**Original article**

# Climate zoning of Mayarí municipality based on Lang index

## Zonificación climática del municipio Mayarí a partir del índice de Lang

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**ABSTRACT:** The objective of the research was the climatic zoning of the Mayarí municipality; Lang Index was the estimation by use of data from meteorological station and WorldClim 2. The monthly images of precipitation and average temperature provided by WorldClim 2 were used with a spatial resolution of 30 seconds in the system of WGS 1984 EPSG coordinates: 4326. The images were processed in ArcGIS 3.10 software; and in the Raster Calculator option, the Lang Index was obtained. For the extraction of the values, a representation of 40 random points was made that covered the entire region under study, separated at a distance of 10 km. It was determined by linear regression in the STATGRAPHICS Plus 5.0 software; the relationship between Lang Index estimated by WorldClim 2 and that calculated with data from the Guaro meteorological station located in Mayarí municipality. The use of WorldClim 2 showed the existence of three climatic zones (arid, semi-arid and semi-humid). Its estimation had a high determination and correlation for the calculated values of said index, which allows it to be used in territories where there is a low number of meteorological stations for taking climatic data.

**Key word:** climate zoning, soil.

**RESUMEN:** La investigación tuvo como objetivo la zonificación climática del municipio Mayarí, mediante el empleo del índice de Lang estimado a partir de datos de una estación meteorológica y del WorldClim 2. Se utilizaron las imágenes mensuales de precipitación y temperatura promedio que proporciona el WorldClim 2, con una resolución espacial de 30 segundos en el sistema de coordenadas WGS 1984 EPSG: 4326. Las imágenes se procesaron en el software ArcGIS 3.10 y en la opción *Raster Calculator* se obtuvo el Índice de Lang. Para la extracción de los valores se realizó una representación de 40 puntos aleatorios que abarcaron toda la región en estudio, separados a una distancia de 10 km. Se determinó mediante regresión lineal en el software STATGRAPHICS Plus 5.0; la relación entre Índice de Lang estimado por WorldClim 2 y el calculado con datos de la estación meteorológica de Guaro, ubicada en el municipio Mayarí. El uso del WorldClim 2 mostró la existencia de tres zonas climáticas (áridas, semiáridas y semi húmeda). Su estimación tuvo una alta determinación y correlación para los valores calculados de dicho índice, lo cual le permite ser utilizada en territorios donde existe un bajo número de estaciones meteorológicas para la toma de datos climáticos.

**Palabras clave:** zonificación, clima, suelo.

## INTRODUCTION

The characteristics that define climates are the result of the climate system functioning and reflect the influence of different components that act together on it. In the study of their behavior, distribution and evolution, different meteorological elements (temperature, precipitation, wind, atmospheric pressure, humidity) are analyzed for different ranges and time intervals, which can be considered in isolation or in combination. In the latter case, the coupling of values given for a place defines the nature of its climate. These combinations lead to more or less complex parameters and indexes, whose values are used to establish climatic types (1).

Richard Lang in 1915 presented a climatic classification based on the volume of annual precipitation (accumulated) expressed in millimeters and the average temperature in degrees Celsius. The quotient of the first parameter between the second is called Lang's Index, from which six types of climate are obtained. The index is now widely used as a measure of the oregion aridity degree, rather than as a climate classification system.

Aridity is one of the major affectations that occur in tropical countries due to the presence of stable anticyclones or as an effect of continentally, although in some cases it is a consequence of mountain barriers, which prevent the passage or arrival of humid air currents. Its determination facilitates the management of the concept of aridity, especially at times of planning and management of natural resources, mainly water resources (2).

In the field of agricultural planning, agroecological zoning is one of the main tools used to reduce the risks to which agriculture is subjected; its objective is to allocate space for crops, taking into account their soil and climatic requirements to ensure their growth, development and yield to a large extent (3).

To analyze an area climatically, it is necessary to have information from meteorological stations, equidistantly distributed and with a time series greater than or equal to 30 years. The scarcity of these data generates inconveniences now of characterizing the climate of a region. For this reason, indirect methods have been developed to obtain information, which are useful tools for the study of a climatic variable. A factor to consider in the climatic studies of a region is the spatio-temporal variation of climatic elements in the tropics, which vary over short distances, according to topography and other conditions. Current climate models are non-spatial because they are based on the concept that a measured value represents a homogeneous area around the evaluated point (4,5).

Through the validation of tools such as satellite images, aeronautical data, numerical models, among others, it has been possible to obtain meteorological data from long time series for the study of the impact of aridity, intense droughts and high temperatures on agriculture (6-8). For the above reasons, the research presented here aims at the climatic zoning of Mayarí municipality based on the Lang index, estimated from a meteorological station and WorldClim 2.

