Open Access Library Journal
2025, Volume 12, e13481
ISSN Online: 2333-9721
ISSN Print: 2333-9705

High Productive Potential Areas for Rice (*Oryza sativa* L.) in Campeche, Mexico, under Rainfed Conditions

Genovevo Ramírez-Jaramillo, Alejandro Cano-González, Jorge Humberto Ramírez-Silva, Mónica Guadalupe Lozano-Contreras*

National Institute of Forestry, Agricultural and Livestock Research of Mexico (INIFAP), Southeast Regional Research Center (CIRSE), Merida, Mexico
Email: *lozano.monica@inifap.gob.mx

How to cite this paper: Ramírez-Jaramillo, G., Cano-González, A., Ramírez-Silva, J.H. and Lozano-Contreras, M.G. (2025) High Productive Potential Areas for Rice (*Oryza sativa* L.) in Campeche, Mexico, under Rainfed Conditions. *Open Access Library Journal*, **12**: e13481.
https://doi.org/10.4236/oalib.1113481

Received: April 22, 2025
Accepted: May 27, 2025
Published: May 30, 2025

Abstract

Rice is a staple food in the Mexican diet; however, in recent decades, the cultivated area has diminished substantially and the production is so low that it is compulsory to import more than 1 million t of rice annually. Faced with the need to strengthen rice production, without compromising the ecosystems, the Mexican government launched the *Campeche Plan* as part of the 2025-2030 *National Development Plan*. This initiative is looking forward to enhance rice production in Campeche through sustainable agricultural practices, ensuring quality, and food self-sufficiency. Therefore, the objective of this research was to identify areas, in the state of Campeche, with high productive potential under rainfed conditions. The altitude, temperature, precipitation, light intensity, and soil requirements for rice were considered by consulting databases, bibliographies, and crop experts. QGIS 3.22.14 Batioweiza software was used to determine potential areas. The databases used were the INEGI digital elevation models, and the WorldClim version 2.0 related to the average temperature, precipitation and soil models with a scale of 1: 250,000. It has 26,414 ha of high productive potential for rice production, **Carmen**, **Palizada**, **Escárcega**, **Candelari**a, and **Champotón** being the 5, out of 11 municipalities, with the higher potential areas. **Carmen**, **Palizada** and **Escarcega** showed to be the largest areas with 9,470.00, 8,000.00 and 5,000.00 has, respectively for rainfed production.

Subject Areas

Agricultural Engineering

Keywords

Regionalization, Geographic Information System, Staple Food, *Campeche Plan*

1. Introduction

Rice is a traditional crop in the tropical regions of Mexico, where three agro-climatic zones have been identified: humid tropics, sub-humid tropics, and dry tropics [1]. In the humid tropics, it is mainly grown under rainfed conditions with auxiliary irrigation, covering an area of 34,307 ha, which represents 57% of the country's rice-growing areas [2].

On the other hand, in the dry tropics, the crop is established under irrigation, by direct sowing or transplanting, in an area of 26,464 ha, equivalent to 43% of the national area dedicated to this crop [2]. According to Favila Tello and Herrera Corral (2023) [3], rice production in Mexico is based on three main cultivation systems: transplanting under irrigation (predominant in the central and southern parts of the country); direct sowing under irrigation (common in the north and west); and sowing under rainfed conditions in the southeast. Currently, rice cultivation is concentrated mainly in the states of Nayarit, Campeche, Michoacán, Veracruz, Colima, Jalisco, Tabasco and Morelos [4].

In 2019, the average rice yield in Mexico was 6.37 tons per hectare. The irrigated cultivated area reached 32,084.95 ha between the fall-winter and spring-summer cycles, representing 78% of the total planted nationwide. Approximately 9,000 ha were planted under rainfed conditions [5]. By 2021, the planted area increased to 40,841.11 ha, with a total production of 257,041.44 tons and an average yield of 6.38 tons per hectare.

Campeche located, in the Mexican tropic, had the largest producing area with 15,165 ha, followed by Nayarit, in the northwest, with 7,360.75 ha. However, in terms of yield per unit area, the state of Morelos, in central Mexico, stood out with 10.46 tons per hectare, followed by Michoacán with 8.6 tons per hectare [6] whilst Campeche produced 5.0 t ha^{-1}.

