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A study of the spatial extension of agricultural drought in Cuba and its hyper-annual trends

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Abstract The average conditions of the spatial extension of agricultural drought in Cuba during a natural year and in the hydrological rainy and semi-rainy seasons were studied. The methods used to diagnose agricultural drought were based upon the water balance results from each element of the soil–plant–atmosphere complex, which made it possible to identify for each period the zones of the country that were most affected by this extreme climatic event and its hyper-annual trend. The results achieved show a trend to a surface increase of severe agricultural drought in Cuba during the study period.

Key words agricultural drought; geographic information systems; agroclimatic zoning; hyper-annual trends; Cuba

INTRODUCTION

The process of adapting to the potential impact of climate change demands adequate interpretation and knowledge about the threat imposed by significant extreme events. Therefore it was deemed appropriate to research those trends, patterns and general behaviour of agricultural drought that has an impact on both food safety and the country's social and economic life.

The general objective of this work was to establish the historical values of the spatial extension of agricultural drought in Cuba during a natural year and in the rainy and semi-rainy seasons as well as its hyper-annual trends on a proper scale, for exploratory purposes.

DATA

Data for the climatic variables used in this research work were taken from 62 meteorological stations and 809 raingauge stations belonging to the Institute of Meteorology and the National Hydraulic Resources Institute networks. This information was processed taking a decade (ten days) as the base temporary period.

A time span from 1951 to 1990 was selected to analyse climate data on the historical values of the spatial extension of agricultural drought in Cuba during a natural year and in the rainy and semi-rainy hydrological periods, and the 1951–2005 period was taken to study hyper-annual trends.

METHODS

For the purposes of this research, agricultural drought was assessed on the basis of the soil moisture deficit resulting from the soil water balance in the rhizosphere. The methods used to this end are based on a temporary and spatial assessment of agricultural drought after analysing the moisture index dry condition described by Solano *et al*. (2005a,b,c).

A summary of the process used to forecast agricultural drought by combining the tools available in computer software packages, such as EXCEL and the Geographic Information Systems (GISs), is shown graphically in Fig. 1.

Due to the exploratory nature of this research work, a 7626-dot grid whose pixel represents a lateral spatial resolution of 4-km was designed for the country.

The term "presence of agricultural drought" in this work corresponds to the dry period that has kept vegetation under moderate or severe water stress for a period of at least four decades following the beginning of soil water depletion.

The scale used to diagnose the spatial extension of agricultural drought, shown in Table 1, comprises seven categories according to the percentage area of the territory being assessed, which

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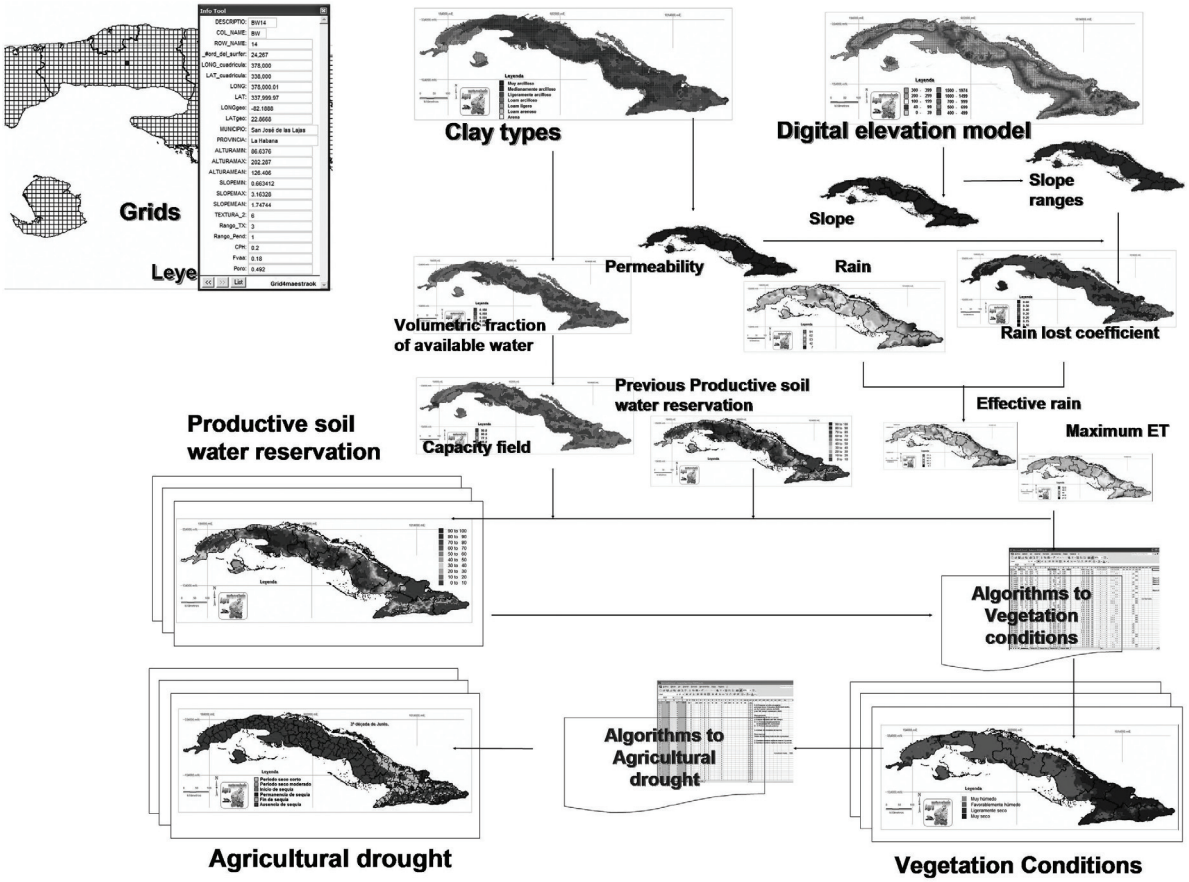

