Scientific Paper

Variations of the growth periods for three tropical pastures, under the effects of climate change

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Abstract

The objective of this study was to analyze the changes of the growth periods for three tropical pastures, under the effects of climate change in Cuba. Information from a 30-year record (baseline 1961-1990) of monthly mean temperature and rainfall was used, from the database of the Climate Center –belonging to the Cuban Institute of Meteorology–, corresponding to 61 meteorological stations. The reference evapotranspiration was calculated by Penman Monteih's formula, modified by FAO and adjusted to local climate conditions. The water deficiencies, of the beginning and end dates of the growth periods, and of the aridity index, were analyzed. For the analysis of future climates, daily outputs of the General Circulation Model Echan4 were used, forcing the emission scenarios A2 and B2. The growth period, for 2071-2099, will start with a delay of between 12 and 15 tens for C*ynodon nlemfuensis* Vanderyst and *Cenchrus purpureus* (Schumach.) Morrone. In contrast, an advance of the ending date of the period between the second and third tens of November for *C. nlemfuensis* and *C. purpureus,* and in the first ten days for *Megathyrsus maximus* (Jacq.) B.K. Simon & S.W.L. Jacobs, is foreseen. It was proven that the climate of Cuba will undergo an extreme desertification process, and will be classified as dry sub-humid. It is concluded that the performance of rainfall and crop evapotranspiration have a marked impact on the duration of the growth period of the studied pasture species, with a reduction of this period, which will be shown in the delay of the beginning dates and advance of the ending dates. This would have wide repercussion on the duration of the phenological phases, yield components and crop nutritional quality, as well as the appearance of pests and diseases.

Keywords: climate, *Cynodon nlemfuensis*, *Cenchrus purpureus, Megathyrsus maximus*

Introduction

The climate fluctuations recorded in diverse regions of the earth have their direct impact on the farming activity, although in a differentiated way. In temperate climates, as a product of global warming, the period for pasture production is expected to increase, although with a decrease and variability in the forage quality, because of the changes the rainfall patterns in those regions will undergo. On the other hand, in the tropical zones it is foreseen that the impact is not similar for all crops; some will have affectations in yield while others will reach better results. These variations in climate also affect Cuba and are object of study and concern, mainly due to their impact on food and feed production. At present, farmers observe more intense climate anomalies than the ones experienced years ago. In this sense, Planos *et al*. (2013) stated that agriculture would be developed in an environment affected by the increase of drought frequency and intensity, climate desertification, increase of the real evapotranspiration of ecosystems and marked water deficit. In the case of feed this is of higher interest, if it is taken into consideration that cattle feeding, based on pastures, constitutes the most economical productive system. Currently, there are valuable data about the productivity and milk production potential of tropical pastures, as well as on their management and the factors that rule it.

It can be said that rainfall variability derives in economic considerations, according to which it is accepted that the production of a crop could be economically acceptable. The lack of water in the planting period or the excess during the maturation and harvest phases has direct impact on yield. Regarding pastures, the topic of rainfall variability is important because their productivity is closely related to rainfall seasonality.

The growth period is the time of the year during which the temperature and rainfall conditions are favorable for plant development; thus a favorable environment must be present for their growth, development and reproduction. In the face of the environment variations caused by men, expressed in the alteration in thermal and rainfall patterns, it is necessary to specify the local environmental changes with higher incidence on agriculture. That is why the objective of this study was to analyze the performance of growth periods for three tropical pastures, under the effects of climate change in Cuba.

Materials and Methods

The information of monthly mean temperature and rainfall, from the database of the Climate Center of the Meteorology Institute of Cuba (INSMET), corresponding to 61 meteorological stations located throughout the country, was used. A 30-year record (1961-1990) was taken as baseline to know what was happening with the performance of these variables before introducing a projection analysis of future climate.

The studied pasture species were Guinea grass likoni (*Megathyrsus maximus* Likoni), CT-115 (*Cenchrus purpureus* cv. Cuba CT-115) and Jamaican star grass (*Cynodon nlemfuensis* cv. Jamaicano). The selection took into consideration that they were the most representative and widely used pastures in Cuba for animal feeding, besides showing high ecological plasticity.