The Mexican government launched in 2024 the so called ***Campeche Plan*** according to the National Development Plan (NDP) 2025-2030. The plan pretends to strengthen rice production without increasing deforestation, promoting sustainable agricultural practices, improving rice quality and enhance the country's food self-sufficiency.

Therefore, the objective of this work was to identify the most suitable municipalities for rice cultivation and their corresponding classification into optimal and suboptimal productive potential areas under rainfed conditions.

2. Materials and Methods

2.1. Geographic Information and Map Algebra

A geographic information system and map algebra were used. Map algebra was a tool combining different territorial layers or variables in order to obtain alternative maps linked to specific characteristics of the territory [7]. In this case, map algebra was applied to locate the most suitable areas for rice production under rainfed conditions.

It was considered an ecological criterion combining, as a whole, the climatic, soil, slope and altitude cartography.

With the help of symbols, the ***most suitable*** areas were distinguished as ***high-potential*** ones, and the ***least suitable*** ones as ***unsuitable*** ones. In this study, three fundamental stages (Figure 1) were considered to define the grade of potentiality: 1) To identify altitude, temperature, precipitation and soil requirements for rice cultivation; 2) locate databases of agro-climatic conditions for the state of Campeche; and 3) data processing.

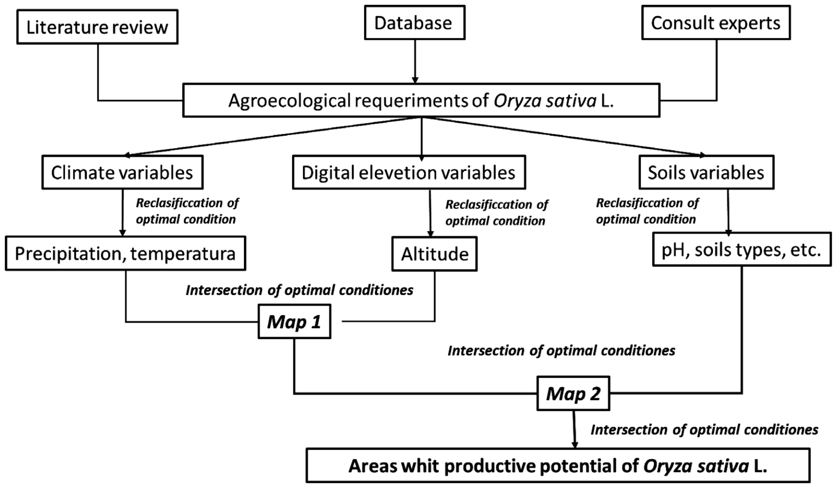

Figure 1. Methodological model used to determine productive potential.

2.2. Determining Agroecological Needs for Rice

The variables used were the agro-climatic requirements of rice in Campeche [8], specifically average temperature, altitude, precipitation, light and soil (Table 1). Agro-climatic information was taken from bibliographic sources [8]-[10] and databases from **Ecocrop**, which identified more than two thousand plant species. The opinions of some rice experts were also considered.

Database of agro-climatic and Geographic conditions of Mexico were also consulted. For soil conditions, the World Reference Base for Soil Resources [11] was considered in vector format [12] at a scale of 1:250,000. The tool used for the climatological data was **WorldClim** version 2.0 [13], specifically for average temperature and precipitation. From the **National Institute of Statistics and Geography**, the Digital Elevation Model with three-second data of altitude values was acquired [14].

From the **National Commission for the Knowledge and Use of Biodiversity**, through its **Geoportal**, the maps of slopes, mangroves, urban areas, water bodies and rural areas of Mexico were obtained, as well as the maps of protected natural areas in vector format with a resolution of 1:1,000,000 [15].

2.3. Database Processing

The procedure consisted on classifying the climatic and soil attributes required under rainfed conditions for rice. The vector format was used to perform analysis, interpolations, cuts and intersections. In this format data were obtained (entities associated with each attribute) with its own spatial characteristics and the geometry of the attribute.

