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Research Article

IDENTIFYING THE POPULAR REFERENCES OF RAINFALL PREDICTION IN OBSERVED PRECIPITATION TRENDS IN THE BRAZILIAN SAVANNA

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ABSTRACT

In Mato Grosso, state located in the Brasilian Midwest, some of these climatic references have names that are known in much of its territory: The "Janeirinho" is the name given to the reference of the forecast of rains for the whole year from the observation of the occurrence of this event in the first days of January; the "rain of *Saint Joseph*", whose absence of can indicate a more rigorous drought in the current year; the "cashew rain" refers to precipitation that occurs at the height of the drought; precipitations that can be favored by the "passage of moon"; and the arrival of the "great waters" from the reappearance in the night sky of the constellation Pleiades. Thus, with the objective of recovering this popular knowledge, this work analyzed daily precipitation data, between 1961 and 2017, and sought to quantitatively identify these references.

INTRODUCTION

By the second month, there seems to be no more. The melancholy sunset, in shades of orange to red, vivid by the dispersion in the dust and smoke present in the air, the difficulty in breathing and the excessive heat are indicative of another day just as it ends, and tomorrow, does not need forecast, will also be equal.

In the local fauna there seems to be no such hopelessness, the calm of the animals is strategy of existence, to limit the energy expenditures until it returns. The vegetation that surrounds this landscape consists of dry, low and twisted trees, most of them by the same strategy, are already almost completely defoliated, prominent among the grasses, also dry.

In such an environment, extremely hostile, the farmer developed a detailed acuity to perceive signs of his arrival, the rain. Their references to weather are usually associated with the behavior of animals and vegetation, weather and sky, moon phases, constellations, and clouds.

However, when these signs are delayed, the religiosity of this population is put to the test. The dates dedicated to devotion to the Catholic saints, on days that usually mark seasonal transitions, are awaited in the hope of beginning a new cycle.

So it is in Mato Grosso, Brazilian state, where popular knowledge about the evolution of weather is still well recognized. Portuguese colonization, the rigor of the dry season, the isolation and the agricultural vocation of the state may be responsible for perpetuating this knowledge about rainfall.

These traditional knowledge, characterized by references to rainfall forecasts, are remarkable because they were developed and tested over the generations and, without any basis, they would have been lost.

In the Brazilian Pantanal, for example, the rainfall prediction for the year is realized using weather conditions of the first 12 days of the January, a reference known as Janeirinho. Also called the Italian calendar in the southern region of Brazil, according to this reference, the month of January will be rainy if on the first day of the year it rains, if it is a sunny and dry day, January will be a hot dry month. The forecast for the month of February would be made from the conditions of January 2(RIBEIRO; ZAVATTINI, 2017).

For the Brazilian Savanna farmer, rain references have the drought period as the center of their life strategy, whose anticipation may reduce the risk of losses in the production of means of survival. Thus, St. Joseph's Day, in March 19, is a reference date, indicating the beginning of the gradual decrease

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of rainfall, marking to the farmer as the deadline for planting dry crops. For this population, the absence of precipitation on Saint Joseph's day indicates a more severe drought in the current year.In the Brazilian northeast, a semi-arid region, farmers believe that agricultural production will be threatened if it does not rain until March 19, the last hope for rainfall for farmers who depend on it to survive (FOLHES; DONALD, 2007).

At the height of the drought, after months without rain, the attention of the farmer returns to the signs offered by nature, interpreted and translated into predictions of some rain that may ease the situation until the arrival of the rainy season. This rain that occurs at the height of the drought make up the climate of the region, interrupting the drought period, without determining its end, being known as Single, or cashew rain, by the importance for the development of the fruit (LANHI, 2010). Other references to rainfall in the dry season in Mato Grosso are associated with changes in the phases of the moon, rainfall, according popular knowledge, may be favored by the proximity of the First Quarter Moon. Science has proven that some of the influences that the early civilizations attributed to the Moon are real, and that teleconnections among these events exist, however, according to Camuffo (1999), these are so weak, that they can be found only with the help of statistical analyses performed on meteorological data from places where measurements have been regularly taken for a very long time. However, the most anticipated event in the calendar of the man of the center-west Brazilian is the return of the rains. One of the most well-known references comes from the Bororó ethnic group, an indigenous people living in the eastern part of the state of Mato Grosso, which awaits the reappearance in the night sky of the constellation Pleiades, foreshadowing arrival of the "great waters". The present study analyzed the rainfall data for 56 years (1961-2017) of the Cuiabá, district of Mato Grosso, seeking to quantitatively describe these climatic references, popular knowledge, recognized in this region of the Brazilian Savanna, supported by empirical knowledge accumulated over many generations.

