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Geographical analysis of rice production and storage in Mexico, 1980–2018

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ABSTRACT

Objective: To analyze the production and storage of rice in Mexico, geographically and along 1980 to 2018; presenting cartography of the geographical location, rice storage centers, nodes, networks, and areas of influence generated by rice production.

Design/Methodology/Approach: The statistical database of "Apoyos y Servicios a la Comercialización Agropecuaria" (ASERCA; a resource database to support agricultural marketing) was used, as well as statistical information from the Mexico's information service "Servicio de Información Agroalimentaria y Pesquera, SIAP). Likewise, the cartographic basis for analysis was built in GIS. A vector database was digitized and integrated into a relational database for spatial analysis.

Results: Results of production, storage, distribution network and the rice consumption-storage forecast for Mexico in 2030 are presented. Using the statistical base, depicted in a GIS projection.

Limitations in the study: It is necessary to perform a spatial analysis per state to determine distance isochrons and to calculate planning scenarios.

Findings/Conclusions: The geographical analysis of rice production in Mexico maintains a territorial organization of cultivation, distribution, storage and consumption, which locates economic activities based on geographical factors of the primary sector, generating some geographical patterns for rice production, such as location, distribution and consumption per human settlement.

Keywords: geographic analysis, rice production, geographic information systems.

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INTRODUCTION

Rice (*Oryza sativa*) is one of the most consumed cereals in the world due to its nutritional benefits. It is considered that rice origin dates back more than 7 thousand years before the Christian era from India and China. The rice grain is the mature ovary and main product; when grain includes the husk, it is called Palay rice (DOF, 2017). The plant belongs to the grass family and to the genus *Oryza*. This genus includes several species; among which rice is very important. The *Indica* group grows in the tropical regions of India, Philippines, parts of the United States and Mexico (Parson, 1988).

Image by Tongpradit Charoenphon at Pixabay

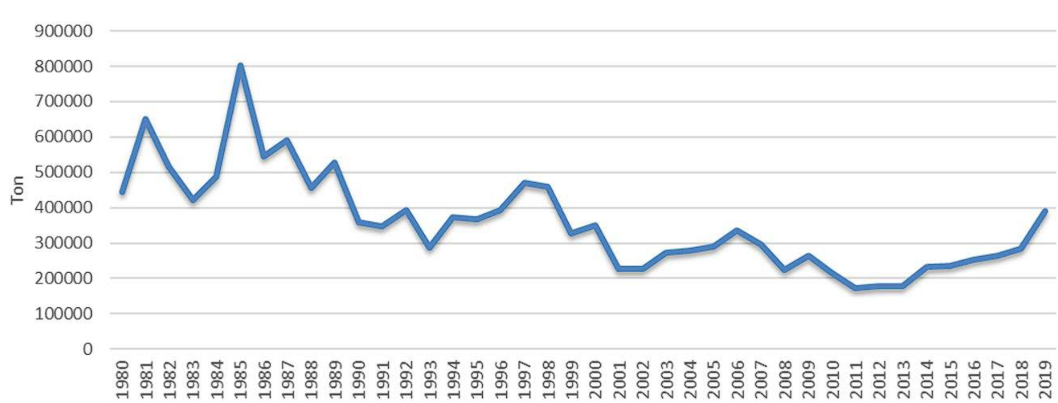
The rice grown in our country is cultivated under irrigation. Especially in central and northern areas of the country; rainfed cultivation areas are along the Mexican southeast. The main characteristic that rice-sowing territories must fulfill is a high content of organic matter that allow longer retention of water, which is essential to rice germination (Valverde, 2020).

Rice production in Mexico has shown variability from 1980 to 2019; also considering the various factors of agricultural activities and public policies that were modified during that period. All of them generated the national scope of rice production system; despite those, rice production in Mexico in 2019 was 390 118 tons (SIAP, 2019). We include below a graph of the historical rice production per year in Mexico.