Fig. 1 Flowchart showing the general methodology of the method used to diagnose agricultural drought by using GISs.

Table 1 Diagnose categories for the spatial extension of agricultural drought according to the percentage of the assessed territory.

Minimum threshold (%)		Category		Maximum threshold (%)
0	≤	Absence	<	5
5	≤	Very small	<	20
20	≤	Small	<	40
40	≤	Average	≤	60
60	<	Large	≤	80
80	<	Very large	≤	95
95	<	Total	≤	100

is at different agricultural drought development stages, with respect to the total area including the said territory.

As defined in this study, the severe category indicates the occurrence of at least a 12-decade-long dry period where the total number of very dry or severely dry decades is equal to or greater than 60% of the overall length of that dry period (Solano *et al*., 2005a).

RESULTS

The Cuban municipalities most affected by the spatial extension of agricultural drought during the rainy period are located in the eastern provinces, and the least affected in the western and central regions (Fig. 2). In the semi-rainy period this surface area increases across the country, the most affected municipalities being those located in the eastern provinces, even if it usually occurs in the central region too (Cienfuegos and Ciego de Avila provinces).

Figure 3 shows 11 episodes of agricultural drought, namely 1951–52, 1956, 1959, 1961–63, 1965, 1967, 1970–71, 1974–76, 1981, 1984–87 and 1989–90.