Study Area

The state of Mato Grosso, Brazil, due to its location within the South American continent (Figure 01), remained for a long time on the margins of the capitalist movement carried out on urban life and only from the 1960s and 70s, with the implementation of the federal policy of occupation of the center-west of Brazil, urbanization happened in an accelerated and disorganized way (BARROS *et al*., 2010). In 2017 the state were ranked as the first in agricultural production in the country, diversified between extensive livestock system and cereal farming, with emphasis on the production of soybeans in savanna lands, estimated at 30.5 million tons for this year (CONAB, 2017).

The study area is located between the parallel of 8° lat. S with the meridian 51° long. W and the intersection of parallel of 19° lat. S with the meridian of 27° long., the state has its vegetation cover composed by three biomes: Amazon Forest, located in the extreme northwest and north, where the highest rainfall are observed (46%); Pantanal, in the extreme southwest and south, with the lowest indexes (22%); Savanna, in the center and in the extreme east, where 32% of the total precipitation of the state occurs (MARCUZZO *et al*., 2011).

Figure 1 Geographic location of the study area

MATERIALS AND METHODS

This work used daily precipitation records, with reasonably complete records over the period 1961 to 2017, of the Cuiabá station, capital of the Mato Grosso, code 83361 (World Meteorological Organization - WMO), obtained from the public-access National Institute of Meteorology database (http://www.inmet.gov.br/portal/). The rainfall data were compiled and organized in spreadsheet.

The Pearson Chi-Square test was applied to quantitatively identify climatic references, from identify significant differences between expected and observed rainfall frequencies, with a significance level of 1% ($p \leq 0.01$), establishing whether the observed difference is due to chance or real (statistically significant).

Climate Characterization

The region is located in the intertropical zone of the planet, the climate of this region is identified primarily by temperature, with annual averages between 28 ºC and 32 ºC, and presents two well-defined seasons, the rainy and the dry season (BARROS *et al*., 2010).

A striking feature this climate is the existence of periods of high temperatures during the months of October and November, days with average temperature, equal or higher, at 30 ºC, between September 24 and October 11, on average, and the occurrence of brief periods with low temperatures, alternating at moderate or elevated temperatures during the winter (dry) period, with average temperature below 18 ºC, which occur as a consequence of incursions of the polar mass of the Atlantic, generally bringing rainfall, with 8 days a year, on average, between days 09 May and September 5 (CAMPELLO JR *et al*., 1991).

The average annual rainfall during the study interval was 1387.8 mm, concentrated in the rainy season, which starts in October and end in April, with an average of 89.9% of the recorded volume, and the dry season occurs in June, July, and August, with an average of 3.0% of the recorded volume, with September and May as transition months (Figure 2).

According to Pennington *et al*. (2000), in seasonally dry tropical forest vegetation, where the rainfall is less than 1600 mm/year, the dry season months receive less than 100 mm.

In the rainy season, the average number of wet days ranges from about 97 days, which corresponds to a rainfall occurrence every 2.2 days. However, there is record annual maximum of 23 consecutive wet days, in January 1966, and, on the other hand, there is records of 11.5 consecutive dry days, on average,

with an annual maximum, of 17 consecutive dry days, in November 1963.

