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Original Article

Agroclimatic characterization of the Uige province, Angola based on the development of Robusta Coffee

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ABSTRACT

During 2018, this research was carried out with the objective of conducting an agroclimatic characterization based on the development of robust coffee in the Uigé province, Angola. The records of the climatic variables rainfall and temperatures were analyzed, as they are the ones that most influence the development and growth of coffee. The historical-logical method was applied to recover the information about the crop requirements and compare them with the edaphoclimatic conditions of the province. The climatic data of the region were recorded from the observations made in each municipality compatible with the information extracted from the World Meteorological Organization (WMO) site, for the period 1990-2010. Suitability maps for temperatures and rainfall were generated from the use of GIS that allowed the manipulation of thematic information layers. The results allowed us to recognize that the largest area of Uigé province (86.3 %), has climatic conditions for the development of robust coffee, with loss of fitness in the municipalities of the west end of the province,

whose main limitation was rainfall. The knowledge about the compatibility between the behavior of the climate in the Uigé province and the requirements of the robust coffee as part of the results of the agroclimatic characterization, allow the adoption of alternatives in order to minimize the limiting factors of the climate on the production of this species.

Key words: climate, precipitation, temperature, requirement, surface

INTRODUCTION

Within Southern Africa, Angola is a country with a positive history and a coffee culture. Before independence in 1975, Angola was one of the main world producers. However, the war almost completely destroyed the coffee plantations. The species of *Coffea arabica* L. (Café arabica) and *Coffea Canephora* Pierre ex Froehner (Café Robusta) distributed in different producing provinces such as, Uigé, Cuanza-Norte and Cuanza-Sul are cultivated in the country. Robusta coffee is particularly produced in the provinces of Bengo, Cuanza-Norte, Uigé and Cuanza-Sul; while the arabica type occurs above 4.000 masl, in the regions of Huambo, Bié, inland of Benguela (Ganda, Cubal) and Caluquembe, province of Huila and a part of Cuanza-Sul [(1)].

In the Uigé province, coffee is grown in an area of 161 thousand hectares, with an average yield of 0.021 (tha^{-1}) considered very low [(2)]. It is pointed out that among the fundamental problems that affect the productivity of the crop are: the abandonment of the production areas, reduction of the labor force, impassable communication routes, aging of the plantations and the lack of renovation, especially in the Mucaba municipality [(3)].

One of the fundamental elements to achieve high productivity in coffee plantations is the efficient use of ecological resources. In this context, the influence of climatic variables on the physiological processes of the crop, together with the genetic factors of the plant, is of vital importance to consider the implementation of management techniques and the application of the basic principles of agroecology [(4)].

On the other hand, in the process of establishing the crop for the fulfillment of the development programs of a determined region, it is essential to analyze its main ecological requirements, to be compared with the behavior of climatic variables.

Therefore, in order to achieve adequate growth and crop production, it is essential to take into account the agro-ecological conditions of the region in question, which considers the

climatic, edaphic and socio-cultural variables. In this context, it is pointed out that agroecological zoning is one of the main tools to reduce the risks to which agriculture is subjected [5].

In the case of the coffee tree, even though it is tolerant to a wide range of ecological conditions, where it grows and develops, many of the coffee plantations are located in areas that present one or more limiting factors that make it impossible to achieve acceptable yields; as well as others that are not dedicated to this crop and that, due to their agro-ecological conditions, may be suitable. Therefore, a favorable environment allows the expression of the maximum genetic potential of the coffee tree; while, if any of the environmental factors is not required, it can be a limiting factor for development and growth, with significant effects on the final results of production that have an impact on the economy [6].

Among the most important requirements to take into account for the establishment of the crop and that directly affect growth and flowering, are climatic factors related to temperature and rainfall, given by their intensity and distribution. Therefore, these variables together with the edaphic conditions limit the areas for coffee development, which is why they have been used in several studies for the agro-ecological zoning of the crop, including those developed in the state of Guerrero, Mexico [7]. In this context, the knowledge of the climatic conditions that affect the cultivation, allows to carry out an agroclimatic characterization of the coffee zones useful for its regionalization.

In Angola, particularly in the Uigé province, the agroclimatic characterization has not yet been carried out according to the requirements of the coffee tree in order to analyze the potential for its development. However, the evaluation of the land based on the compatibility between the cultivation requirements and the ecological conditions of the regions, will allow finding the appropriate ecological niche for the development of coffee cultivation, rational use of natural resources and the elimination of limiting factors of crop productivity [8].