Those states with geographical representation in the rice production in Mexico have an important value as economic spaces in the rural environment. These states are Campeche, Colima, Chiapas, Guerrero, Jalisco, Mexico, Michoacán, Morelos, Nayarit, Oaxaca, Puebla, Quintana Roo, San Luis Potosí, Sinaloa, Tabasco, Tamaulipas and Veracruz, which have historically been the producers of Mexican rice (Valverde, 2020).

Under the guidance of ASERCA (Apoyos y Servicios a la Comercialización Agropecuaria), in the storage program (for grains and oilseeds) "Capacidad Actual de Almacenamiento de Granos y Oleaginosas en México", facilities, locations, storage conditions, equipment and other characteristics that allow to issue a diagnosis on rice storage in Mexico should be accounted. The ambitious mission of this administration entity towards territorial management is strongly based on lands connotation. Therefore, it is geographically oriented, to know the location of the crops, to locate storage facilities and their operating conditions, plus the distribution routes of the grains and seeds of the country. Implementation allows to generate a cartographic sight of the connections needed for agriculture and food marketing.

The aims of the research are to geographically analyze the production and storage of rice in Mexico from 1980 to 2018. The mapping of nodes, networks and areas of influence generated by rice production is presented, which serve as an important input to understand those production and storage flows, generated by trade networks, that allow visualizing the potential distribution routes considering transit safety.



Graph 1. Annual Rice Production in Mexico (1980–2019).
Own elaboration bases on SIAP (2019).

MATERIALS AND METHODS

Statistical information

The statistics provided by the SIAP were integrated in a delimited temporary database classified from 1980 to 2018. This periodical consideration was dimensioned by the accessibility of the data provided by the agency, and a homogeneous database was structured and built for its analysis with the following data. (name; X-Y coordinates; Mexican state; municipality; type of warehouse; usage, storage capacity, product origin, distance to storage facility, destination, and distance from the storage facility to the destination).

The design of the survey on the relationship between the cultivation areas and the storage facilities was generated with the elaboration of a questionnaire, a scientific protocol that allows to gather complete information from a documentary point of view; to obtain a general and comprehensive description of the object of study; to narrow the problem capturing the relevant data; and to model the data in a object-implemented GIS database.

The questionnaire on capacity, infrastructure, equipment and characteristics of storage facilities, was applied at the national scale by the company Control y Tratamiento de Agroproductos S.A. de C.V. That company in collaboration with the association Apoyos y Servicios a la Comercialización Agropecuaria (ASERCA, 2013) set the objective of knowing the location, capacity, function and current storage conditions for grains and oilseeds in Mexico.

The applied questionnaire consisted of 53 questions divided into 5 modules that sought to document the situation in which more than two thousand storage warehouses interviewed operate. Within this large sample, geographic characteristics were obtained from the location of the storage facilities, in addition the knowledge of origin points and destination routes of the stored grains or oilseeds.

The GIS database created

With the assembled databases, we proceeded to digitize by means of polygonal vectors (Ortega, 2016) those rice-growing municipalities. Identifying with point vectors the storage warehouses and with linear vectors the roads fixing the flow route that connects cultivation areas and storage points. In addition, circular buffers were created with a diameter established by the distance (in kilometers) from the storage to the probable commercial destination, delimiting the areas of influence of the Mexican rice industry. This process allows to determine the impedance of the areas of influence that refer to the movement and type of resource flowing through the network, along with the type of geographic object and the direction of movement (Bosque, 2012).

The cartographic interface was carried out using QGIS v. 3.6.0 Noosa. Also, the database design was established with available information about the production development of rice. The data established by SIAP were used again as inputs in the geographic information model.

