Scientific Paper

Agroclimatic land use planning model of the Ciego de Ávila province, Cuba▲

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Abstract

In order to evaluate an agroclimatic land use planning model of the Ciego de Ávila province, Cuba, this study was conducted. The work consisted in the integration of the variable mean temperature, soil and water availability through the elaboration of thematic maps during the period 2016-2018. Maps were elaborated through Geographic Information Systems with ArcGIS. In addition, a documentary analysis was carried out to support the soil and climate demands of the crops. An optimum development threshold was established, based on the mean temperature, soil and underground water availability. A set of suitability maps was made for 11 economically important crops, of high bearing on local and national food security. The thermal differences in seasonal spatial distribution did not reach high values; temperature did not show great limitations for crop growth in the territory. The same does not occur with the hydrogeology particularities of the province, which constitute a highly limiting factor. With the development of this study, there are thematic maps available, which show the areas of higher aptitude of soils (agroproductive categories I and II), mean temperature and sectorized water availability for different agricultural crops. In addition, it constitutes a tool available for government officials, decision-makers, specialists, technicians and farmers who participate in the agroclimatic land use planning in Ciego de Ávila.

Keywords: water availability, soil, temperature

Introduction

Soil, water and climate are essential natural components for the development of vital activities for mankind, like agriculture, which guarantees the feeding of society.

The knowledge of the potentialities of each region under changing climate conditions, when considering the geospatial distribution of resources in a territory, facilitates their rational and sustainable use and increases agricultural efficiency and productivity, by guaranteeing the suitable conditions for crops. Defining the most propitious zones for a crop establishment, will allow to utilize it rationally, according to the productive capacity of natural resources and to the conservation of ecosystems (Cortez *et al.,* 2005).

Agroecological zoning is part of the response to the need of the different regions to promote land use planning (Jiménez, 2003). It constitutes a tool that allows the definition of territorial planning policies that favor the sustainable development of regions.

According to Jiménez *et al.* (2006) territorial land use planning is defined as a spatial projection of the environmental, social, economic and cultural policies. It is a group of planning instruments and management mechanisms that facilitates the appropriate organization of the land use and regulation of the economic life. Through this process, with the municipal and institutional action, agreed with the population and the key actors, the planning of the geophysical space is achieved which favors the reduction of vulnerability and rational utilization of basin resources (soils, forests and trees, water, mining, construction materials, tourism, recreation, infrastructure and others).

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Ciego de Ávila has a total surface of 10 988,4 ha aimed at agricultural production. From them, 2 733,6 ha are cultivated. In the state sector, there are 6 093,1 ha, from which only 523,1 are cultivated. In the non-state production forms 2 210,4 are cultivated, from 4 895,3 available ones (ONEI, 2016). These conditions make the Ciego de Ávila region constitute one of the most important agricultural scenarios of Cuba, which turn it into a locality highly committed to territorial and national food security. Nevertheless, at these moments, Ciego de Ávila does not have agroclimatic territorial land use planning, adjusted to a better integration of available natural resources (soil, climate and water) for the establishment of agricultural crops.

Geographic Information Systems (GIS) facilitate these planning actions, because they constitute an advantageous tool to reach optimum georeferencing of natural resources in a territory. Their fundamental usefulness lies on the capacity to construct models or representations of the real world from digital databases, which are used in the simulation of the effects that a natural process or an anthropic action exert on certain scenario at a specific time (IGAC, 1995).

Due to the above-explained facts, the elaboration of a compendium of thematic maps is necessary, which identify locally the zones of higher suitability for the production of agricultural items. Hence the objective of the work was to evaluate an agroclimatic land use planning model of the Ciego de Ávila province, Cuba, by integrating the variable mean temperature, soil and water availability during the period 2016-2018.

Materials and Methods

A documentary analysis was performed to know the edaphoclimatic requirements and soil and water needs of the potato (*Solanum tuberosum* L.), plantain and banana (*Musa* spp), beans (*Phaseolus vulgaris* L.), corn (*Zea mays* L*)*, rice (*Oryza sativa* L), citrus fruits (*Citrus* spp), mango (*Mangifera indica* L.); guava *(Psidium guajava* L.), pineapple (*Ananas comosus* L., Merryl), tobacco (*Nicotiana tabacum* L.) and sugarcane (*Saccharum officinarum* L.) crops.

