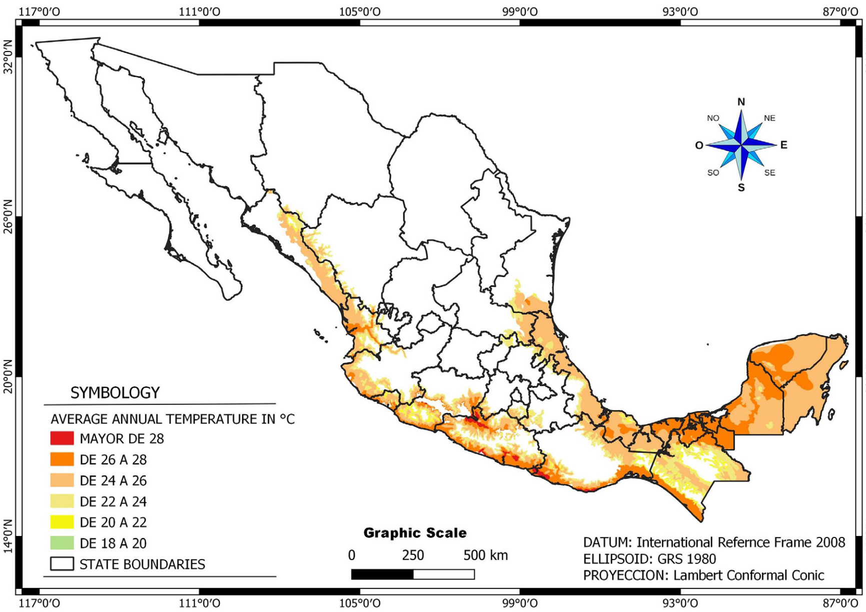

Figure 3. Geographic distribution of the average annual temperature in the Tropics of Mexico.

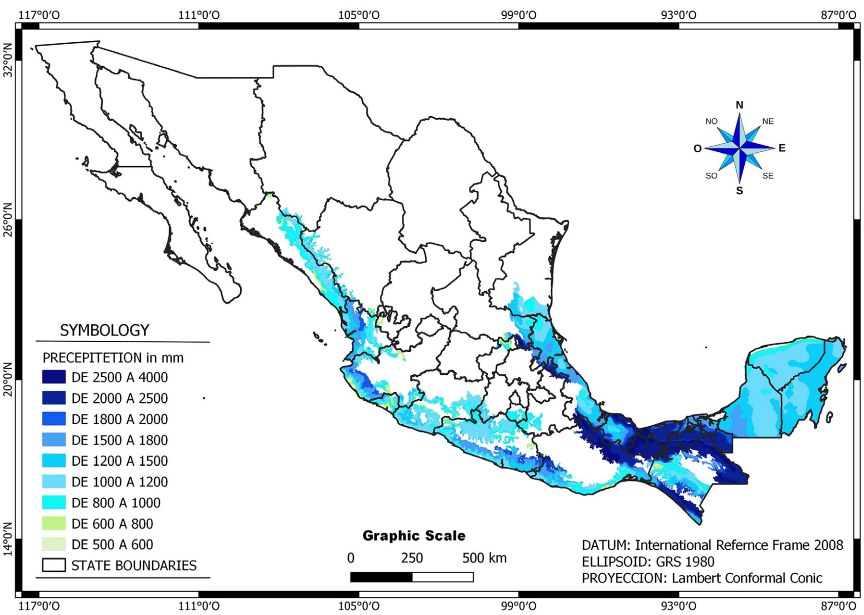

Figure 4. Geographic distribution of the average annual precipitation in the Tropics of Mexico.

In the case of the tropics, there are also 26 of the 32 of the recognized soils, *Leptosols* being the predominant ones with 26% of the tropical territory, followed by *Luvisols* (14.15%), *Phaeozems* (13.16%), *Vertisols* (13.21%), *Regosols* (12.50%), *Cambisols* (6.10%), *Gleysols* (3.94%), *Solonchaks* (1.32%) and *Fluvisols* (0.85%) (**Figure 5**). Together they occupy 92.55% of the tropical soils in Mexico. The other types of soils that correspond to 7.45% are: *Andosols*, *Arenosols*, *Chernozems*, *Calcisols*, *Ferrosoles*, *Kastañozems*, *Nitisols*, *Planosols*, *Umbrisols*.