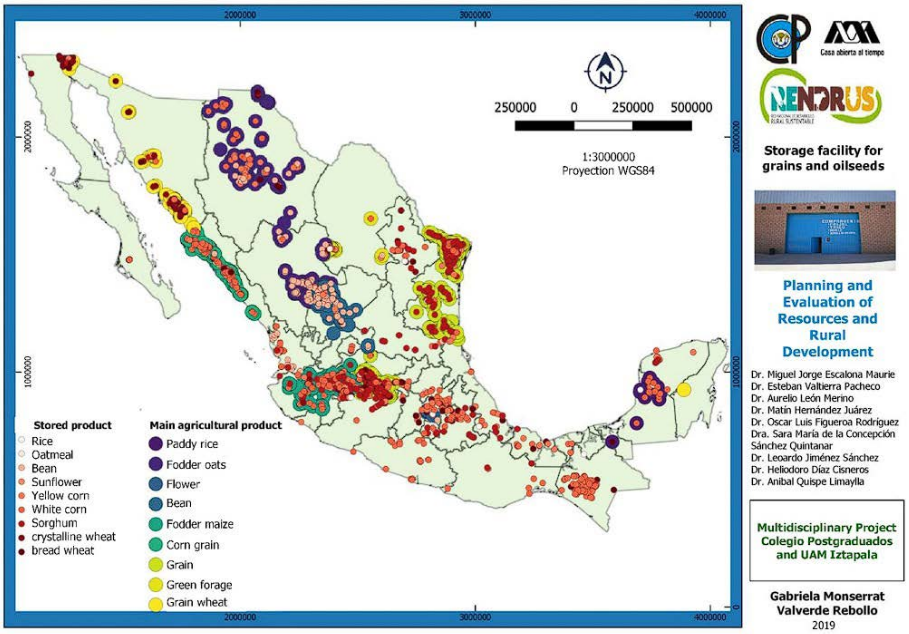
The spatial structure of the data starts from georeferencing the location of the Municipalities recorded with the presence of rice plantations from 1980 to 2018, based on the following records:

- Name of the rice-producing state
- Name of the rice-producing municipality
- Location (geographic coordinates)
- Hectares of Annual Cultivation
- Hectares of Annual Harvest
- Annual Production, in tons
- Productive Value, in MXN pesos
- Tons for annual consumption
- Consumption, in kg *per capita*
- Totals of National population census and intercensal population figures
- Presidential period
- Name of the President in the presidential period

The combined geographic, statistical and geometric data were classified according to their alphanumeric characteristic, in vectors represented as points, lines and polygons modeling their position and dimension values. This procedure was done through the use of GIS and cartographic products as complements of the scientific analysis of research (Buzai, 2011).

Once assembled the database of the total of 2,580 interviewed grain and seeds storekeepers, the first action was to concentrate the data of geographic relevance into maps. We determined to convert the coordinate system of each warehouse location represented in a sexagesimal system (degrees, minutes and seconds) to the metric units of UTM coordinates with the following formulas:

$$\text{Longitude}=((\text{Hours})+(\text{Minutes}/60)+(\text{Seconds}/3600))*-1$$



Map 1. Spatial representation of the location of grain and oilseed storage facilities in Mexico.

$$\text{Latitude}=((\text{Hours})+(\text{Minutes}/60)+(\text{Seconds}/3600))$$

The method of geographical analysis was based on a conceptual framework generated with studies of economic, agricultural and regional geography of Mexico, and a wide bibliographic consultation of documents such as Tratado de Geografía Humana (or Human Geography Framework), which laid the theoretical foundations of the research. (Hiernaux, 2006).

A total of 5 maps were obtained that allow visualizing the geographical scope of the economic, historical and cultural networks of rice production. Adding a little perspective of the proposed planning to improve the projective situation of rice consumption in Mexico.

