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Impact of climate change in forest fire generation in Las Tunas, Cuba†

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Abstract: The purpose of this paper is to determine the possible impact of the climate change in forest fires generation in Las Tunas, Cuba. Relating forest fires distribution and magnitude with meteorological variables and aridity, it was developed a long term index to determine areas with favorable conditions for the development of forest fires. Future generation risk at the province was evaluated considering climatic conditions under RCP2.6 and RCP8.5 scenarios. Las Tunas is moving to warmer conditions, with a reduction in rainfall and a decrease of relative humidity, which will increase forest fires danger.

Keywords: climate change, aridity, forest fires, regional climate models.

1. Introduction

Climate change constitutes an additional pressure on ecosystems and the goods and services they provide, fundamentally in tropical areas like Central America and the Caribbean [1,2]. It significantly aggravates other anthropic pressures such as land invasion, deforestation and forest degradation [3]. Among these impacts, forest fires stand out.

There is still much uncertainty regarding the future evolution of climate change, its specific repercussions and possible responses [4]. Thanks to the use of regional climate models, projections of the trend of different meteorological variables are available for different climate change scenarios with relatively high resolution and without requiring huge computational resources [5].

The province of Las Tunas, Cuba has been considered one of the most vulnerable to aridity processes and forest fires [6,7], due to the characteristics of the soils and climate of the region (scarce annual rainfall, high temperatures and frequent and intense drought processes). That is why the objective of this work is to determine the impact of climate change on the generation of forest fires in Las Tunas.

2. Materials and Methods

2.1 General characteristics of the territory

Las Tunas province (Figure 1) is located in the eastern region of Cuba between 20º 30′and 21º 27′ north latitude and 77º 48′ and 76º 58′ west longitude. The provincial capital is the municipality Las Tunas. The province has a surface area of 6 592.66 km² [8]. The orography is eminently flat [8] and semi-desert soils, savanna-type dry forests and areas destined for agriculture [9].

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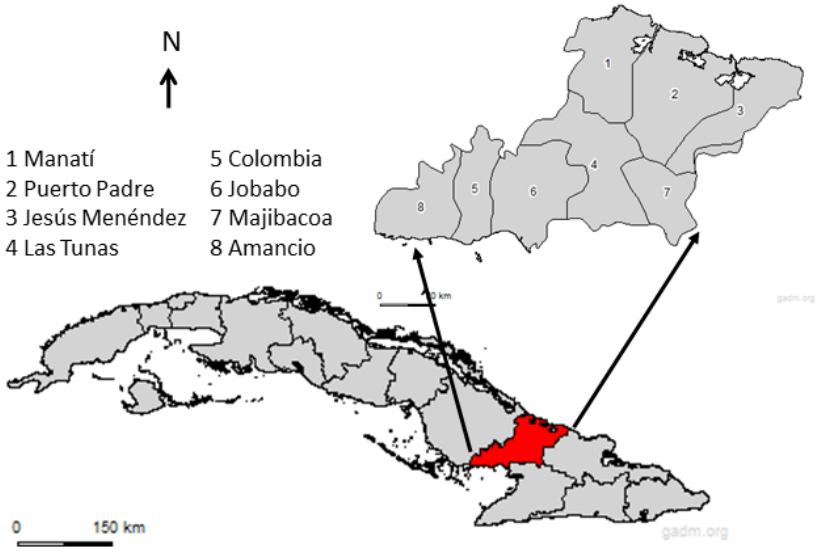

Figure 1. Study area.

2.2 Data collection

Forest fires data were obtained at the CITMA's (Ministry of Science, Technology and Environment) office in Las Tunas province for the period 2008 to 2012. The series of meteorological data were extracted from the database of the Climate Center belonging to the Institute of Meteorology of the Republic of Cuba (INSMET). The meteorological stations closest to the study region were used (Fig. 2) in the period from 1989 to 2018. The variables considered were: Hr-relative humidity (%), T-air temperature (ºC), Tmax-maximum Temperature, Td-dew point temperature (ºC), FF-wind speed (m/s) and R-precipitation (mm). Furthermore, the reference evapotranspiration value (Et_0) was obtained from the FAO Penman-Monteith equation for Cuba conditions [10,11].

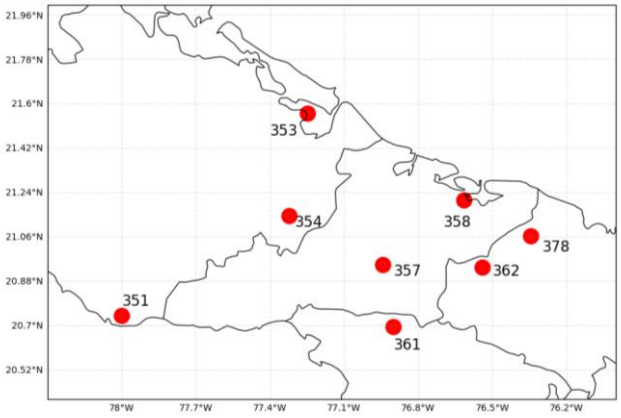

Figure 2. Location of meteorological stations at Las Tunas province.