Taking this background into account, the objective of the research was to carry out an agroclimatic characterization based on the development of Robusta coffee in the Uigé province, Angola, as a useful tool for decision-making in the development of coffee production, on an agro-ecological basis.

MATERIALS AND METHODS

The research was carried out during the period from February-December 2018 in the Uigé province, Angola (Figure 1). It is located in the northern part of the Republic of Angola, with a dimension of 58.698 km^2. It limits the East with the Democratic Republic of the Congo and the South with the province of Zaire. The province is essentially agricultural and coffee crops are obtained (*Coffea arabica* L., corn (*Zea mays* L.), almonds (*Prunus dulcis* (MILL)) D.A.WEBB, coconut (*Cocos nucifera* L.), rice (*Oryza sativa* L.), beans (*Phaseolus vulgaris* L.), banana (*Musa paradisiaca* L.), pineapple (*Ananas comosus* L. Merr), sweet potato (*Ipomoea batatas* L.), mango (*Mangifera indica* L.), bomba fruit (*Carica papaya* L.) and cocoa (*Theobroma cacao* L.) [9].

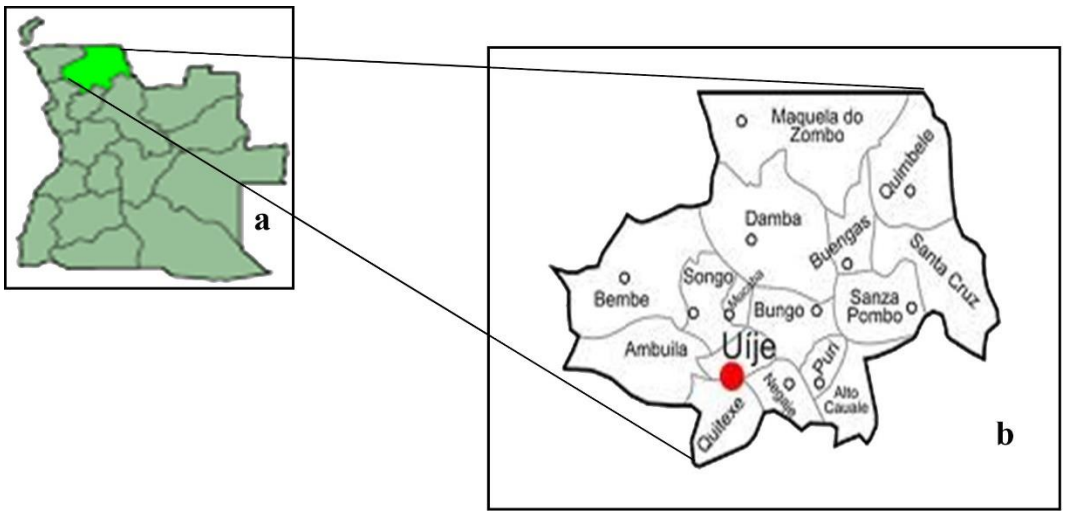

Figure 1. Localization of the study area: a- country Angola; b- Province Uigé

To perform the agroclimatic characterization of the coffee region, the behavior of rainfall and temperatures was evaluated, as they have the greatest influence on the development and growth of the coffee tree [7].

Climatic data were recorded from observations made in each municipality; as well as, in the experimental polygons of the Experimental Center belonging to the National Coffee Institute of Angola (INCA). In addition, the data obtained was corroborated with the information available on the World Meteorological Organization (WMO) site, where an average of 20 years (1990-2010) observations was considered [10].

The historical-logical method was applied to retrieve the information on the requirements of the crop and compare them with the edaphoclimatic conditions of the province.

The raster calculator of the Geographic Information System (GIS) ArGis ver. 9.3 for calculating and plotting on 1: 5,000,000 scale maps the mean annual temperature and total annual rainfall by manipulating the thematic information layers. Aptitude maps (suitable, unsuitable and acceptable) were generated for temperatures and rainfall depending on the development of Robusta coffee. Based on the scarce information and antecedents that exist on the subject of research in the country and particularly in the province, the research was based on the results presented in the agroclimatic zoning for coffee in Angola [(11)] for the analysis and interpretation from the results.