RESULTS AND DISCUSSION

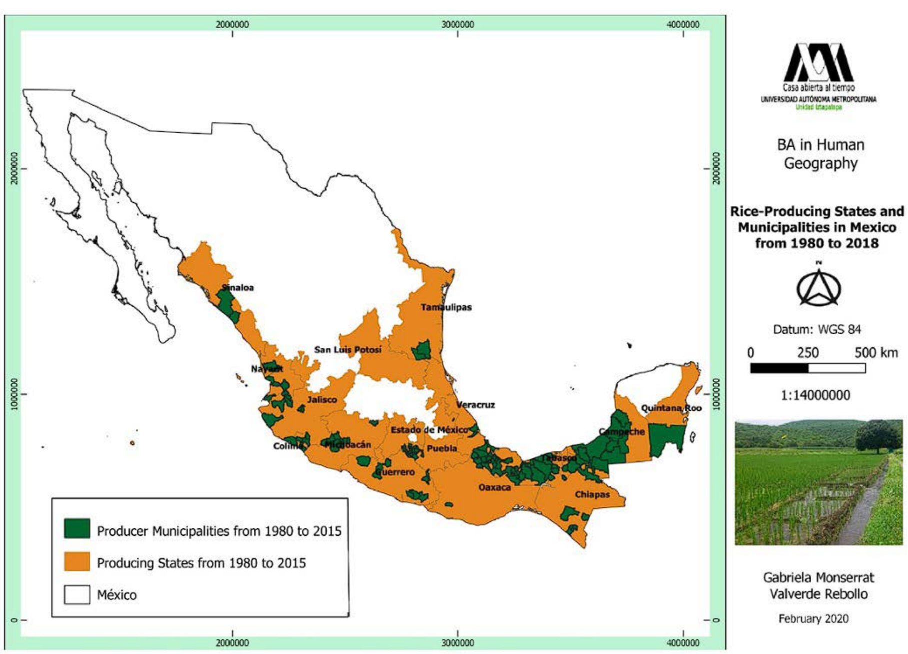
Rice Spatial Analysis from 1980 to 2018

Mexican producing states: The coverage that Mexico allocates for the rice production in 2018 was 17 out of the 32 Federation states allocating rice cultivation areas, according to the production surface records of the SIAP (2019).

The following map of rice producing municipalities and states in Mexico (1980 to 2018) shows that the southern part of the country is where to a greater extent the rice growing areas are located. However, the northern part of the country is where the highest production yield is obtained, especially in the state of Sinaloa.

It is remarkable the great coverage that Mexico allocates for the production of rice; until 2015, 17 out of Mexico's 32 Federation states are registered with rice production area.

Morelos has 14 rice-producing municipalities, followed by Veracruz with 8 and Chiapas with 7; Guerrero, Jalisco and Michoacán tie with 6 Municipalities dedicated to



Map 2. Rice producing municipalities and states (1980 to 2018).

rice production; Campeche and Nayarit have 5 Municipalities; Colima And Tabasco with 3 Municipalities; the state of Mexico 2, like Oaxaca; Sinaloa, Tamaulipas and Quintana Roo are leveled with 1 rice-producing municipality.

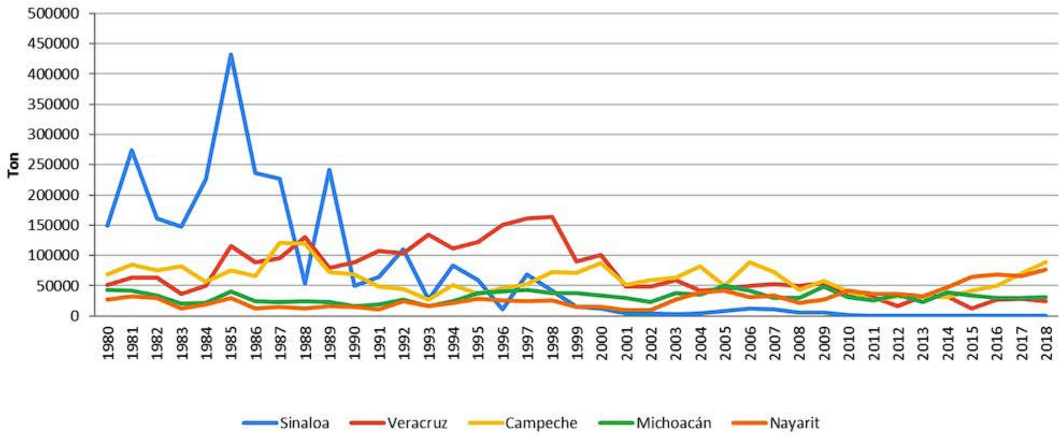
In 1980 there was a total area of 106,541 hectares of rice cultivation; with the exit of San Luis Potosí, the cultivation area was reduced to 96,838 ha in 1992; and in 2002 total rice production area was 54,982 ha given the null production of Puebla. In 2011, rice sowing area was further reduced to 36,811.44 ha, due to the loss of Sinaloa, which was rebounding as a producer state.