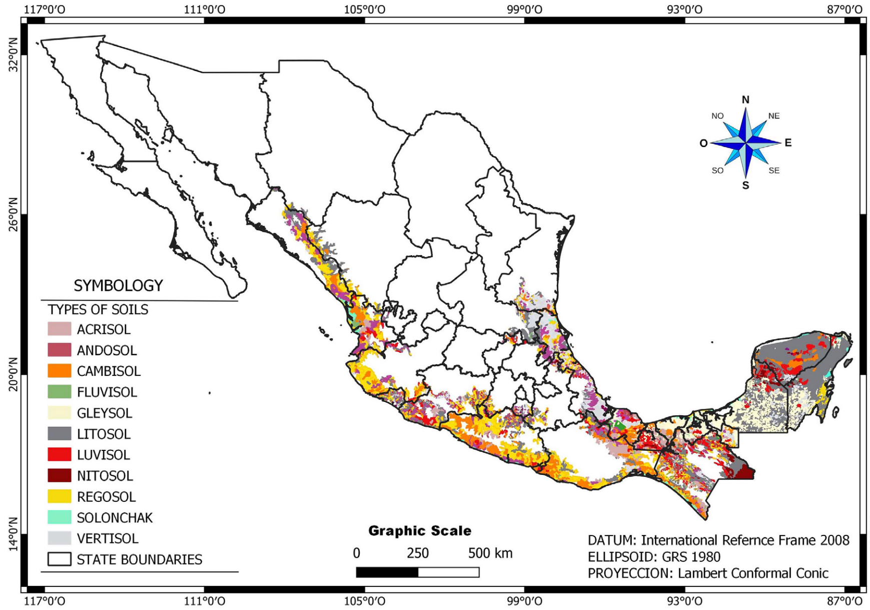

Figure 5. Geographic distribution of soils types in the Tropics of Mexico.

4. Discussion

Mexico is considered a country with a humid, hot or desert tropical climate. But this is a short or contradictory version [7]. The problem being faced is that the definition of *tropics* has been based just on *Latitude*, frequently ignoring the *Altitude*. The above mentioned problem has led to an incomplete understanding of the real surface of the Mexican tropic and other methods employed in other countries are not applicable to the Mexican Republic. However, many of Mexico's climatic types tend to fall into extraordinary categories, unrelated to the conventional classification systems, evidencing the deficiency of the classification criteria.

The concept of the *tropics* has in itself a geographical and climatological connotation; It expresses a warm climate with high rainfall, especially in the case of the Humid Tropics. Its temperatures are high and well distributed through the year with little thermal oscillation and two wet and the dry seasons.

In Mexico, the tropics are mainly located in the southern and southeastern region; although there are other states, no considered as tropics but with tropical areas, such as San Luis Potosí and Tamaulipas in the northeast [8].

In this work, the tropical region was limited mainly to 16 states of the 32 belonging to the Mexican Republic, especially in the coast areas.

When considering the variables studied, especially altitude, temperature and precipitation, it can be stated that the s*tereotypical* idea that Mexico has a predominant tropical climate is not exactly correct.

Although a considerable proportion of the Mexican territory is located within the intertropical zone, its physical configuration states that lands classified as *tropicals*, due to latitude, are in fact temperate or semi-arid areas.

Two thirds of the country, including states such as Chiapas, Oaxaca, Guerrero and Michoacán, considered as *tropicals*, have temperate and cold zones in their geography.

In the tropics of Mexico, the predominant temperatures are warm and to a lesser extent very warm and semi-warm.

Those areas exceeding 2000 mm of recipitation were classified as humid tropics and those ones with less than 2000 mm as subhumid regions.

Although the predominant soils are the stony, thin and very fragile *Leptosols* [9] special care should be taken when cultivating. They are used in the south-southeast region of the country for pastures and livestock rising such as the case of the state of Yucatán. The soils with better production potential such as the: *Luvisols*, *Fluvisols*, *Nitisols*, *Vertisols*, *Phaeozems* and *Regosols* are mainly used for fruit, vegetables, sugar cane and corn production.