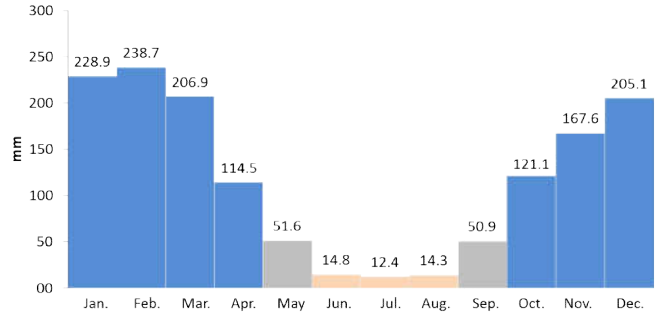

Figure 2 Average Monthly Rainfall (1961-2017)

In the dry season, the average number of wet days ranges from about 5.6 days, which corresponds to a rainfall occurrence every 16.4 days. The intervals between two occurrences of rains, in the seasonal drought, is 54.0 days, on average, between June 18 and August 10, on average. In 2017, the drought started on May 24 and ended on August 14, 84 consecutive days without rain in the region. There is record annual maximum of 96 consecutive dry days, between July 4 and September 7, in 1967.

According to Souza *et al*. (2012b), six daily rainfall categories have been considered: Light ($P < Q_{0.05}$); Light-Moderate ($Q_{0.05} \leq P < Q_{0.25}$); Moderate-Heavy ($Q_{0.25} \leq P < Q_{0.50}$); Heavy ($Q_{0.50} \leq P < Q_{0.75}$); Heavy-Torrential ($Q_{0.75} \leq P < Q_{0.95}$); Torrential ($P \geq Q_{0.95}$) (Figure 3).

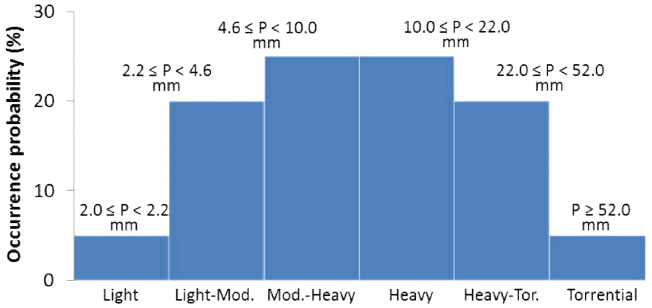

Figure 3 Rainfall classification according to Souza *et al*. (2012b)

In the process of this analysis, and throughout the work, daily precipitation <2.0 mm was discarded from the analysis, Rainfall below this value are of little importance for agriculture, water supply and infiltration, due to the high temperatures and evapotranspiration rates observed.(NIEUWOLT, 1982; ADEJUWON and ODEKUNLE, 2006; SOUZA *et al*., 2012b).

According to Naghettini and Pinto (2007), by the Gumbel probability distribution, are considered torrential rains in this analysis, with a probability of 2.3% ($P > Q_{0.977}$), accumulated rainfall from 72 mm/day. The mean annual value of such torrential rains shows rainfall above 100 mm/day for 0.3 days for the observation period of 1961–2017. The 18 occurrences greater than 100 mm / day are uniformly distributed throughout the study period, with only one of these not occurring in the rainy season, a record of 103.5 mm on May 22, 1983. The highest recorded daily rainfall has been 134.3 mm, on March 16, 1995

Here it will be examined if farmer perceptions, popular references about rainfall, can be identifying in the historical records of rainfall for this region.

DISCUSSION

Janeirinho

The month of January is the wettest month in the region, with a monthly cumulative average of 228.9 mm, about 16.3% of the annual accumulated volume, and an average record of 19.6 precipitation occurrences, one each 1,5 day. Therefore, how as 7 months of the year are rainy, there is a good probability that rain, according to folklore, in the days of January that correspond to the rainy months.

A However, the simple counting of precipitation occurrences in each of the first 12 days of January, during the study period, does not allow to confirm it: fewer occurrences in the days, referring to the drought months, 6 corresponding to June, 7 to July and 8 to August (Figure 4).