Former positioning changed among the states; to the South by Campeche, Tabasco and Chiapas, as to the North by Tamaulipas. As well as to the East by Veracruz and to the West by Nayarit, Jalisco, Colima, Michoacán and Guerrero, plus the central region made up of the sates of Mexico and Morelos. That production dynamics reflects extension of the territory suitable for rice agriculture.

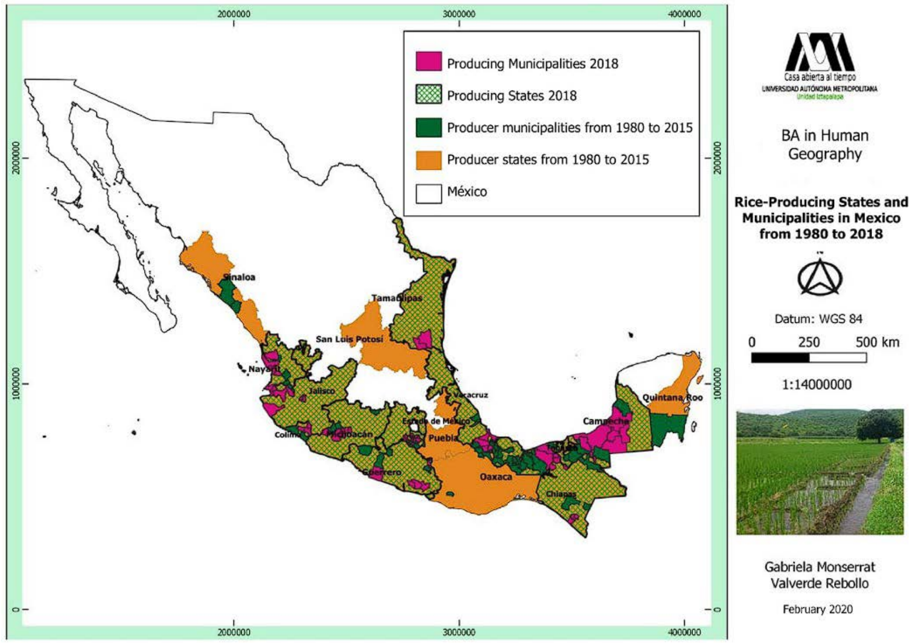
If the 5 years of study presented in the Atlas Agroalimentario (2012–2017) is extended to 38 years (1980 to 2018), the positions of rice-producing states change very little. Veracruz, Campeche, Michoacán and Nayarit remain in the ranking of 5 municipalities. The only significant change is that from 1980 to 2018 Sinaloa was present and with valuable contributions in terms of production. In contrast with the period from 2012 to 2017 when Colima appeared, but with fewer elements of cultivation and harvest areas as well as rice tons produced annually. For this reason, it appears of utmost importance to regain the position of the productive performance that Sinaloa represented for the Mexican rice industry.

The timely comparison among the states and municipalities producing rice between 1980 and 2018 shows the negative loss of five rice-producing states, from the South (Quintana Roo) and Southwest (Oaxaca), across the Center (Puebla), to the Northeast (San Luis Potosí) and Northwest (Sinaloa).

Geographical location of the infrastructure, equipment and characteristics of storage facilities. The diagnosis obtained from the responses to the questionnaire allows a deeper approach to the key characteristics with which warehouses operate to keep the grains



Graph 2. Main rice producing states in Mexico (1980 to 2018).
Own elaboration bases on SIAP (2019).



Map 3. Map of rice producing states and municipalities.