The data for climate change scenarios were obtained in the Atmospheric Physics department of the Institute of Meteorology in NetCDF format. Data from the PRECIS (Providing REgional Climates for Impacts Studies) system were used, which consists of the Hadley Center's regional climate model, HadRM3P, fed with the boundary conditions produced by the outputs of the updated atmospheric component of the Hadley's Center global coupled model, HadAMP3, with a resolution of 25 km.

2.3 Data processing

Forest fires were studied in the period 2008-2012 taking into account their distribution in years, months, affected forest formation, total affected area, hydrological period and causes [12].

The RCP2.6 and RCP8.5 scenarios were chosen to analyze the trends of the meteorological variables in coming years, which model the extreme weather conditions (minimum and maximum scenarios, respectively). The study period (2020-2099) was divided into three stages: a near period (2020-2049), an intermediate period (2050-2079) and a distant period (2080-2099).

The aridity indexes were selected following international and national criteria [13]. It was chosen the Aridity Index [14], the Water Deficit Index (DH), the Modified Fournier Index (MFI), the Concentration Index of the Precipitation (ICP) and the Lang Index. In addition, the values of these indexes were obtained for the RCP 2.6 and RCP 8.5 scenarios in the near period (2020-2049), intermediate period (2050-2079) and distant period (2080-2099).

A long-term index was created to determine the distribution of areas with favorable conditions according to monthly meteorological variables and arid conditions for the occurrence and dissemination of forest fires. This index was evaluated for the three future periods, and the two climate change scenarios analyzed. This will make it possible to determine the areas that present the greatest risk to the impacts of climate change and how the fire season may affect them.

All maps were made through the Python 3.6.3 cartopy module.

3. Results

In the 2008-2012 period, a total of 504 fires occurred in the province of Las Tunas, with a total affected area of 17 344.3 ha, which represents 2.63% of the total surface of the mainland of the province. Sugarcane was the most affected forest formation, with about 60% of the fires, especially in the municipalities of the north coast. The municipality with the highest number of fires and affected area was Puerto Padre. The months with the highest number of fires and the largest affected area were those of the dry season of the year, especially from February to April.

For the RCP2.6 scenario, meteorological variables and aridity indexes remain almost constant in the three periods of study, while the greatest differences occur in the RCP8.5 scenario, especially in the period of 2080-2099. In general, the territory of Las Tunas moves to warmer conditions with reductions in rainfall, especially towards the north coast, a decrease in the relative humidity of the air and an increase in the reference evapotranspiration.

Forest fire generation risk index was evaluated taking into account the projections given by the climate change scenarios. The results showed that in the RCP2.6 scenario (Figure 3) the conditions remain almost constant in the three periods with a slight downward trend in the areas with high and moderate risk. In general, in the last period with respect to the reference period, a 10% decrease in moderate conditions is observed throughout the year and consequently an increase in areas with low risk. The months of highest risk remain March and April, although high-risk areas appear in July and August on the north coast, especially in the period 2020-2049. Therefore, favorable conditions for forest fires can be expected in other months of the year, when before they were not so likely.