Soil mapping. It was carried out according to the fertility need and the edaphological and agroproductive characteristics demanded by these crop species. It was zoned from the location of soils with categories I and II in each municipality, which constituted the initial basis element of the general mapping. The agroproductive evaluation responds to the one performed by the Provincial Soil Direction of the Delegation of Agriculture in Ciego de Ávila. The elements for the agroproductive categorization I and II correspond to the classification proposed by Mesa and Mesa (1985).

Mapping of the climate variable (mean temperature). The mean temperature, important variable for the phenological development of crops, was mapped. In each case, the optimum development threshold was determined, according to the specialized documentation that was reviewed.

The temperature data came from the records of the meteorological stations, located in the provinces Sancti Spíritus (Jibaro 78341, Sancti Spíritus 78349), Ciego de Ávila (Júcaro 78345, Venezuela 78346 and Camilo Cienfuegos 78347) and Camagüey (Florida 78350 and Esmeralda 78352). They are values that correspond to the period 2006-2015, which allowed to know the distribution, at municipal scale, of the climate variable, once mapped through the GIS. From such distribution, the thermal behavior ranges were extracted and tables were elaborated to concentrate the information for its better analysis and a new spatial distribution of the ranges. The recommendations of agroecological zoning works (FAO, 1997) were taken into consideration.

Methodological procedure through ArcGIS for integrated mapping. The agroclimatic land use planning model of the Ciego de Ávila province is the result of the integration of three variables: soil, mean temperature and water. For the variable soil, the maps of the agroproductive categories (I and II) were considered. Regarding climate, the variation ranges of mean temperature from 2006 to 2015 were taken, according to the elaborated tables to define the thermal potential. For the treatment of this meteorological variable its homogeneous manifestation in the territory was considered, according to the considerations expressed by Sorí *et al.* (2017).

For the characterization of the water resource the spatial distribution of the hydrogeological sectors by municipality was used, according to the two basins: Morón (located in the North) and Ciego (in the South). The Morón basin, integrated by 12 sectors, and of higher importance, supplies water to Chambas, Morón, Bolivia, Florencia, Ciro Redondo, Primero de Enero; Ciego de Ávila, Majagua and Baragüá. Ciego, with only three sectors, contributes water to part of Majagua, Ciego de Ávila, Venezuela and Baragüá (González-Abreu *et al.* 2017).

After selecting the crops and having the variables ready, they were processed. For such purpose, the tool module *ArcToolbox* of the GIS ArcGIS was used. The analysis started from the conversion of the variables water and soil to raster format. For temperature, with the file with the information in Excel format, a point map was elaborated and the range of favorable temperature (thermal threshold by crop) was chosen as value. Afterwards, with the resulting point map, the interpolation was carried out with Interpolation, which belongs to the tool set of spatial analysis (Spatial Analyst Tool); the method used was inverse distance weighted (IDW). Once the interpolation was finished, the values were reclassified with the Reclassify tool, and the variables were processed. When they were in the raster format, the weighed interpolation was performed through Weighted Overlay, which is part of the spatial analysis tool set (Spatial Analyst Tool).

Results and Discussion

Compendium of thematic maps for the agroclimatic zoning of agricultural crops in Ciego de Ávila. A set of suitability maps was elaborated for 11 crops of economic importance, of great bearing on local and national food security. Six of the maps that represent the crops are shown below: *S. tuberosum* (figure 1), *P. vulgaris*, (figure 2), *O. sativa* (figure 3), citrus fruits (figure 4), *S. officinarum* (figure 5) and *N. tabacum* (figure 6).

This agroclimatic land use planning responds to the geophysical particularities of the soil, climate and water resource in Ciego de Ávila. The soils, with abundant arable surface of agroproductive category I and II, require other resources for their total adequacy in the cultivation of the different botanical species, because they need the climate, mainly an optimum temperature, and also water, essential factor for plant growth.