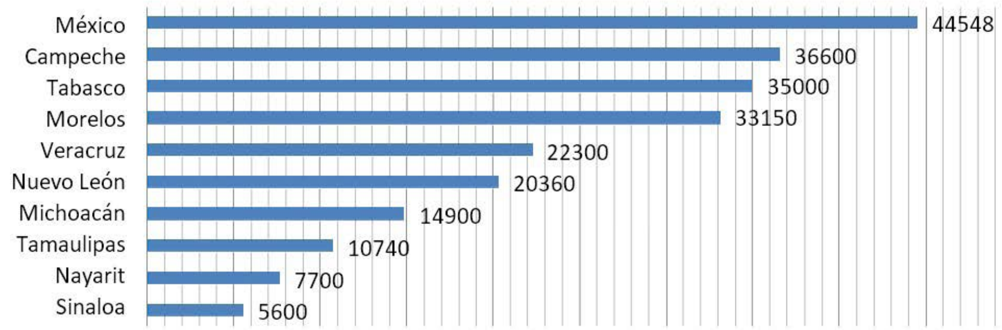
of white and yellow corn, beans, bread wheat, crystalline wheat, rice, sorghum, oats, barley and rye; along with the seeds, chickpea, soybean (and soybean paste), safflower, sunflower, sesame, canola (turnip seed), cottonseed, among others. In addition to identifying their conservation and the routes of transfer for distribution.

The databases obtained from applying the questionnaire (ASERCA, 2013), allow us to find the tonnage capacity to safeguard the commercialized seeds. We found a total of 2,580 storage locations, divided into 2,118 active and 462 inactive. Out of the 2,118 active warehouses, 17 rice processing facilities were identified in the country, in 10 states of the Republic.

The largest storage capacity is in the state of Mexico (44,548 tons). At La Paz municipality, the rice stored there comes from crops of Veracruz, transferred by rail from Veracruz port to the rice-processing facilities in the state of Mexico, where the product is allocated for commercialization within that state territory.

Campeche has two rice-processing facilities, one in the municipality of Campeche and the other in Hecelchakan, with a joint capacity of 36,600 tons. Those facilities receive Palay rice from the same municipalities and from Quintana Roo, in order to distribute that type of rice to another state in the North.
Tabasco, in the municipality of Teapa, has a hub and distribution center, which means that Teapa receives, stores and distributes the grains. That facility has a capacity for 35,000 tons of rice, grown in the same state and sold to another state in the north.

Rice production, storage and distribution network. The analysis of networks and flows in geography has become an essential methodological path to understand the unity of the world and the diversity of places. The study of social networks has diverse backgrounds and 67 paths for geographic research. On the one hand, there are references to the mainly



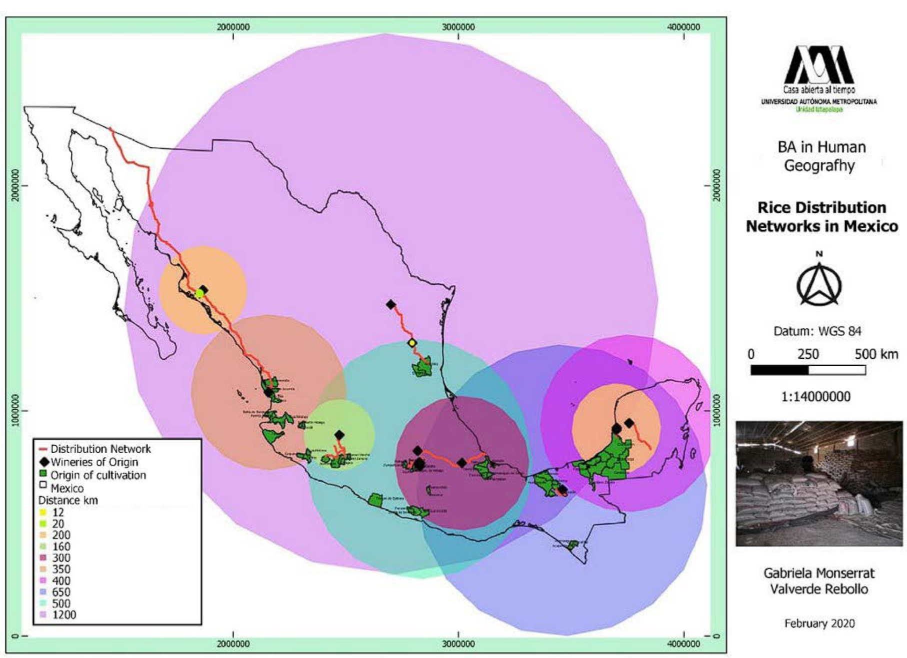
Graph 3. Capacity (tons) of rice storage per state.
Own elaboration bases on SIAP (2019).

material characteristics of their assets, which is expressed for example in the organization of transport (Rosales, 2010).