Considering that one third of Mexico's surface has a tropical climate (humid and subhumid), it is important to highlight the agricultural potential of this region. It was usually considered (in the 60's) that the agricultural potential of the tropics in the world was low in relation to the same crops planted in temperate zones. However, this idea has been changing over time. "*the vast areas of the humid tropics*, *with a warm year-round climate*, *high rainfall and deep porous soils*, *have the greatest potential in the world for pasture and livestock production*" [10].

The tropics, with optimal temperatures for growing crops throughout the year, represent the largest untapped food source in the world today. It is a large *ring* around the globe and constitutes a potential food resource that man, through research, can turn into a *true horn* of plenty, as long as its sustainability is considered.

The tropics of Mexico have great potential for tropical fruit plantations such as: banana, pineapple, coconut, citrus; forest plantations (mahogany, cedar, rubber, eucalyptus, etc.) [11] [12] [13] [14].

The stablishment of pastures for cattle rising and sheep farming is a good alternative, coinciding with Stewart's proposal in 1970 [10]. On the other hand, the main limitations in the subhumid or dry tropics, to induce high agriculture production, is a shortage precipitation which can be coped by using pressurized irrigation.

5. Conclusions

Mexico has qualified as a predominantly tropical climate country with a humid, hot or desert tropical zones. But the definition of *tropic* is a short or contradictory version. The problem being faced is that the definition of tropics has been based just on *Latitude*, frequently ignoring the *Altitude*. This has led to an incomplete understanding of the real surface of the Mexican tropic and other methods employed in other countries are not applicable to the Mexican Republic. Due to the economic importance of the Mexican tropics, a detailedregionalization was an imperative task and the following conclusions reached in this work were the next:

1) The tropics of Mexico cannot be limited to 23˚27" north latitude.

2) There are areas below this latitude that are classified as temperate and semi-arid zones.

3) Latitude is important to delimit the *tropic of cancer* but it is not a determining factor as in the case of Mexico for regionalization purposes.

4) Temperatures greater than 18˚C are mainly located in areas close to the Gulf and Pacific coastal plains.

5) Temperature, altitude and precipitation are three of the most important variables that influence the delimitation of the tropical zone.

6) The amount of precipitation appropriately delimit the humid and subhumid tropics.

7) The perception of the agricultural potential of the tropics has changed favorably over time.

8) In 16,out of the 32 Mexican states, can be launched agricultural programs to enhance the sustainable development of the Mexican tropics.

9) The regionalization of the tropical zone determined a total area of 70 million hectares, 18% (12.6 million has) considered as humid and most of the area 82% (57.4 million has) as sub-humid or dry tropics.

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Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] National Geographic en español (2021) ¿En qué región del mundo habita la mayor parte de la diversidad biológica? https://www.ngenespanol.com/traveler/en-que-region-del-mundo-habita-la-mayor-parte-de-la-diversidad-biologica/

[2] Organizaciones de las Naciones Unidas (2017) Día Internacional de los Trópicos, 29-de junio. El futuro le pertenece a los Trópicos. https://www.un.org/es/observances/tropics-day

[3] Espínoza Rodríguez, J.M., Lara Vázquez, A., Cervantes Zamora, Y.,Lucero Márquez, R., Miranda Viquez, E. and Pineda Velázquez, A. (1985) La clasificacion de regiones naturales de México como base para los estudios de ordenamiento ecologico del territorio. Observatorio Geográfico de América Latina, 1-10. http://observatoriogeograficoamericalatina.org.mx/egal3/Geografiasocioeconomica/Ordenamientoterritorial/03.pdf

[4] Sjögersten, S., Black, C.R., Evers, S., Hoyos-Santillan, J., Wright, E.L. and Turner, B.L. (2014) Tropical Wetlands: A Missing Link in the Global Carbon Cycle? *Global Biogeochemical Cycles*, **28**, 1371-1386. https://doi.org/10.1002/2014GB004844

[5] Instituto Nacional de Estadística e Informática (INEGI) (1992) Carta geográfica de la República Mexicana. 5a. Dirección General de Geografía. 5a. Impresión INEGI. Aguascalientes, Ags. https://www.inegi.org.mx/app/mapas/