Temperature is fundamental for plants, and the Ciego de Ávila territory has large thermal possibilities for the development of highly important cultivable species, like the ones that integrate the group of crops object of this planning. It is advantageous to utilize the climate good virtues of the province, because most of its territories, according to the mapping, do not offer limitations for the crops.

According to Sori *et al.* (2017), the mean temperature in Ciego de Ávila, according to the studies conducted from the data recorded in the meteorological stations of Júcaro, Venezuela, Camilo Cienfuegos and Cayo Coco, shows a marked seasonal cycle, among the months of the summer and winter. Low temperatures in January begin to increase until July and August to then decrease until December. Thus, the seasonality in the thermal regime of this territory becomes appreciable.

In the northern region of Ciego de Ávila, according to the records of the Camilo Cienfuegos station, a slight decrease of temperatures was observed during December and January compared with the performance of this variable in the Venezuela and Júcaro stations, located in the South. In the Cayo Coco station, the influence of the marine thermal regime was fully defined, with the existence of higher values than 23 ºC of mean temperature in the coldest months, and higher throughout the annual cycle, with the maximum in July and August (temperatures close to 29 ºC).

This performance allows to identify the effect of semi-continentality. The central-southern zone stands out for a warmer environment than the northern one, situation that is also identified for the dry season. The analysis of the performance of the daily temperature variations allow to define the existence of a seasonal temperature differentiation. Nevertheless, these considerations about the thermal regime are not absolute, due to the masking that occurs when using the monthly mean values (Sorí *et al.,* 2017).

The temperature values used for this planning (2006-2015), along with the data belonging to the records of the meteorological stations of Sancti Spiritus and Camagüey (in order to achieve better spatial distribution), allowed to know that the annual mean value of this variable was 20,3 ºC. The mean minimum temperature showed the lowest values from November to April.

All the above-explained facts allow to state that the thermal differences in the seasonal spatial distribution did not reach high values. Thus, it can be said that, according to the performance and characteristics of the thermal regime, and according to the values of the temperature thresholds, required for each of the implied botanical species, temperature did not show great limitations for crop growth. Thus, the edaphoclimatic characteristics did not constitute a highly limiting element for this territory.

The same does not occur with the hydrogeology particularities of the Ciego de Ávila province, which