RESULTS AND DISCUSSION

According to the Koppen classification [(12)], the region's climate is of the rainy tropical type of dry season in winter (Aw).

The behavior of the average annual rainfall per month in the Uigé province, allowed to observe a distribution during the year with nine rainy months and three dry months, in addition to an annual average of 1409 mm and a monthly average of 187 mm. dry, the relative humidity was low with an average of 67.5 % [(10)] due to dry air and evaporation, which caused frequent and persistent fogs, mainly at night, with a higher incidence in the early hours of the morning, where small rainfall was recorded (Figure 2).

The average annual temperature per month in the last 20 years was below 25.0 °C. The warmest month is April with an average of 27.3 °C and the coldest months are July and August, with minimum average values of 13 and 14 °C.

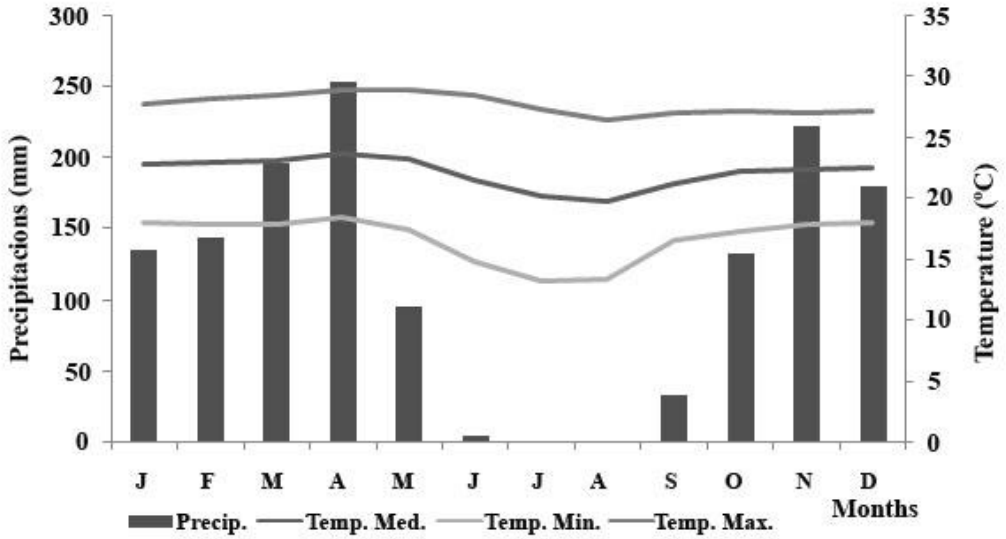

Figure 2. Climate graph of the province Uigé, Angola. Series 20 years

The behavior of these variables (temperature and rainfall) adjusts to the climatic requirements for coffee cultivation and especially for the Robusta species. In general, it was reported that the optimal rainfall should be 1200 to 1800 mm, as long as there is a good seasonal distribution and short dry periods, as occurs in the studied areas. Said period or resting phase facilitates the induction of flowering, which is the most critical stage in water needs to stimulate a subsequent process of fruiting and ripening of the fruits [(6)]. However, the optimal average temperatures for their production range between 16 and 22 °C, with an optimum night and daytime of 17 to 23 °C [(13)].

Arabica coffee and Robusta coffee are the most important species for the world coffee industry, therefore, they have the most commercial plantations. The first species is generally cultivated in the highlands and is distinguished by its high cup quality; while the second one is grown mainly in low-lying areas due to its resistance to high temperatures, although it has larger grains, high yields and a higher caffeine content. However, Robusta coffee is of lower quality, therefore it has a lower monetary value in the market [(14,15)].

The spatial distribution of the maximum possible total precipitation with a 95 % probability of occurrence, by degree of aptitude in the province for the development of Robusta coffee in three categories (suitable, unsuitable and acceptable), showed a decrease in these from the Northeast to Southwest of the province, which also covered the Southeast, which limits the production of Robusta coffee in these latter regions (Figure 3).