The reference evapotranspiration (Eto) was calculated by Penman Monteih's formula, modified by FAO and adjusted by Solano *et al.* (2003) to local climate conditions. The crop evapotranspiration (Etc) was calculated through the formula Etc = Eto^{x}kc, in which the following were taken as crop coefficients (kc): 1,0 for *M. maximus*, 0,8 for *C. nlemfuensis* and 0,75 for *C. purpureus*. After obtaining the Etc, a graphic analysis was made of its relation to rainfall to identify the monthly performance of water deficiencies and the beginning and end dates of the growth period, established at the point where rainfall exceeded half the Etc, were determined.

The aridity index uses the ratio average annual rainfall (P) and potential evapotranspiration (ETP) to classify arid lands into hyper-arid, arid, semi-arid and sub-humid dry, according to the *World Desertification Atlas*. Arid lands have a P/ETP ratio lower than 0,65.

For the analysis of future climates, daily outputs of the General Circulation Model (GCM) Echan4 were used, forcing the scenarios of emissions (SRES) A2 and B2 proposed by IPCC (2001), of a spatial resolution of 25 km. This model is among the available ones and adequately represents the general circulation of the atmosphere in the Caribbean (Campbell *et al.,* 2011). In addition, these scenarios were selected, according to Bárcena et *al.* (2014), because the conditions of Latin America and the Caribbean will continue to be determined by the economic development, with new «clean» technologies, mainly at region or locality scale. The temporary horizons 2040, 2070 and 2099 were considered, to establish performance parameters at short, medium and long term of each one of the studied variables. Afterwards, the values were standardized to make the average equal to zero and obtain the anomalies, through the statistical package SPSS.

Results and Discussions

Each species has specific requirements regarding its water demand, for which covering the species requirements for its growth and development is highly important. Taking into consideration the above-stated fact, high spatial differentiation was observed in the water potential for the development of each crop (fig. 1).

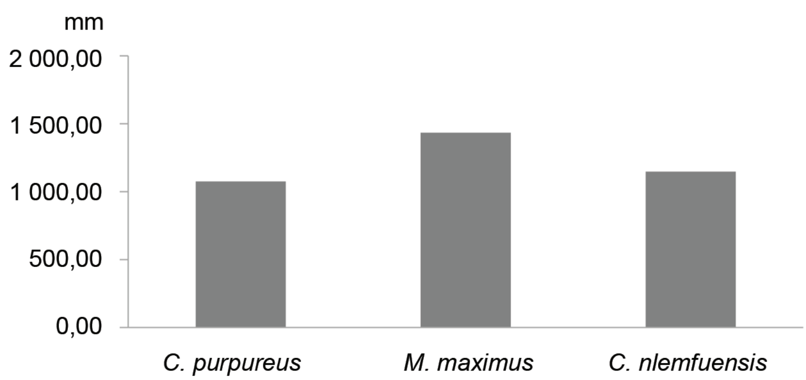

Figure 1. Evapotranspiration of the *C. purpureus, M. maximus* and *C. nlemfuensis* crops (1961-1990).

According to the short-term rainfall predictions (2011-2040), *C. nlemfuensis* will find larger areas with restrictions for its development due to water excess, especially in the western region and in some eastern areas, where rainfall will not be able to supply its water demand. In *M. maximus* the impact will be lower, and *C. purpureus* will be the species that will suffer less in the short term. Nevertheless, by the late 21st century the last one will be the species that will lose more areas, due to the decrease of rainfall, which will not be able to satisfy its water demands (Álvarez-Adán *et al.,* 2016).

The reference evapotranspiration during 1961-1991 was 1 434 mm as average, higher than rainfall in 125 mm, which indicates that the latter could not supply the evapotranspiration demand of the atmosphere in that period. On the other hand, the results for each pasture showed differences regarding its water requirements for growth, development and reproduction. *M. maximus* was the most demanding species, followed by *C. nlemfuensis* and *C. purpureus* (figure 1). These differences were directly shown in the duration of the growth period.