This vector data geometry was implemented through the intersection of the edaphic and climatic layers; and the mangrove, protected areas and urban and rural settlements were eliminated. All the information was processed and reclassified using the QGIS 3.22.14 Batioweiza software [16]. The potential zones were classified into **high potential zones**, where all the agro-climatic variables considered are combined to achieve optimal crop conditions; **Medium potential zones**, where more than one climate and soil variable presents a suboptimal condition (the range is less than optimal but greater than unsuitable), and **unsuitable zones**, where all conditions are limiting for crop development and not recommended for rice cultivation. With this information, maps of temperature, precipitation, light intensity, soils, and potential areas were drawn up.

Table 1. Agroecological requirements of rice under rainfed conditions.

Variable	Unit	Optimal	Suboptimal	Not suitable
Average Annual Temperature	˚C	25-30	20 - 25 30 - 35	Less than 20 Over 35
Altitude	*masl*	0-500	1500 - 2000	Over 2000
Average Annual Precipitation	*mm*	1500-2500	1000 - 1500 2500 - 3500	Less than1000 Over 3000
Soil	*Type*	Fluvisoles Luvisoles Nitisoles Vertisoles Gleysoles	Cambisoles Phaeozems	Solonchaks Leptosoles Arenosoles Calcisoles Regosoles
Texture	*Type*	Heavy to Medium	Medium	Heavy and Light
Depth	*m*	Over 1	0.5 to 1	Less than 0.5
pH	*Indicator*	6.5 to 7.0	5.5 to 6.5 7.0 to 7.5	< de 5.5 > de 7.5
Ligth hours per year	*Hours*	Over 3000	2500 to 3000	Less than 2500
Drainage	*Type*	Moderately Efficient	Efficient	Very efficient

3. Results

3.1. High Potential Areas

The distribution of areas with different potentialities are being shown in **Figure 2**. Campeche has a total of 26,414 hectares available for cultivation under rainfed conditions.

The municipalities with the greatest productive potential for rice cultivation are: **Carmen**, **Palizada**, **Escárcega**, **Candelaria**, and **Champotón**. In particular, **Carmen**, **Palizada**, and **Escárcega** account for more than 50% of the land area with high potentiality (**Figure 2**).

Carmen, being the municipality with the largest high potential surface (9,476 hectares) and the unique region where, in nowadays, farmers are planting rice in both agricultural cycles: **spring-summer** and **fall-winter**. However, despite its extensive high productive potential, only **780 hectares** are actually planted, which indicates a significant opportunity to expand production and strengthen rice self-sufficiency.

On the other hand, **Palizada** with an estimated 8,016 suitable hectares for rice production (Figure 2) only 1,500 hectares are currently planted. In **Escárcega**, the high productive potential of 5,167.00 hectares was found (Figure 3). This area also represents a significant opportunity to strengthen rice production in the region.

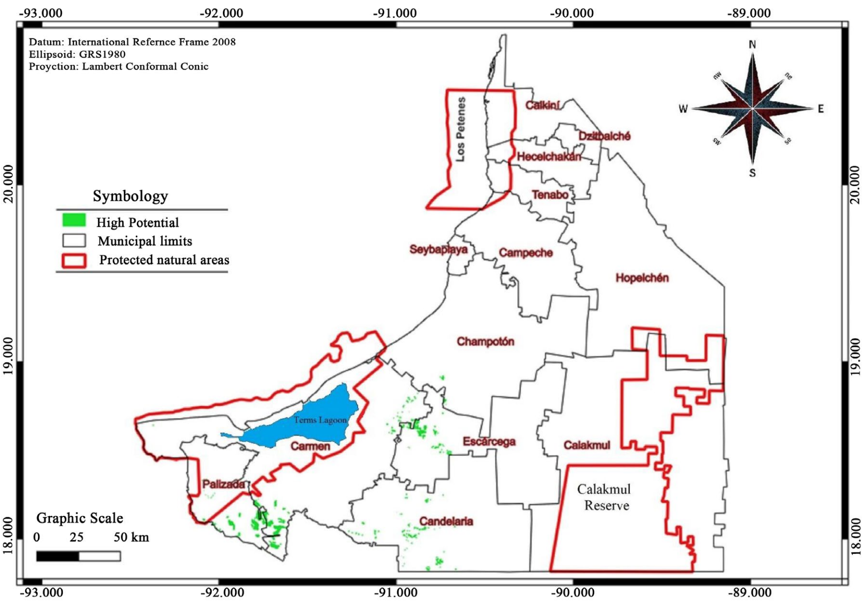

Figure 2. Distribution of high-potential areas in Campeche, Mexico, under rainfed conditions.