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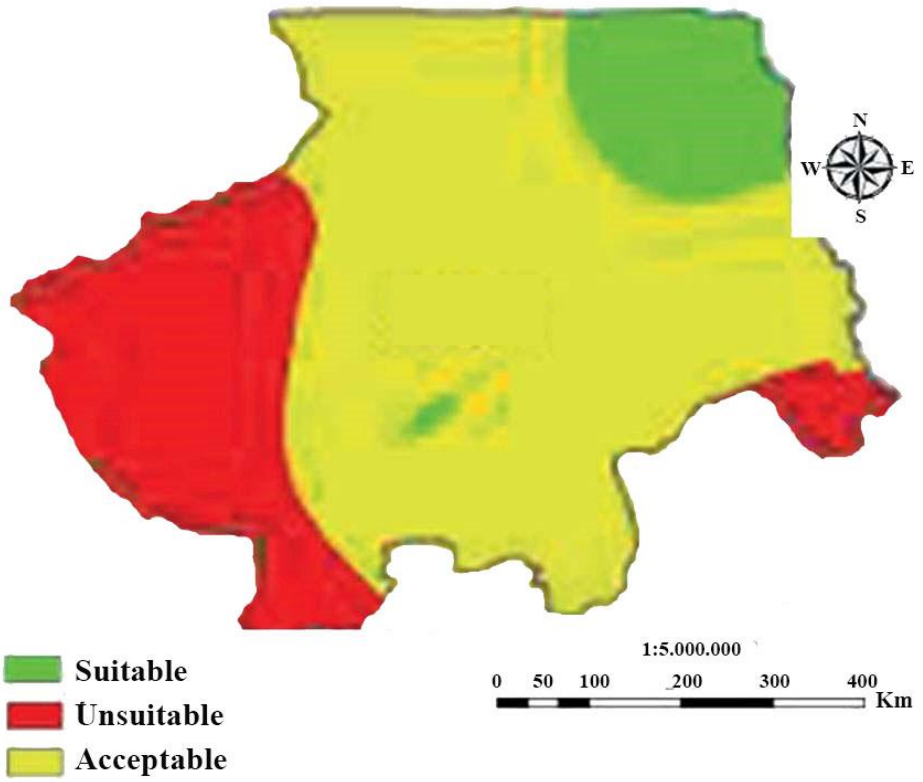

Figure 3. Aptitude of the annual total precipitations on the province Uigé, Angola for the development of the robust coffee

The aforementioned is conditioned by the height above sea level, with rainfall of more than 1200 mm per year at 870 meters above sea level in the Northeast part of the province and maximum values in the Quimbele municipality. However, the low values were registered in the municipalities of Ambuila, Bembe, Songo and the Agro-ecosystems of Quitexe and Santa Cruz (Figure 1), which did not exceed 400 mm of annual rainfall. For this reason, these agroecosystems require irrigation for the growth and development of coffee, mainly in the establishment of Robusta coffee plantations.

The results described above on the compatibility between the rainfall requirements of the Robusta coffee species and the existing conditions in the province, are similar with the results presented in the studies of crop zoning in the country [(11)], where they demonstrated that the areas suitable for Robusta coffee throughout the country, were only identified in this province. In this sense, the surface with aptitude (apt and acceptable) that supply the rainfall

requirements for this species in the province (65.1 % of the territory) is greater than the unsuitable surfaces.

On the other hand, the results on the spatial distribution of the annual average temperature in the province, suggest that in the municipalities with less precipitation, the temperature was higher and, in addition, it was conditioned by the height above sea level that each agroecosystem presents coffee grower in the province (Figure 4).