In the base period (1961-1990) it was observed that, due to the low water requirements of *C. nlemfuensis* and *C. purpureus*, they could be cultivated throughout the year, because rainfall was enough to supply their evapotranspiration demands. However, *M. maximus* was cultivated only during 214 days per year: from the first ten of May until the second ten of December. In the case of cutting pastures, such as *C. purpureus*, changes must be made in management for their utilization, such as the use of irrigation; this means cost increase, for which conservation methods should be considered, such as ensiling, for the dry season.

When analyzing the predictions of the Fifth Report of the IPCC (2014), it can be perceived that the demand of water for irrigation will be increased where the climate is warmer, which will increase the soil evaporation and will accelerate plant transpiration. This will cause higher competition between agriculture and urban and industrial users. The increase of potential evapotranspiration is likely to intensify the drought-caused stress, especially in semi-arid tropics and subtropics.

For Cuba, towards 2009 a decrease is foreseen in the growth periods for each of the species, according to the projections of rainfall decrease between 10 and 20 % and the increase of Eto between 20 and 24 %.

Although *M. maximus* is the most demanding species in its water requirements, it will be the one for which less affectations are foreseen in the duration of the growth period; that is, in the long term (1971-2099) it will experience a reduction of only 52 days for both scenarios. Meanwhile, *C. nlemfuensis* will suffer a reduction between 172 and 178 days for scenarios A2 and B2, respectively. On the other hand, *C. purpureus* will show a more variable behavior, because a decrease between 166 and 232 days is foreseen (fig. 2); this could be corroborated, according to Álvarez Adán *et al.* (2016), in the spatial distribution of the species throughout the country, especially in the last 30 years of the 21st century, with a decrease of 58 % of the available areas for its growth and development.

Another aspect of the analysis is the beginning and end dates of this period. For all the species the growth period will be very variable, especially the beginning date, and more stressed in the long term. In the case of the temporary horizon 2071-2099 it will begin in May, which indicates a remarkable delay (between 12 and 15 tens) for *C. nlemfuensis* and *C. purpureus*. In contrast, an advance of the end date of the period is foreseen: between the second and third ten of November for *C. nlemfuensis* and *C. purpureus* and in the first ten for *M. maximus*. (fig. 3a, b and c).

This analysis should not stay only at the level of the duration of the rainy season, capable of satisfying the water needs of the crop, but it also has wide repercussion on the duration of the phenological phases, yield components, nutritional quality of the crop and appearance of pests and diseases. At present, there are many studies that prove these effects.

Regarding the distribution of the water requirement in the different growth phases of *C. purpureus*, according to Murillo Solano *et al.* (2014) the same trend is observed, with low values at the beginning of the growth stage, high during the maximum growth phase and a decrease at the end of the growth stage if it is planted in August. On the other hand, Calvillo-Sánchez (2018) reported that the pests that affect *C. purpureus* normally appear in the rainy season when there is abundant relative humidity, as in the case of the cabbage looper larva and the grass spittlebug, among others which seriously damage forage yield.

According to Herrera (2013), the drought-tolerant *C. purpureus* clones showed a different performance in the western region with regards to