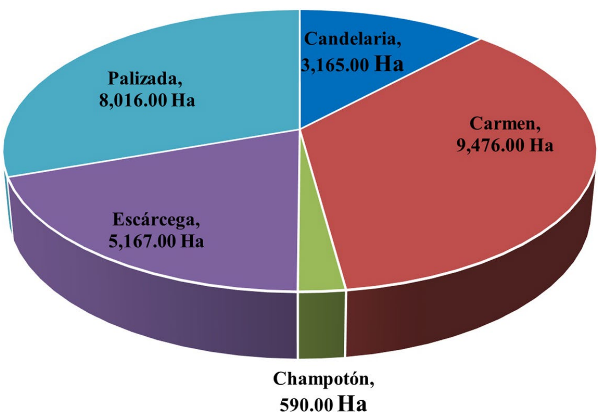

Figure 3. Municipalities of Campeche with high potential areas (ha) for rice production.

4. Discussion

The high potential areas (26,414 has) for rice cultivation, in **Campeche Mexico**, far exceed the surface currently planted (3,710 has) according to SIAP (2023) [17], concentrated in five municipalities. These findings highlight the great possibility of successfully expanding rice cultivation.

It is not surprising that the municipality of **Carmen**, showed to have the largest high potential surface. Historically speaking, rice was cultivated since the 1970s. However, in the 1980s, the proliferation of **Johnson grass** (*Sorghum halepense*), as an aggressive invasive weed, and the and the lack of government subsidies led to the abandonment of rice fields [18].

However, rice cultivation continued in other regions of the state, where various mechanisms were implemented to improve production such as: the introduction of improved varieties, use of herbicides, insecticides and inorganic fertilizers, which significantly increased yield, positioning the state at the top of the national list in rice production [19].

It is worth noting that rainfed rice production is only carried out in the state of **Campeche**; in the rest of the Mexican states rice is mainly produced under irrigation conditions and rainfed areas are very scarce [20].

Rice demands a high volume of water during its biological cycle and is the only commercial cereal cultivated in water-saturated soils, where the plants can remain partially or totally submerged in in water. Therefore, an adequate water supply is the key factor for its yield [21].

The success of rice cultivation in **Campeche** is due, in large part, to the favorable climate of the region and the abundance of surface streams in the south-southwest portion of the state. There are several basins converge in this area, the largest being the **Grijalva-Usumacinta rivers** system, followed by those of the **Candelaria**, **Chumpán**, and **Mamantel rivers**. The **Palizada River** is the most abundant branch of the **Usumacinta river**, which crosses an alluvial plain and flows into the **Eastern Lagoon**, where it receives contributions from other currents before flowing into the **Términos Lagoon**, thus favoring the availability of water for rice [22].

With an average annual temperature of 26 - 27˚C, this region provides an ideal environment for rice growth and development. Furthermore, local conditions meet the thermal requirements for crop germination, ranging from 30 to 35˚C, favoring its establishment and optimal production [23].

In addition to the favorable climate and abundant water availability, the soils of **Campeche** play a key role in the success of rice cultivation. Their high-water retention capacity and rich organic composition create an optimal environment for healthy development of the plant [23].

Rice-producing areas are located in **Gleysol** soils, which are characterized by prolonged saturation of water, poor drainage with some top soil rich in organic matter mainly in the west part of Campeche [24].

The **Vertisols** are another type of suitable clayey soils for rice cultivation located in the lowest parts of the landscape, mainly found in the central-southern region of Campeche, in karst cumulative plains [24]. These soils are very fertile due to their high organic matter contents.