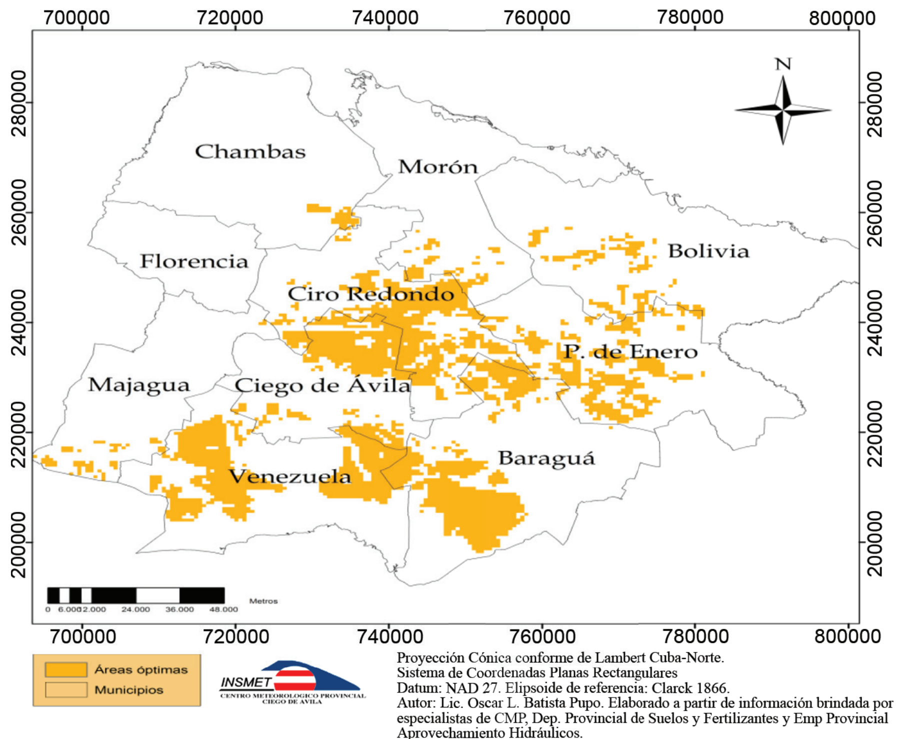

Figure 1. Identification of optimum areas for the cultivation of *P. vulgaris*.

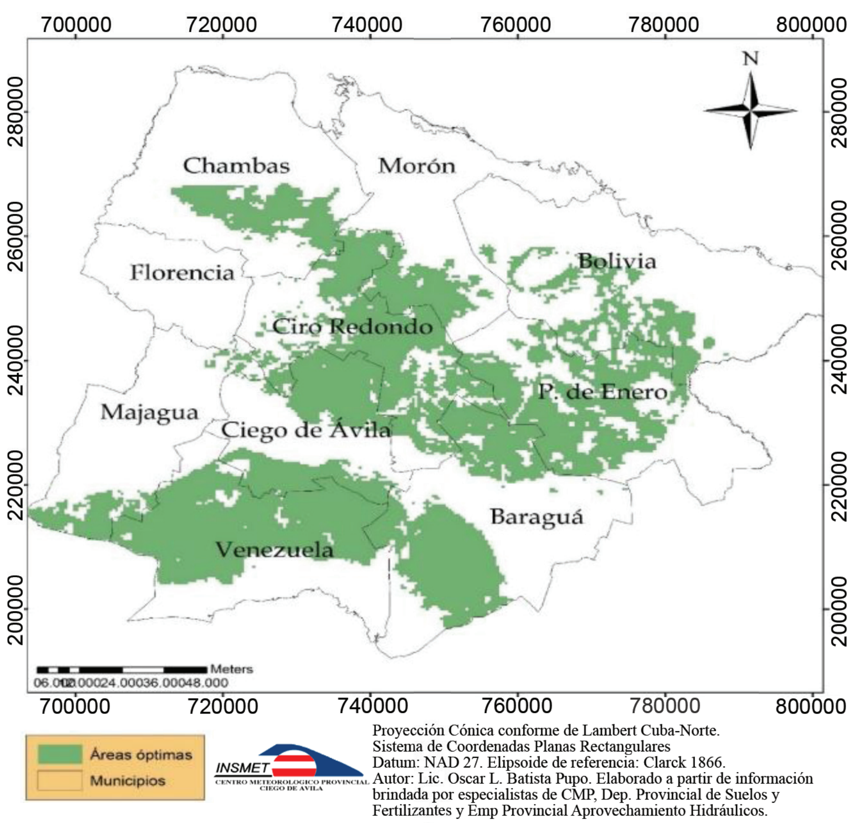

Figure 2. Identification of optimum areas for the cultivation of *S. tuberosum*.