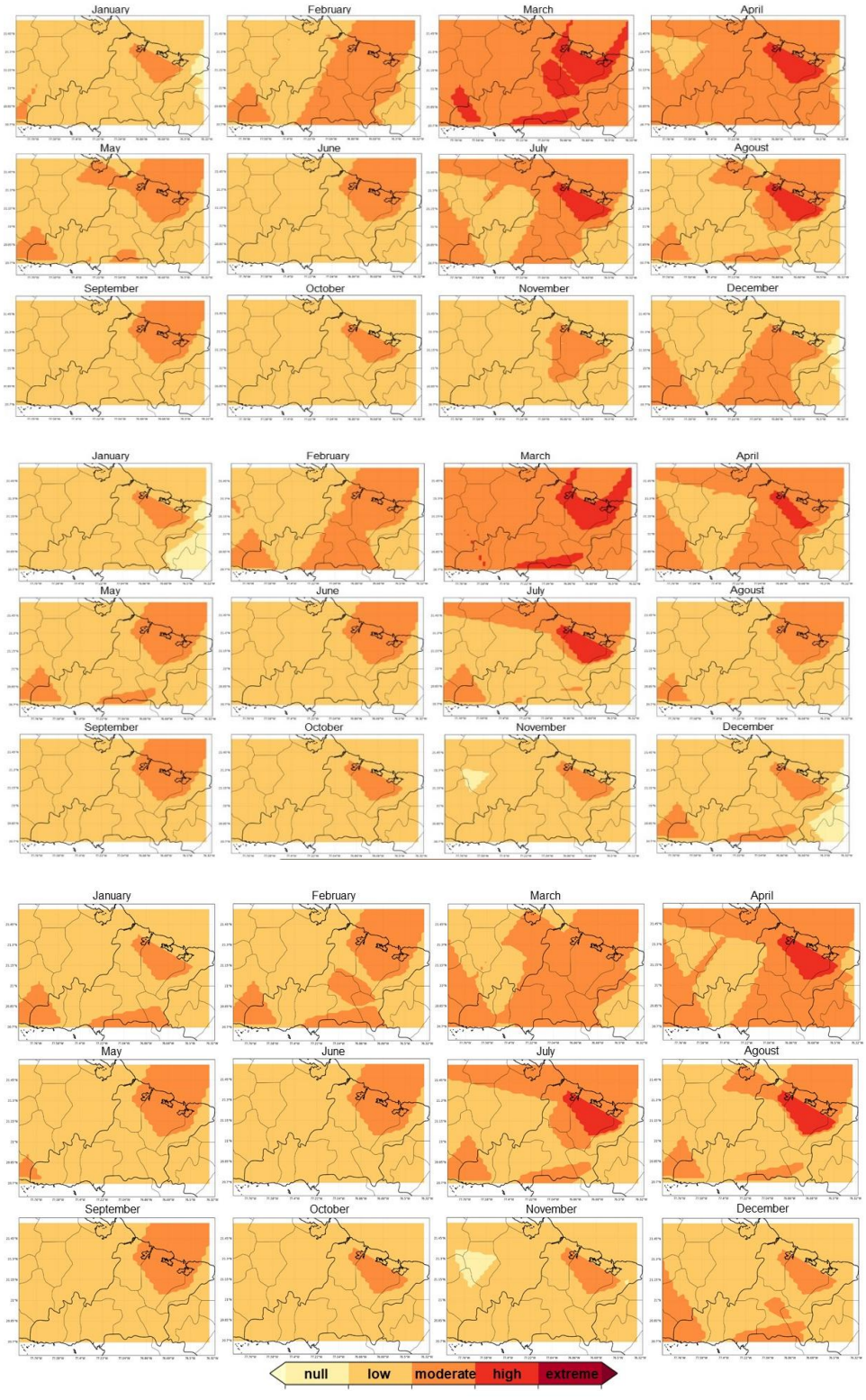

Figure 3. Monthly forest fire risk at Las Tunas province under RCP2.6 climate change scenario at three periods: A: 2020-2049, B: 2050-2079 y C: 2080-2099.