With an average yield of 6.0 t ha^{-1} [5] for high potential areas, a production cost of $44,000 Mexican pesos and the current price per ton of $9,080 Mexican pesos, the gross income is of about $54,480 pesos per hectare and a net profit of $10,480 pesos.

When considering the whole high potential area of 26,000 hectares the total net income is of $272,480,000 pesos.

Furthermore, it is of utmost importance that future studies include an assessment of the potential impacts of climate change on rice production in the state and provide sufficient information to ensure sustainable technological, social and economic management for rice production.

5. Conclusions

Rice is considered a staple food in Mexico. However, in recent decades, the cultivated area has diminished substantially so there is a need to import more than 1 million tons of rice annually. Worry for this problem, the Mexican government launched the ***Campeche Plan*** looking forward to enhancing rice production in **Campeche** through sustainable agricultural practices, ensuring quality and food self-sufficiency.

Keeping in mind the foregoing, this research aimed to identify areas, in the state of **Campeche**, with high productive potential under rainfed conditions. At the same time, the purpose was to discard any areas with very low productive potential and low economic feasibility.

It was found that there are optimal agroecological conditions to produce rice under rainfed conditions. High production potential areas are located in 5 of the 11 municipalities that make up the state. The municipalities with the largest areas suitable for rainfed rice production are **Carmen**, **Palizada**, **Escárcega**, **Candelaria**, and **Champotón** which cover more than 50% of the 26,414 hectares identified as high potential ones.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] López-Hernández, M., López-Castañeda, M.B., Kohashi-Shibata, C.J., Miranda-Colín, S., Barrios-Gómez, E.J. and Martínez-Rueda, C.G. (2018) Rendimiento de grano y sus componentes, y densidad de raíces en arroz bajo riego y secano. *Agrociencia*, **52**, 563-580. https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1405-31952018000400563

[2] García Angulo, J.L., Hernández Aragón, L. and Tavitas Fuentes, L. (2011) El Silverio: Nueva variedad de arroz para el trópico mexicano. *Revista mexicana de ciencias agrícolas*, **2**, 607-612. https://doi.org/10.29312/remexca.v2i4.1649

[3] Favila Tello, A. and Herrera Corral, M.A. (2023) Competitividad internacional del arroz mexicano: un análisis con base en datos de comercio exterior. *RECAI Revista de Estudios en Contaduría*, *Administración e Infomática*, **12**, 18-31. https://doi.org/10.36677/recai.v12i35.21268

[4] SIAP (Servicio de Información Agroalimentaria y Pesquera) (2023) Datos abiertos. Estadística de Producción Agrícola. https://nube.siap.gob.mx/avance_agricola/

[5] SIAP (Servicio de Información Agroalimentaria y Pesquera) (2019) Avance de siembras y cosechas. Arroz palay. https://nube.siap.gob.mx/avance_agricola/

[6] SIAP (Servicio de Información Agroalimentaria y Pesquera) (2021) Avance de siembras y cosechas. Arroz palay: Rico en carbohidratos y libre de colesterol. https://nube.siap.gob.mx/avance_agricola/

[7] Arias, G.A.J. and González, B.R. (2016) Análisis espacio temporal de la piezometría en el acuífero de Irapuato Valle de Santiago. *Jóvenes en la Ciencia*, **2**, 6-10. https://www.jovenesenlaciencia.ugto.mx/index.php/jovenesenlaciencia/article/view/987

[8] Ruiz, C.J.A., Medina, G.G., González, I.J.A., Flores, H.E.L., Ramírez, G.O., Ortiz, C.T., Martínez, R.A.P., *et al.* (2013) Requerimientos Agroecológicos de Cultivos. Libro Técnico No. 3. Campo Experimental Centro Altos de Jalisco, Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias, 564.