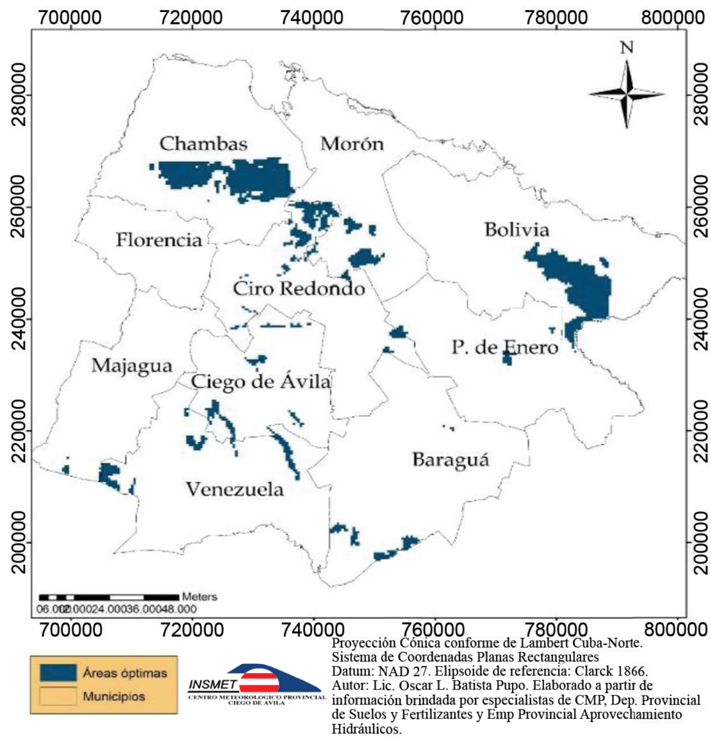

Figura 3. Identification of optimum areas for the cultivation of *O. sativa.*

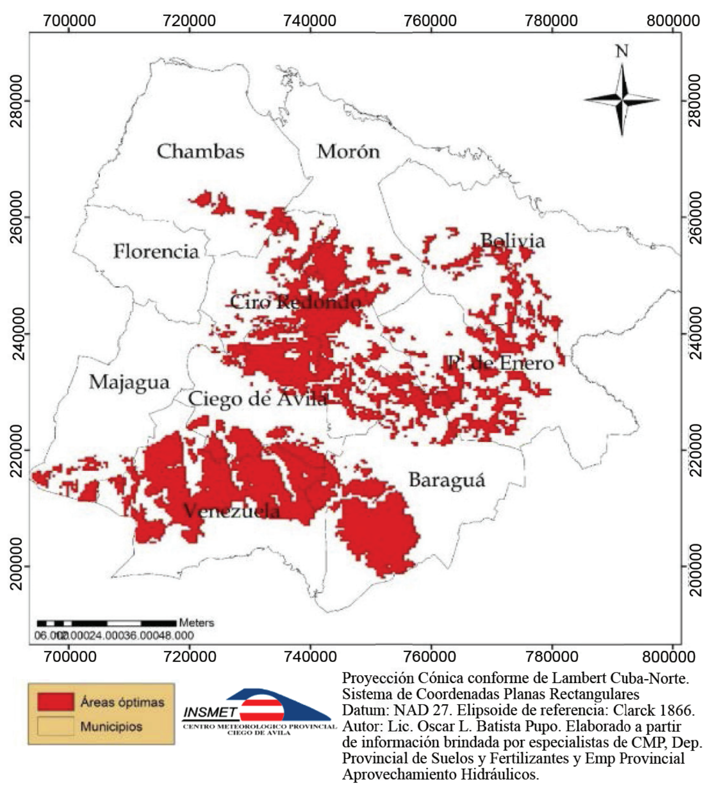

Figura. 4. Identification of optimum areas for the cultivation of citrus fruits.