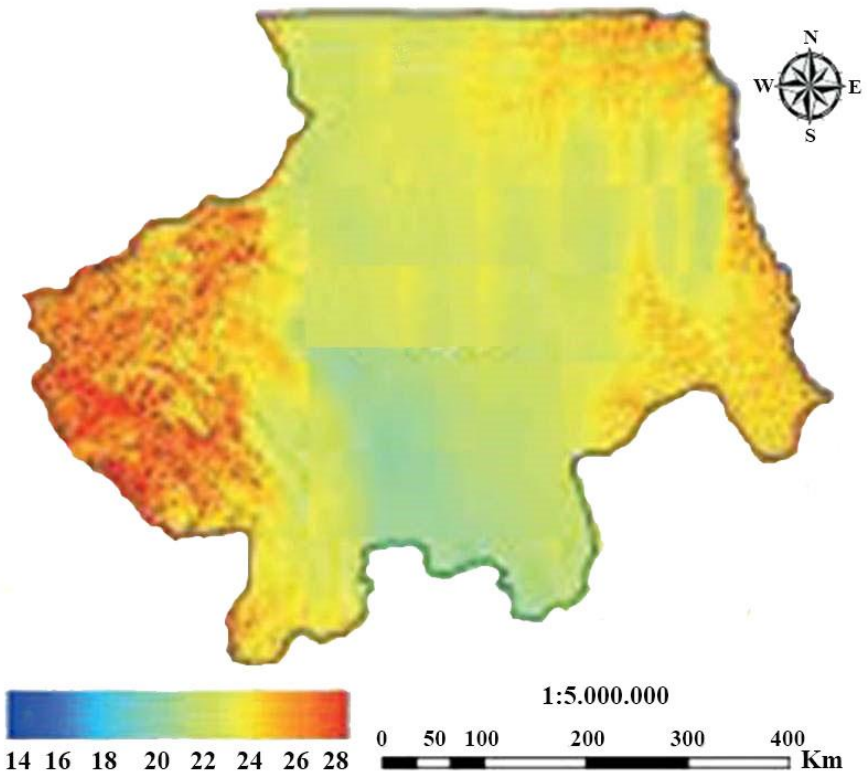

Figure 4. Distribution of the temperature annual average of the province Uigé, Angola

The municipalities that presented optimum temperature for the growth and development of Robusta coffee were Quimbele and part of Milunga within the Mucaba municipality. However, these municipalities do not have a background in the production of Robusta coffee; therefore, these results should be considered in the perspective development programs of the species, taking into account the climatic conditions of the province for coffee production.

Robusta coffee, unlike Arabica coffee, is more vigorous, productive, resistant to pests and diseases, and develops better in hot climates, in addition to having drought-tolerant genotypes such as INIFAP P5 in Mexico [(16)].

If the results of the behavior of rainfall and temperatures are combined with their spatial distribution, it can be argued that from the agroclimatic point of view, the province of Uigé in Angola, has adequate conditions for the development of Robusta coffee by 86.3 % Of the territory; of these, only 12.6 % of the total surface concentrates the best combinations of rainfall and optimum temperatures for cultivation. However, the main limitations for the development of Robusta coffee in this province are related to the distribution of rainfall in each of the evaluated municipalities.

The aforementioned results represent the basis for future soil and climate zoning of coffee cultivation or the Robusta coffee species in the province, which contribute to the rearrangement of coffee areas, depending on the potential for cultivation, promoting better yields by hectare [(7)].

The behavior of the climate in the province has allowed coffee development despite the irregularities in some years caused by dry periods and increases in temperature [(10)]. This should allow the implementation of crop management systems that minimize the effects of irregular climate behavior in order to increase productivity.

The current climatic changes are evidence of the existence of adverse phenomena to coffee production in the territory. For this reason, technology such as agroforestry systems with adequate tree diversity and shading of plantations and the application of a technique for the conservation and improvement of soil moisture should be alternatives to consider within the agro-ecological management of the crop.

The aforementioned results also constitute the basis for conducting zoning studies of the potential areas and vulnerability for the development of Robusta coffee on a smaller scale that allows a decision-making process. In this context, the results of agroclimatic characterization allow effective evaluations to be carried out and future scenarios for coffee establishment in the province to be predicted based on changes in global weather patterns.

Investigations carried out in Mexico showed that if an increase in the average daily temperature of 1.6 ºC occurs by 2050, under the worst case scenario, the surface very suitable for growing Robusta coffee in the state of Tabasco does not change. However, average potential yields will decrease by 41 % by 2050, due to the effect of increased daytime temperatures on the maximum photosynthetic rate [(17)].

On the other hand, the knowledge of the behavior of the precipitations in the province in function of the development of the Robusta coffee will allow to estimate the future harvests since the influence that this exerts on the crop yields has been demonstrated. Research carried out in Cuba found a strong relationship between annual rainfall and maximum stable yields, which is why it is necessary to take this variable into account in harvesting forecasts, to guarantee, together with an adequate supply of nutrients and care work to the crop, a stability of the coffee production [18].

CONCLUSIONS

- The largest area of the Uigé province has climatic conditions for the development of Robusta coffee, with loss of ability in the municipalities of the extreme west of the province, whose main limitation was rainfall.
- The knowledge of the compatibility between the behavior of the climate in the Uigé province and the requirements of Robusta coffee as part of the results of the agroclimatic characterization, allows to project technological alternatives in order to minimize the limiting factors of the climate in the production of this species.

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