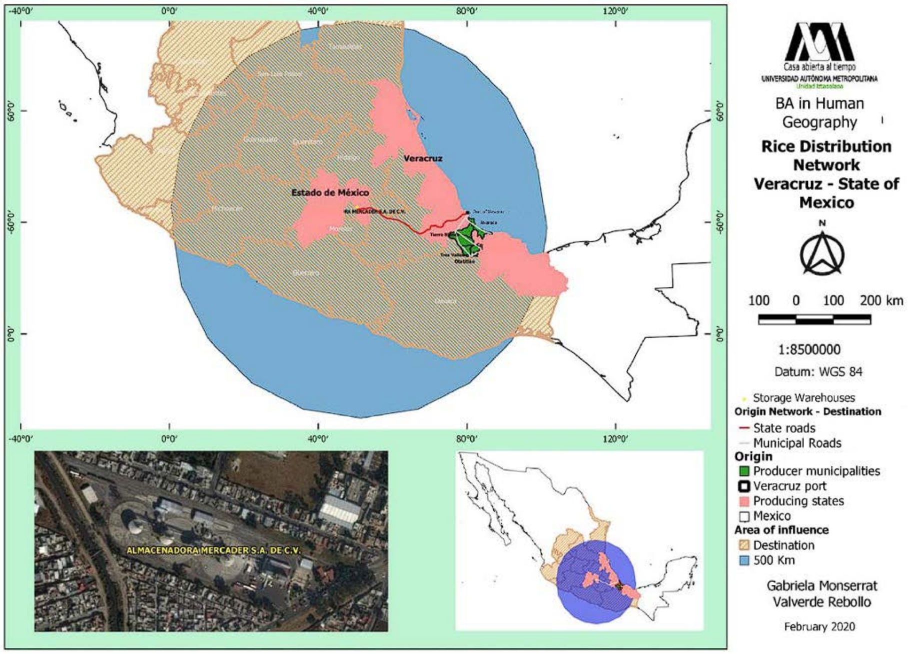
The rice distribution networks in Mexico are strongly marked on the territory, the sowing surface shows the potential area for the commercial development of the grains that after their harvest are taken to the warehouses that process the product. Then, with the rice packed for sale, it is distributed to the most populated places and to those territories where rice cultivation does not exist.

Both crop lands and warehouses are fixed production points, therefore locatable. Roads or railways form the commercial connection networks which generate an area of economic influence.

Monetary flows circulate in the opposite direction to material flows. Information flows are inscribed in all directions and are reciprocal (Claval, 1980).



Map 4. Rice distribution network in Mexico.



Map 5. Rice distribution network Veracruz-Estado de México.