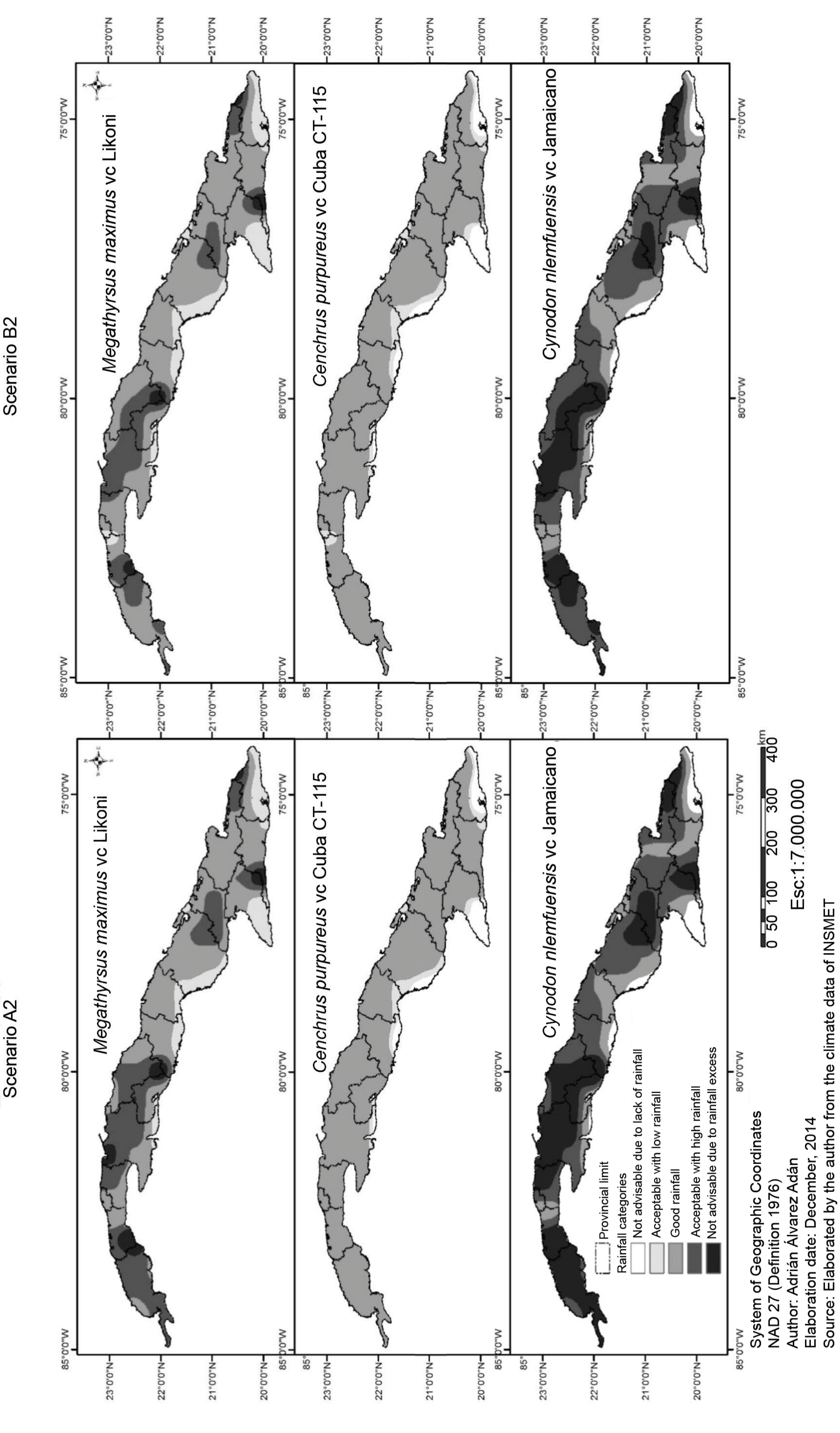

Figure 2. Rainfall potential for the growth and development of the species *C. purpureus*, *M. maximus* and *C. nlemfuensis* under the climate change scenarios A2 and B2 (2011-2040).