## MATERIALS AND METHODS

Mayari municipality is located in Holguin province, with a surface of 1304.2 km$^2$. It has a zone of fundamental relief, Nipe plateau, where Pinares de Mayari plateau is located and in it appears the highest altitude of the municipality, the hill "La Mensura", with 995 meters. The territory has several remarkable geographic places of the province and the nation, such as the Nipe Bay, which is the largest pocket bay in the country. It presents a developed fluvial network, with a high percentage of the hydraulic potential of the province and abundant rainfall (9).

WorldClim 2 is a high spatial resolution database of meteorological and climatic data at a global level and the most updated version is dated March 13th, 2020. The databases provided by the program can be downloaded in "*zip*" format, which contains 12 "*GeoTiff*" images, one for each month of the year. A site gathers climate data worldwide. It has different spatial resolutions, from 30 seconds (1 km$^2$) to 10 minutes (340 km$^2$) approximately at the Equator. These data are in the WGS 1984 EPSG: 4326 coordinate system and can be used to create maps and spatial modeling with Geographic Information Systems (GIS). The dataset provided by WorldClim 2 is current as of 2018. This database includes the main climatic variables (maximum, average, and minimum temperature; precipitation; solar radiation; wind speed; and water vapor pressure), as well as 19 bioclimatic variables (10).

In the ArcGIS 3.10 software, the climatic zoning of the municipality of Mayarí was determined from images of the average temperature (°C) and precipitation (mm) obtained from WorldClim 2 and in the *Raster Calculator* option, Lang Index was obtained, by means of the expression used in previous research (11). For the extraction of the values, a representation of 40 random points was made covering the entire region under study, separated at a distance of 10 km (Figure 1).

In the STATGRAPHICS Plus 5.0 software, a linear regression analysis was performed with the values obtained from the calculation of Lang's Index obtained from temperature and precipitation data recorded at the Guaro meteorological station located at 75°46'55,458 "W and 20°40'13,899 "N Mayarí municipality, in a period of time from 1980 to 2020.

For the Lang Aridity Index classification, the climatic classification shown in Table 1 (8) was used.

**Table 1.** Lang's Index climatic classification of aridity according

| Coefficient | Type of climate |
|---|---|
| 0.0-20,0 | Desert |
| 20,1-40,0 | Arid |
| 40,1-60,0 | Semi-arid |
| 60,1-100,0 | Semi-humid |
| 100,1-160 | Humid |
| >160 | Super humid |

## RESULTS AND DISCUSSION

Figure 2 shows the spatial-temporal distribution of climatic factors related to the aridity index. The minimum and maximum temperature values observed, according to WorldClim 2, ranged from 19.50 to 26.54 °C, while precipitation values ranged from 1094.59 mm to 1733.19 mm. In other research (12), to compare three climate models in Argentina, WorldClim was used as a tool for mapping the distribution of temperature and precipitation data, which had a better fit for the mean temperature values.

In our country, several studies have been carried out, which show that the areas of the country most affected by aridity, is the Eastern portion, due to long periods of severe drought that have caused valuable losses to the agricultural activity (13), either by the accelerated increase of temperatures or by the deficiency in the rainy period of precipitations.

To understand the origin of the drought processes in Cuba, it is necessary to start from the fact that the climate, in the last decades, has experienced remarkable alterations, because of a high level of response of the regional atmospheric circulation to the main changes of the climatic system occurred at global scale G. According to which, they generate very unfavorable impacts in the economic, social and environmental fields (13).

The agroclimatic zoning of a territory, climatic factors, especially rainfall, evapotranspiration and temperature, have a vital role in determining zones of suitability in irrigation conditions, especially to recommend the supply of water in irrigated crops, without the attention or the need for a large amount of precipitation in the growing period (14).

The determination of Lang Index from maps of precipitation and average temperature of the WorldClim 2 (Figure 3) showed that there are three types of climatic zones in Mayarí municipality. The first arid climatic zone covers the values of the aridity index that are between 20.1 and 40.0. The second the semi-arid climatic zone with values between 40.1 and 60.0 and the third semi-humid climatic zone with indexes between 60.1 and 100.0.

There are examples of research where WorldClim 2 was used to obtain bioclimatic models for the future adaptation of rice producing areas in Portugal, based on temperature and precipitation information, obtaining high-resolution models in the grids analyzed and concluding that this productive activity could have negative impacts on the region (15).

As illustrated in Figure 4, there is a statistically significant relationship between the variables analyzed, the model explains 89.89 % of the variability in the estimation of the aridity index using WorldClim 2. The correlation coefficient (0.9481) indicates a relatively strong relationship between the variables, with a mean absolute error of 2.4596 of the residuals. The Durbin-Watson statistic for statistical tests refers that the residuals determine the significant correlation based approximately significance less than 0.05.