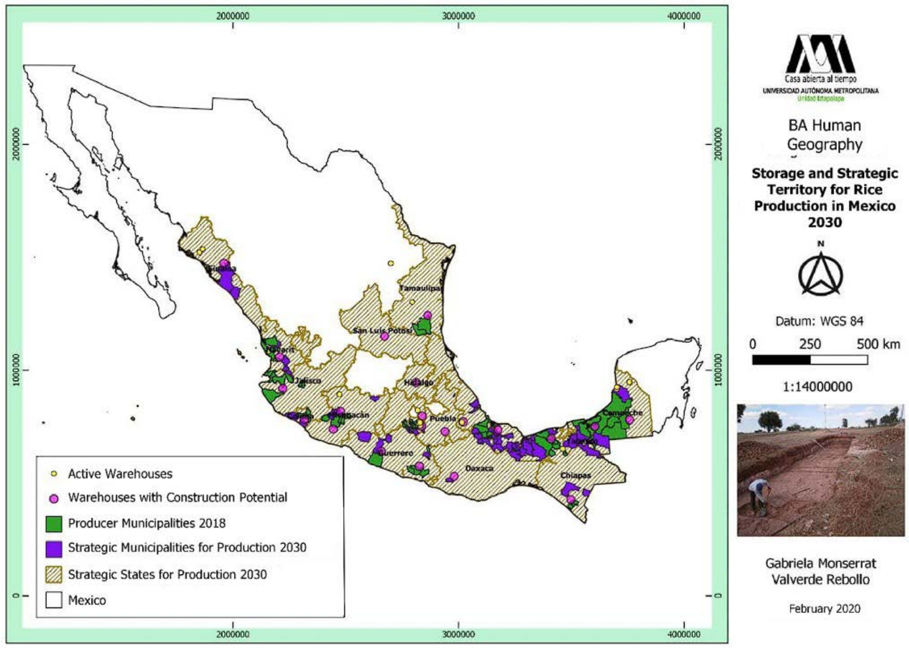
Undoubtedly, this cartographic activity has shown the importance of the geographic foundation in the study of the diverse rural expressions in the country, which could widen the path for the institutionalization of rural geography in Mexico (Ávila, 2010). The disposition of activities around the markets where flows converge and where decisions are readjusted and clarified (Claval, 1980) is proposed.

The analysis of the various forms of agricultural activity occupies one of the most prominent places in geo-economic studies, not only because it represents a great variety of crops and working conditions, but because, on the one hand, agriculture is a very accurate exponent from the influence of natural and social factors and, on the other hand, despite the advances registered in the industrialization of large areas of the planet, this work is still the most important of all that is carried out in most nations (Bassols, 1984).

Mexico's National Planning 2017-2030. The concern of the Mexican government to achieve food self-sufficiency in the rice sector has remained constant and visible. Since 2016, a study was carried out to plan the future of rice-production in the country, resulting in the "Planeación Agrícola Nacional 2017–2030 for Mexican Rice".

With the strategies proposed for 2030 and seeking to achieve Mexico's domestic self-sufficiency, it is necessary to at least quadruple annual rice production. This means expanding the number of hectares for sowing and also protecting soil resources through the care of harvesting techniques.

The challenges that Mexico has to face in order to achieve productive self-sufficiency are extensive and are even more dimensioned when considering the National territory extent. Consumption is a factor for growth, just like the population. Mexico should be prepared to increase national productivity, as well as increasing the value of rice grain paid to producers; tough at the same time it should seek to favor local consumption by inhabitants of the rice-producing municipalities.



Map 6. Strategic storage for rice production in Mexico (2030 scenario).

CONCLUSIONS

Rice is for the world, a basic good that satisfies one of the inherent needs of human beings. Rice production and consumption contribute 20% of the food energy of the planet due to its nutritional value. Because of this, it is of paramount importance to care for the terrestrial surface containing the favorable environmental elements for rice cultivation, between the latitudes 23° S and 23° N. These areas are under tropical climates with warm temperature and rains in summer; mainly located in coastal areas that configure a favorable territory for agricultural use.

Mexico has the geographical, hydric, social and cultural conditions to increase rice production, considering as a limit the 23° N parallel within the Tropic of Cancer, across (from East to West) the states of Tamaulipas, San Luis Potosí, Zacatecas, Durango and Sinaloa. The limit to the South is the state of Quintana Roo; thus, so for that state we recommend planning the reactivation of rice production.

The Mexican government should consider the increase in the area under rice cultivation. As well as that increase should respect the established agricultural land-use frontiers and the geographical and ecological characteristics of those areas adequate for sowing and harvesting rice.

The periodic review of grain storage locations can influence the search and implementation of technological innovations that maintain optimal environmental conditions to keep rice grain safe. At facilities with low temperatures, long periods of aeration, and low relative humidity; primarily considering that storage factors are completely opposite to the characteristics necessary for sowing seeds and growing rice plants.

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