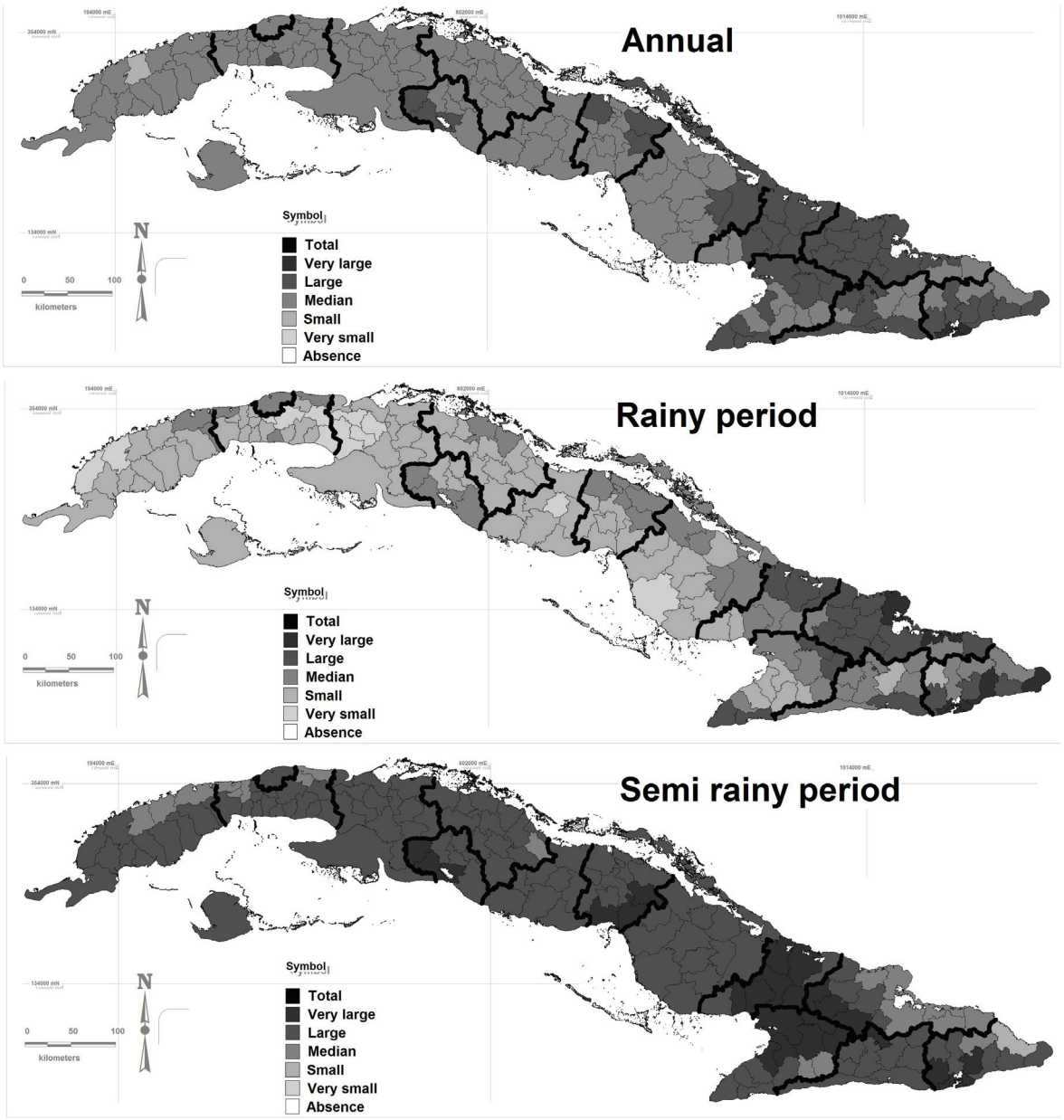

Fig. 2 Diagnose of the average municipal spatial distribution of the spatial extension of agricultural drought in the historical values rainy, semi-rainy and annual periods.

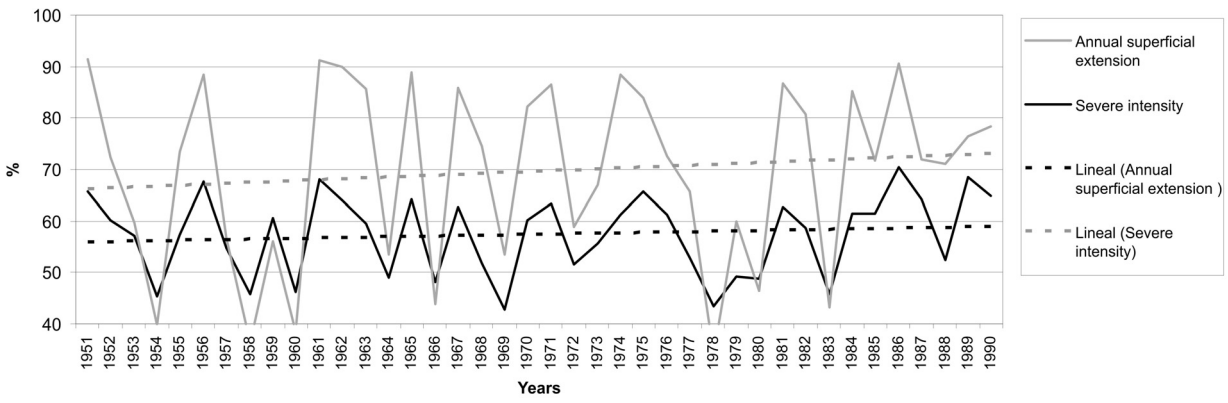

Fig. 3 Hyper-annual behaviour and trends of both spatial extension and (severe) intensity of annual agricultural drought in Cuba, in percent affected area.

The spatial extension of Cuba's annual severe agricultural drought tends to increase in the period under study. As indicated by the equation of this hyper-annual trend ($y = 0.07444x + 55.829$), the area affected by agricultural drought during the said period in Cuba shows an annual increase of about 8000 ha per year.

The results of analysing the spatial extension trends of severe agricultural drought for one natural year in Cuba are in conformity with those from research works made by the Climate Center of the Meteorology Institute of the Republic of Cuba regarding the behaviour of rainfall and meteorological drought in the country (Lapinel *et al*., 1993; Centella *et al*., 1997), in the sense that both agricultural and meteorological drought have increased in frequency and intensity, together with a reduction of the overall yearly precipitation from 10 to 20% and a higher year-to-year variability of 5 to 10% and the fact that precipitation has decreased in the rainy period and increased in the semi-rainy period.

When the hyper-annual spatial extension progress was studied as a percent area affected by agricultural drought in Cuba during the more recent 1999–2005 period, an increasing trend in time was also found, which indicates that current trends are in line with those resulting from the 40-year period and those mentioned in the above paragraph.

The diagnosis of the hyper-annual progress and trends in Cuba's agricultural drought surface area and severe intensity corresponding to the natural year indicates that, during the period being studied, this extreme climate event has increased its annual spatial extension and intensity, with an average annual progress in previously unaffected areas of about 8000 ha, an increasing spatial extension and intensity in the rainy period and a reduction of these parameters in agricultural drought in the semi-rainy period, with a smaller value than that achieved in the rainy period increase.

New agroclimatic products developed as a result of this research work provide information both to assess the threat of agricultural drought in our country and to enable handling of climate risk in selecting the best strategic decisions and devising tactics for agricultural operations.

The results stemming from the spatial assessment of agricultural drought in Cuba, generated by and shown in this paper, lay the foundations to undertake new agroclimatic research and study the risk posed by this extreme climate event, since they improve our understanding of agricultural drought and the agrometeorological service's output, and therefore extend scientific knowledge about drought in Cuba.

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