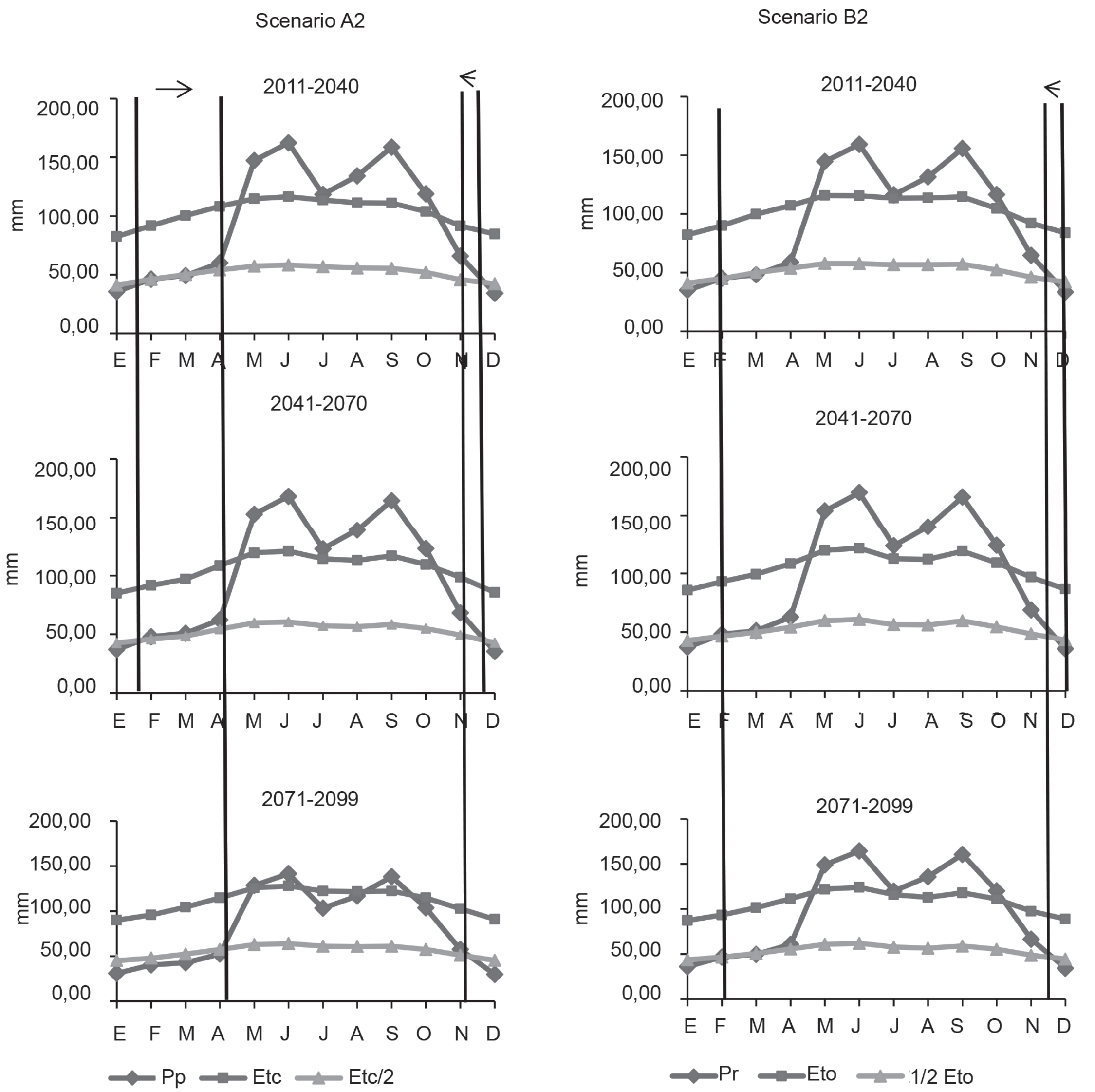

Figure 3a. Performance of the beginning and end dates of the growth period for *C. purpureus*.

the eastern region of Cuba; this is closely related to the climate characteristics under which they were grown.

Ramírez *et al*. (2011) found correlations between yield and temperature, rainfall and days with rain, in *C. purpureus* cv. Cuba CT-169. Similar results were reported by Herrera *et al*. (2013) in six pasture varieties, arguing that each one showed a specific correlation coefficient. In addition, Álvarez Adán *et al*. (2013) found multiple linear equations between yield and temperature, rainfall and days with rain.

For the good establishment of *M. maximus* during planting, the seed requires a surface with optimum humidity for germination (Pico Herrera, 2017). Thus, the long drought periods after planting can cause its partial or total loss; for such reason, the adequate establishment season is the rainy one, always avoiding the midsummer drought. In addition, the presence of water deficit during the reproductive phase (March-May) has a more marked effect on plant growth and physiology. In the studies conducted by Velazco *et al*. (2018), it was proven that the biomass production per season of the ear was proportional to the recorded rainfall. The highest leaf biomass coincides with the best climate conditions. In the central region of Chiapas state –Mexico–, in winter and without rainfall