[6] Kahsay, A., Haile, M., Gebresamuel, G. and Mohammed, M. (2018) GIS-Based Multi-Criteria Model for Land Suitability Evaluation of Rainfed Teff Crop Production in Degraded Semi-Arid Highlands of Northern Ethiopia. *Modeling Earth Systems and Environment*, **4**, 1467-1486. https://doi.org/10.1007/s40808-018-0499-9

[7] Mosiño, A.P. and García, E. (1974) The Climates of Mexico. In: Cesario Gonzalez Sanchez y, M.C. and Lauro Nava Vargas, M.C., Eds., *The Climates of North America. World Survey of Climatology*, Elsevier Publ. Co., Amsterdam. https://www.researchgate.net/profile/Jose-Ruiz-Corral/publication/31697892_Los_climas_de_Mexico_una_estratificacion_ambiental_basada_en_el_componente_climatico_G_Medina_Garcia_JA_Ruiz_Corral_RA_Martinez_Parra/links/00b7d5352face92c30000000/Los-climas-de-Mexico-una-estratificacion-ambiental-basada-en-el-componente-climatico-G-Medina-Garcia-JA-Ruiz-Corral-RA-Martinez-Parra.pdf

[8] FAO-SAGARPA (2015) Evaluación Nacional de Resultados 2013. Proyecto Trópico Húmedo. Organización de las Naciones Unidas para la Alimentación y la Agricultura, Secretaría de Agricultura Ganadería, Desarrollo Rural, Pesca y Alimentación. México, D.F., 4-7. https://www.agricultura.gob.mx/sites/default/files/sagarpa/document/2018/11/14/1531/14112018-evaluacion-nacional-de-resultados-pth.pdf

[9] López-Galindo, F., Muñoz-Iniestra, D., Hernández-Moreno, M., Soler-Aburto, A., del Carmen Castillo-López, M. and Hernández-Arzate, I. (2003) Análisis integral de la toposecuencia y su influencia en la distribución de la vegetación y la degradación del suelo en la Subcuenca de Zapotitlán Salinas, Puebla. *Boletín de la Sociedad Geológica Mexicana*, **56**, 19-41. https://www.jstor.org/stable/24920375

[10] Stewart, G.A. (1970) High Potencial Productivity of the Tropics for Cereal Crops, Grass Forage Crops, and Beef. *Journal of the Australian Institute of Agricultural Science*, **36**, 85-101. https://produccioncientificaluz.org/index.php/agronomia/article/view/25775

[11] Vélez-Izquierdo, A., Espinosa-García, J.A., Uresti-Gil, J., Jolalpa-Barrera, J.L., Rangel-Quintos, J. and Uresti-Duran, D. (2020) Estudio técnico-económico para identificar áreas con potencial para producir piña en el trópico húmedo de México. *Revista mexicana de ciencias agrícolas*, **11**, 1619-1632. https://doi.org/10.29312/remexca.v11i7.2594.

[12] Sánchez, D.G. and Ríos, G.L. (2002) Manejo de la palma de coco (*Cocos nucifera* L.) en México. *Revista Chapingo. Serie ciencias forestales y del ambiente*, **8**, 39-48. https://www.redalyc.org/articulo.oa?id=62980105

[13] Murillo-Brito, Y., Domínguez-Domínguez, M., Martínez-Zurimendi, P., Lagunes-Espinoza, L.D.C. and Aldrete, A. (2017) Índice de sitio en plantaciones de Cedrela odorata en el trópico húmedo de México. *Revista de la Facultad de Ciencias Agrarias*, **49**, 15-30. https://www.redalyc.org/articulo.oa?id=382852189002

[14] Medina Urrutia, V.M., Zapiaín Esparza, G., Robles González, M.M., Pérez Zamora, O., Orozco Santos, M., Williams, T. and Becerra Rodríguez, S. (2007) Fenología, eficiencia productiva y calidad de fruta de cultivares. *Revista Fitotecnia Mexicana*, **30**, 133-143. https://www.redalyc.org/articulo.oa?id=61030204