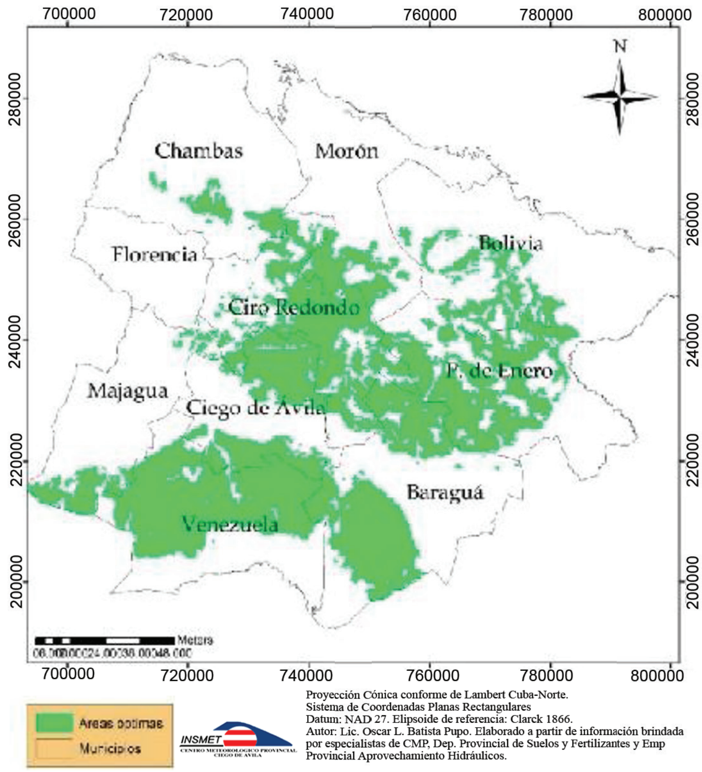

Figura 5. Identification of optimum areas for the cultivation of *S. officinarum*.

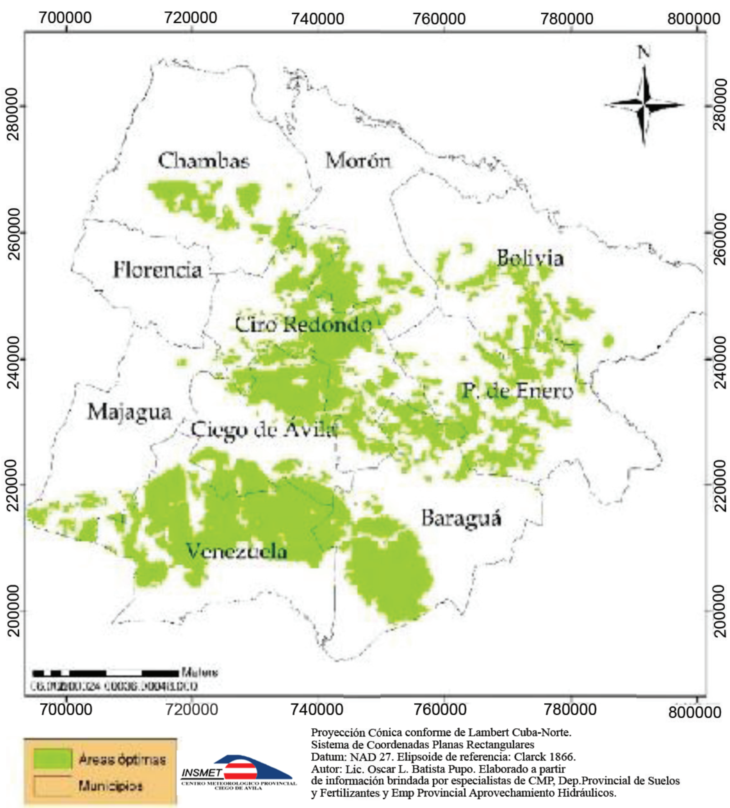

Figura 6. Identification of optimum areas for the cultivation of *N. tabacum*.

constitute a highly important limiting factor. This is explained because in the territory there are two large basins, Morón and Ciego, which are affected by their bad management. These basins supply water for the crops.

In this sense, water is essential for production of the studied crops, for which in this planning the water resource is totally decisive. For the crop exploitation the localities that did not have this zoned resource are not considered suitable.

It is recommended that those crops under dry conditions, such as cassava, pineapple (Spanish red variety), mango and guava, are managed in localities where there is no underground water availability. For these crops, the suitability of the areas will be based on the existence of soils with agroproductive categories I and II, as well as on temperature variation, with values capable of satisfying the biological thermal requirements of these botanical species.

It can be assumed that the crops that do not require high water volumes, and others like corn (in the rainy season) can also be sown and cultivated in zones with absence of aquifers, which confers higher capacity of agricultural exploitation to the territory. However, with purposes of productive efficiency and local development, land use planning offers a superior productive organization, and constitutes a useful tool for the management of the agrifood process.

Conclusions

With the development of this study, there are thematic maps available, which indicate the higher-aptitude areas of the soils (agroproductive categories I and II), mean temperature and zoned water availability for different agricultural crops. In addition, it constitutes a tool available for government officials, decision-makers, spacialists, technicians and farmers who participate in the agroclimatic land use planning in Ciego de Ávila.

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