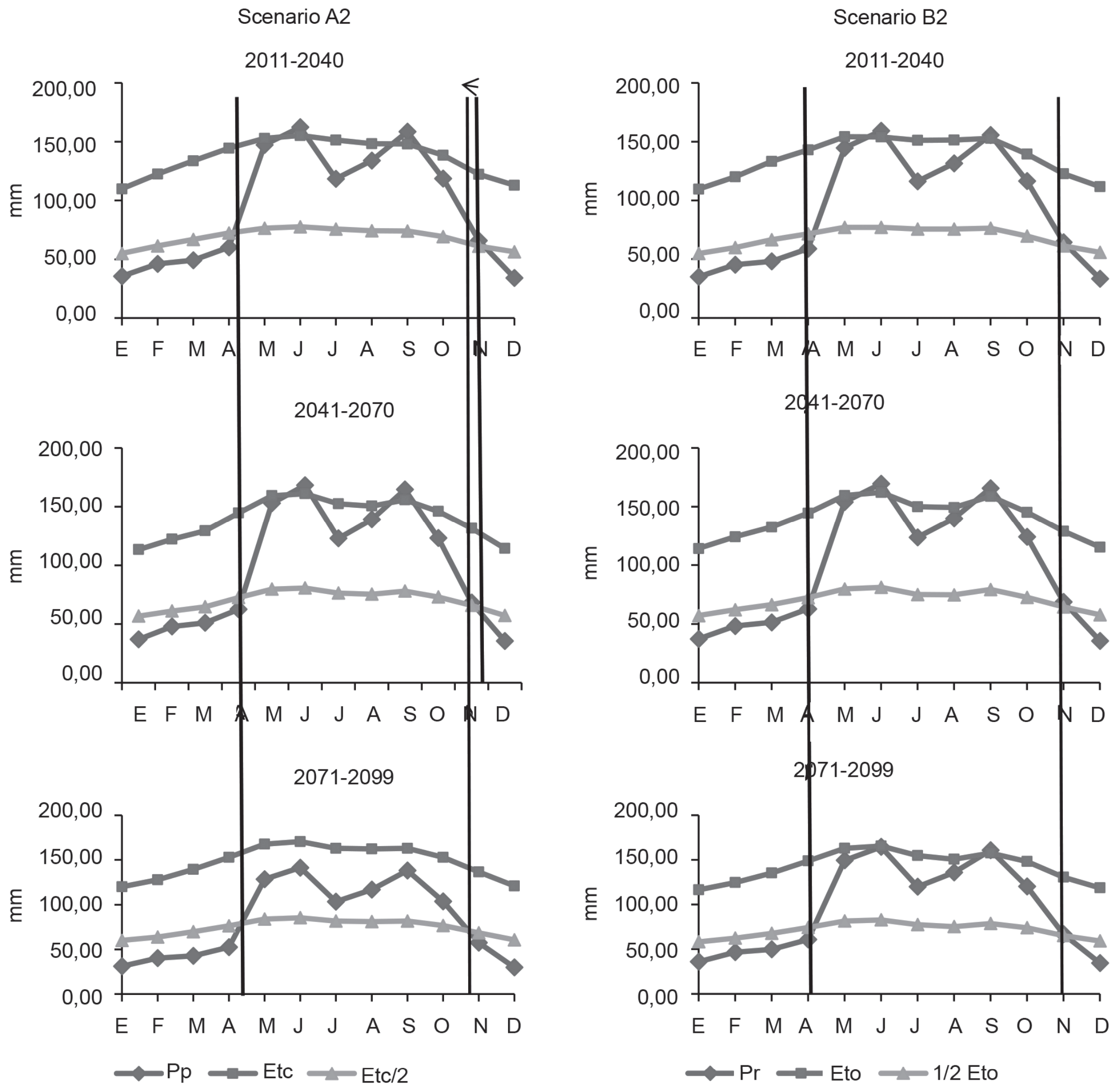

Figure 3b. Performance of the beginning and end dates of the growth period for *M. maximus*

record, pasture growth decreased, along with the decrease of temperature. In this regard, it should be considered that hydric stress reduces photosynthesis rate, causes leaf death, and induces plants to search for strategies, such as leaf shedding. With regards to hydric stress, Njauri *et al.* (2014) and Dutra *et al.* (2014) reported that 7 from 20 *M. maximus* Jacq. ecotypes, with low resistance to drought, did not prosper when evaluated in three sites in Kenya; and in them decrease of leaf and stem growth was recorded, as fundamental physiological effect.