According some authors (16), in order to carry out an adequate validation of climate data provided by WorldClim,
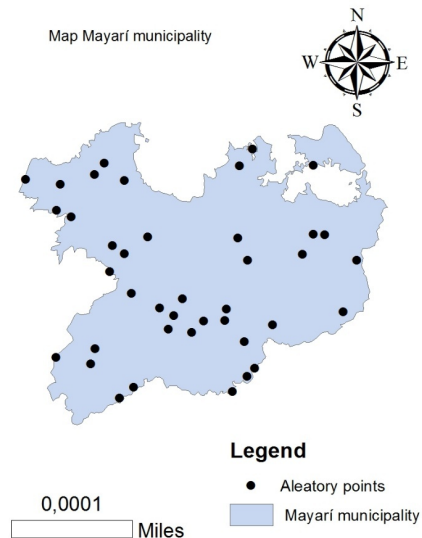


**Figure 1.** Municipality Mayarí with the representation of the random points taken for the extraction of the values in each pixel of the WorldClim 2 image
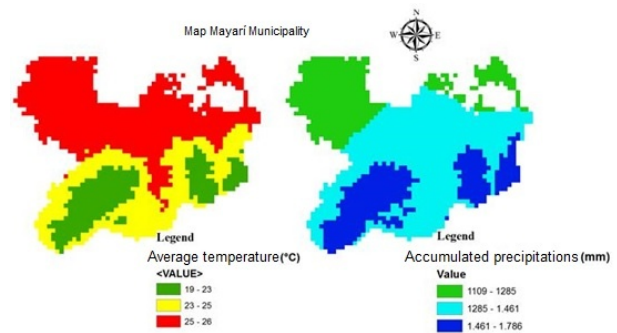


**Figura 2.** Spatial-temporal distribution of average temperature and accumulated rainfall in Mayarí municipality obtained from WorldClim 2 image processing

it is necessary to have observed data from meteorological stations for the period 1970-2000, since the WorldClim global climate models have data for the period in question. In this research, when using climate data for the period from 1980 to 2020, significant correlation and determination values were obtained.

In another study, a high correlation and determination was found in statistical tests of the data provided by this global climate database, using the De Martonne aridity index, which predicts the potential impact of climate change and provides information to develop adaptive strategies to deal with a changing climate (17). The results confirm that spatial models are often more accurate when the study areas are larger (18).

## CONCLUSIONS

- The use of WorldClim 2 showed the existence of three climatic zones in Mayarí municipality (arid, semi-arid and

semi-humid), according to the climatic classification of the Lang Index, referring to the state of aridity.

- Its estimation had a high determination (89.8875) and correlation (0.9481) for the calculated values of this index, with data from the meteorological station of Guaro, which allows it to be used in territories where there is a low number of stations for the climatic data collection.

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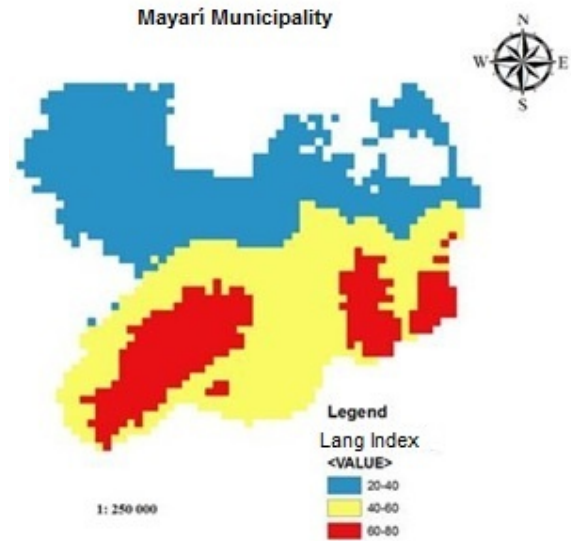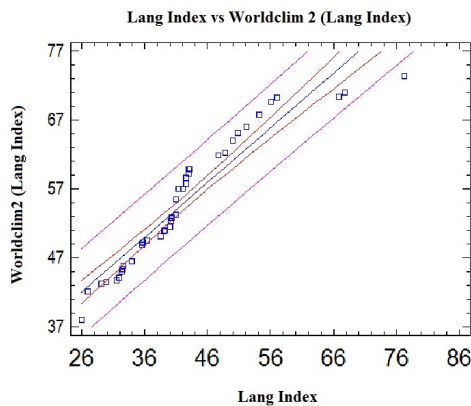
**Figura 3.** Lang index for Mayarí municipality determined from WorldClim 2 precipitation and average temperature maps

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| Parameter | Value |
|---|---|
| Correlation coefficient | 0,94809 |
| Determination coefficient | 89,6213 % |
| Standard Error | 3,02572 |
| Mean absolute error | 2,4722 |
| Durbin-Watson statistic | 0,330005 (P=0,0000) |
| Residual autocorrelation | 0,68383 |
| **Equation of the model** | |
| Lang Index = 21,416 + 0,793966*Worldclim2 | |

**Figure 4.** Linear regression analysis of Lang Index, calculated from meteorological data and in ArcGIS 10.5 software with WorldClim 2 imagery

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