[9] FAO (Food and Agriculture Organization of the United Nations) (2020) Ecocrop, Database of Crop Constraints and Characteristics. Food and Agriculture Organization of the United Nations. https://gaez.fao.org/pages/ecocrop

[10] Jiménez, M.B. (2021) Importancia de los factores climáticos en el cultivo de arroz. *Ciencia y Tecnología Agropecuaria*, **6**, 28-34. https://ojs.unipamplona.edu.co/index.php/rcyta/article/view/1080

[11] IUSS (The International Union of Soil Sciences) (2015) World Reference Base for Soil Resources 2014, Update 2015. International Soil Classification System for Naming Soils and Creating Legends for Soil Maps. World Soil Resources Reports No. 106. FAO, 40.

[12] FAO (Food and Agriculture Organization) (1997) Zonificación Agroecológica. Guía General. Boletín de Suelos de la FAO 73. Organización de las Naciones Unidas para la Alimentación y la Agricultura, 94.

[13] WorldClim (2022) Historical Climate Data México. WorldClim. https://WorldClim.org/data/worldclim21.html

[14] INEGI (Instituto Nacional de Estadística y Geografía) (2020) México en cifras. Instituto Nacional de Estadística y Geografía. Aguascalientes, México. https://www.inegi.org.mx/app/areasgeograficas/?ag=21188#collapse-Resumen

[15] CONABIO （Comisión Nacional para el Conocimiento y Uso de la Biodiversidad） (2024) Portal de Información Geoespacial. Sistema Nacional de Información sobre Biodiversidad (SNIB). Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. Ciudad de México. http://www.conabio.gob.mx/informacion/gis/

[16] QGIS Development Team (2022) QGIS: A Free and Open Source Geographic Information System. Open Source Geospatial Foundation Project. https://qgis.org

[17] SIAP (Servicio de Información Agroalimentaria y Pesquera) (2023) Sistema de Información Agroalimentaria de Consulta (SIACON 2023). Servicio de Información Agroalimentaria y Pesquera. https://www.gob.mx/siap/documentos/siacon-ng-161430

[18] Márquez Isaac, R., Ayala Arcipreste, M.E. and Isaac Márquez, A.P. (2022) Palma de aceite, uso del suelo y deforestación. El caso de los pequeños productores de Campeche, México. In: Sarmiento Franco, J.F. and Valles Aragón, M.C., Eds., *Volumen V de la Colección*: *Escenarios territoriales ante la reconfiguración del orden mundial*, *Universidad Nacional Autónoma de México*, 618.

[19] Vadillo López, C. (2000) Campeche: sociedad, economía, política y cultura. CIICH/ UNAM, 235-261.

[20] Hernandez Garcia, A.L. (2018) Análisis de los factores de que determinan la superficie cosechada de arroz palay en México. Ph.D. Thesis, Chapingo University.

[21] Chatel, M., Guimarães, E.P., Ospina, Y., Rodríguez, F. and Lozano, V.H. (2010) Mejoramiento de poblaciones de arroz de secano empleando selección recurrente y desarrollo de variedades. In: Degiovanni, V.B., Martínez C.P.R. and Motta, F.O., Eds., *Producción Eco-eficiente del Arroz en América Latina*, Centro Internacional de Agricultura Tropical (CIAT), 216-222.

[22] Rebolledo Vieyra, M. (2010) Hidrología. In: Villalobos-Zapata, G.J., and Mendoza Vega, J., Eds., *La Biodiversidad en Campeche*: *Estudio de Estado*, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO), Gobierno del Estado de Campeche, Universidad Autónoma de Campeche, El Colegio de la Frontera Sur, 730.

[23] SADER (Secretaría de Agricultura y Desarrollo Rural) (2023) Arroz de Campeche: Potencial de crecimiento y calidad. https://www.gob.mx/agricultura/articulos/arroz-de-campeche-potencial-de-crecimiento-y-calidad

[24] Bautista Zuñiga, F., Palacio Aponte, G., Mendoza Vega, J., Kú Quej, V.M., Pool Novelo, L. and Cantarell Jiménez, W. (2010) Suelos. In: Villalobos-Zapata, G.J. and Mendoza Vega, J., Eds., *La Biodiversidad en Campeche*: *Estudio de Estado*, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO), Gobierno del Estado de Campeche, Universidad Autónoma de Campeche, El Colegio de la Frontera Sur, 730.