Although these results are preliminary and there could be genotypes which show lower susceptibility to these conditions, the available information shows a potential problem that should be in the aim of current agricultural research. An advance of the planting date, according to Hoffman y Castro (2012), also implies a change in the environmental conditions experiences by the different phases of crop development.

In addition to this consideration, the Cuban climate is undergoing a transition from the humid stage, with an aridity index of 0,88 in the period 1961-1990, to the dry sub-humid stage, with an aridity index between 0,53 and 0,64 for the time horizon 2071-2099 of scenarios A2 and B2,

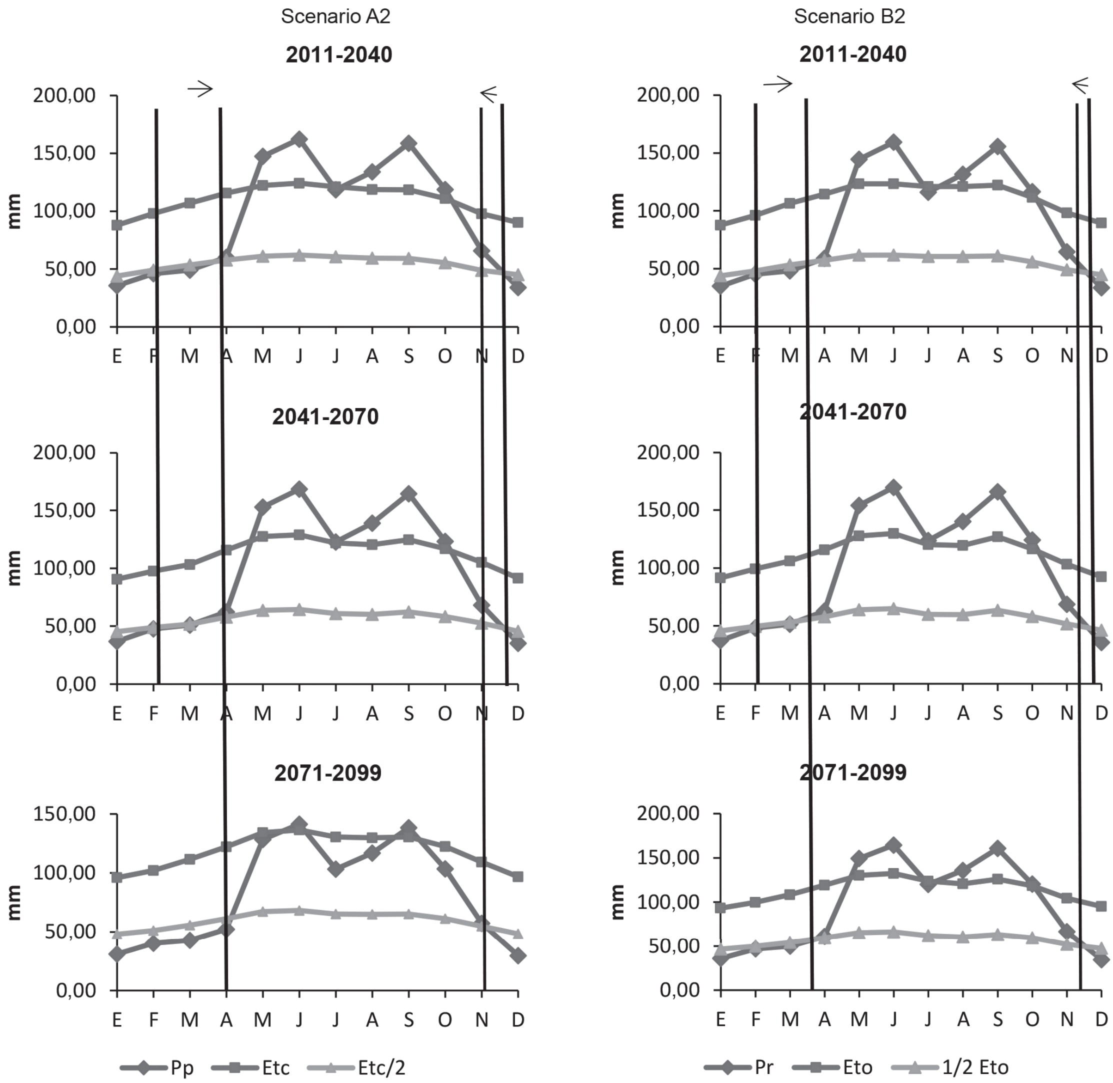

Figure 3c. Performance of the beginning and end dates of the growth period for *C. nlemfuensis*