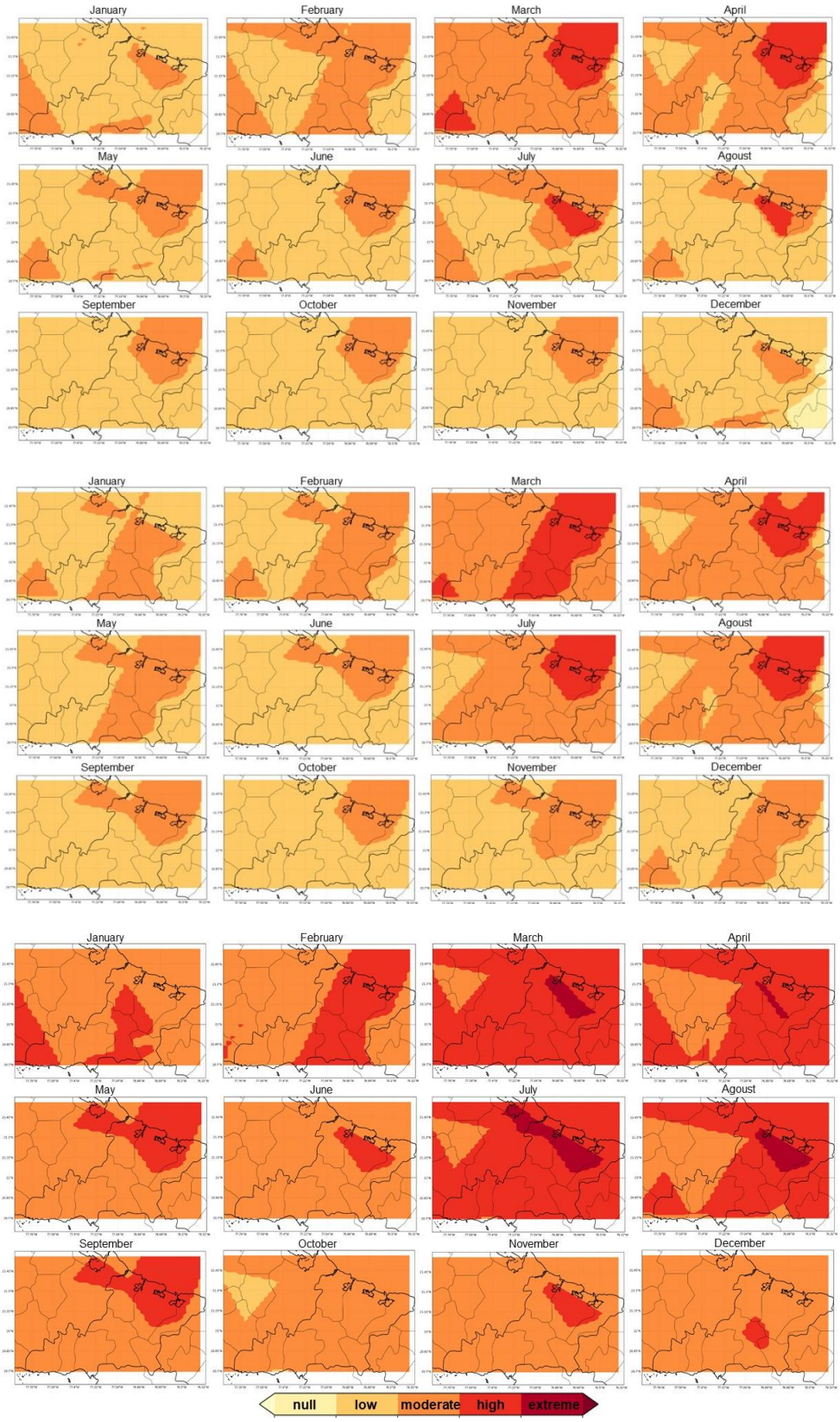

Figure 4. Monthly forest fire risk at Las Tunas province under RCP8.5 climate change scenario at three periods: A: 2020-2049, B: 2050-2079 y C: 2080-2099.

For the RCP8.5 scenario (Figure 4), forest fire risk conditions increase in all periods. In general, throughout the year, for the 2080-2099period an increase of more than 40% of

conditions with high risk is observed. March and April are the months with the highest risk , in the first 50 years but this situation changes as we moves in time, being, in the last period, July and August the months that present the highest proportion of areas with extreme risk of forest fires. This situation can be explained due to the decrease in rainfall in the rainy season months and the increase in rainfall in the dry season. For the period 2080-2099, there are also conditions with moderate risk in every month of the year and conditions with high risk in almost every month, except in October.

4. Discussion

Sugarcane is the most affected forest formation and a large biomass-producing crop and which is also closely related to agricultural burning policies [15]. This differs from the province of Pinar del Río, where the most affected forest formation is that of Pinus spp. [12]. Puerto Padre is the municipality with higher danger of forest fires which also has the lowest accumulated historical rainfall average, the highest reference evapotranspiration values and wind speed. This municipality has also been indicated as one of the 15 municipalities with the highest risk of forest regressive death in the country [7]. The dryer period is the most affected one because in these months, the combustible material tends to increase its flammability and availability due to the low water content of the fibers [12].

The trends in meteorological variables in Las Tunas are in correspondence with the investigations of Planos et al. (2013) where he stated that the impact of climate change on the Cuban archipelago will be evidenced by the existence of a hot and extreme climate and with more areas affected by desertification and drought, among others. These impacts will generate important consequences for the sustainable development and quality of life for Cubans, mainly in sectors such as agri-food, tourism, and human settlements (Pérez et al., 2016).

The result of the increase in favorable forest fire conditions in Las Tunas are similar to results obtain by investigations made in different parts of the world [4,17,18]. These results suggest that there will be longer fire seasons in the province that will lead to an increase in the number of fires or an increase in their intensity, which will cause a larger affected area.

Climate change will affect fire regimes, resulting in large ecological impacts, so fire management strategies must be adapted to this changing in climate and the situation in each locality [4]. In Las Tunas it is necessary to pay special attention to the north coast, especially to the municipality of Puerto Padre, which presents the most dangerous situation. Over time it will become even more necessary to take severe measures with respect to control fires, especially in sugarcane crops.

5. Conclusions

It was possible to determine the possible impact of climate change on the generation of forest fires in Las Tunas Province through the elaboration of a long-term index based on meteorological variables, aridity indexes, possible changes caused by climate change and the characteristics of the forest fires.

The results suggest, with differences between scenarios, that there will be longer fire seasons in the province that will lead to an increase in the number of fires or increase in their intensity, which lead to a larger affected area.

In general, in the territory of Las Tunas, there is progress towards warmer conditions with reductions in rainfall, especially towards the north coast and a decrease in the relative humidity of the air, which will lead to more areas affected by aridity and drought, and larger areas with presence of fire hazard conditions for vegetation.

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Conflicts of Interest: The authors declare no conflict of interest.

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