respectively. This is corroborated in the Second National Communication to the United Nations Framework Convention on Climate Change emitted by Cuba (AMA, 2015; Planos *et al.*, 2018), when stating that «Cuban climate goes from its condition of humid tropical to dry tropical with approximately 1 000 mm of annual average rainfall and 70 days with rain, condition that will propitiate the displacement of dry landscapes of the eastern region towards other zones of the country».

Although there are experiences about the reduction of persistence in these pasture species and on the behavior of other species with higher tolerance to the drought changes that are foreseen in the models, at present in many cases the edaphoclimatic requirements of the crops are obviated and they are still being planted in sites that do not enhance their maximum development and growth. That is, crops are not able to express their maximum genetic potential, even when they survive these drought or humidity excess conditions.

This study, in spite of being conducted for the entire island of Cuba, constitutes a methodological contribution for the phenomenon analysis at a more detailed work scale, such as the provincial and municipal ones, taking into consideration the levels of agroclimate risk of each territory. In addition, it has high practical significance for agriculture officials, particularly those of Farming Insurance; who can use it to obtain agroclimate information from different zones and determine the selection, based on knowledge, of which crops and varieties are feasible to distribute rationally throughout the country. Another important aspect on which this study may have relevance is climate funding, very incipient still and only with some projects. According to Sánchez-Gutiérrez (2017), this should not only be identified with the mobilization of financial resources, but also with the access to technologies, to knowledge and experience transference and to capacity building for facing the effects derived from climate change.

This type of analysis is a valuable tool for planning the sowing dates and determining the premiums that should be established in the agreement of crop insurance, for any region and season. Likewise, it serves as support when estimating the potential possibilities regarding pasture and forage production for cattle.

As a result of a case study in the Güines municipality –Mayabeque province, Cuba–, Pérez Montero *et al.* (2016) reported that the decrease of rainfall and the increase of potential evapotranspiration in the region could generate a decrease of the aridity index to 0,6. This indicates that the region will go towards a dry sub-humid status by the late 21st century. In addition, a delay will be observed in the beginning and end dates of the growth period for both scenarios (RCP4.5 and RC8.5), compared with what was established at the end of the 20th century, which means a decrease of the duration of the growth period of 16 and 25 days, for a total of 222 and 198 days, respectively.

These predictions allow to have a new vision of pasture exploitation in Cuba, as well as to formulate some strategies of adaptation to the climate change within the animal husbandry activity, among which the following stand out:

- Modification of the sowing dates of the different species depending on their water requirements, especially in their emergence phase and at the beginning of the dry season in each one of the localities.
- Development of a plant breeding program to enlarge the genetic basis and obtain new tolerant genotypes or resistant to the expected environmental conditions; for example, the drought-tolerant *C. purpureus* clones obtained by the Institute of Animal Science (Herrera *et al.,* 2012).
- Implementation of methods and technologies for saving water in the crop, such as the application of irrigation with semi-stationary spraying systems.
- Implementation of techniques and methods from precision agriculture and climate-smart agriculture, in order to achieve efficiency in the use of spaces and resources within a new territorial organization.
- Application of the biomass bank technology with *C. purpureus* Cuba CT-115 (Martínez and Herrera, 2015) in order to solve the feed deficit of the dry season.

Conclusions

The behavior of rainfall and crop evapotranspiration has a marked impact on the duration of the growth period of the studied pasture species, with its reduction and expressed in the delay of beginning dates and advance of ending dates. In addition, it was proven that the climate in Cuba will undergo a strong desertification process, for which it will be classified as dry sub-humid.

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