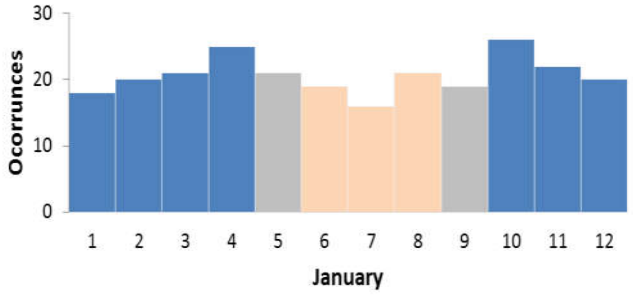

Figure 4 Rainfall in the first 12 days of January (1961-2017)

Otherwise, Janeirinho can be understood as accumulated precipitation above its monthy average in case of rainfall in corresponding day. In this way, predictions were confirmed in 52.3% of the day-month pairs, with 290 positive correspondences between day-month pairs, for a total of 555 pair day-month. Thus, a statistically significant association was not found between the presence of rain in the first days of January and the occurrence of rains above average in the respective months of the current year ($\rho = 0.288$), according to popular references.

As farmers relied on this reference to plant and harvest their crops, rainfall forecasts for the dry season should be the most important. Thus, restricting the analysis only to the drought months, predictions were confirmed in 61.0% of the day-month pairs, with 86 positive correspondences between day-month pairs, for a total of 141 pair day-month. In this case, a statistically significant association was verified between the presence of rain on the 6th, 7th and 8th of January and the occurrence of rains above average in the respective drought months of the current year ($\rho = 0.007$), according to popular references, no rejecting the hypothesis that there is a significant difference between the observed and expected frequencies.

This supposed concordance can justify the references to Janeirinho found in the climatic perception of the residents of this region. For Sartori (2005), the facts observed and reported by the farmers, "weather forecast", in fact, are difficult to explain.

In 2017, on days 6, 7 and 8 of January, rainfall in 24 hours of 9.2 mm, 0.0 mm and 13.6 mm, respectively. The monthly rainfall for the drought months of 2017 were 0.0 mm in June, below the mean monthly rainfall of 14.8 mm, 0.2 mm in July, below the mean of 12.6 mm for the month, and 30.5 mm in the month of August, above mean monthly rainfall 14.4 mm, 66.7% success rate.

For some farmers in Central Europe, the 12 days from Christmas Day to Epiphany (12 old days), on 6 January, are said to set the pattern for the weather for the next year, a prediction of things to come during one of the 12 successive months of the New Year. For Aveni (1999) these days may represent those uncounted days left over at the end of a 12-moon cycle that one needed to tack on to the end of the lunar year in order to complete a full cycle of the sun. Since then, many farmers' almanacs still employ this regenerative concept of time in which the future is contained within the past, the New Year repeating in miniature the whole cycle of creation (AVENI, 1999).

Johnson (1897), describing the folklore and superstitions of New England, also presents the myth of the "twelve days after Christmas", suggesting the weather on each of the twelve days of Christmas predicts what the weather will be for the coming twelve months. Narratives of this type are also found in South Africa, Mexico and Central America.

Rain of Saint Joseph

At the end of the rainy season, March is, on average, the third wettest month of the year, after December and January. Despite the trend of rainfall reduction from the end of January, in the second half of March, during the period of Saint Joseph, there is a significant increase in total daily precipitation amounts (Figure 5).

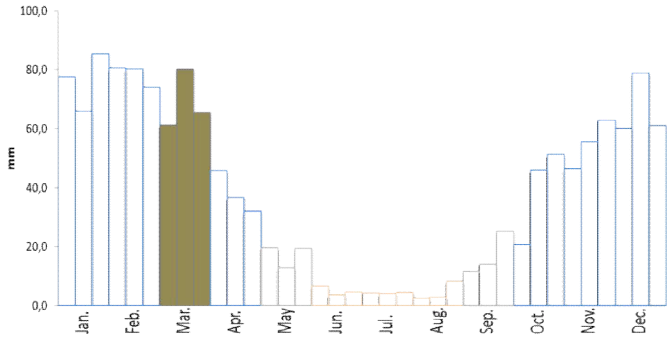

Figure 5 Average Rainfall for a period of 10 days (1961-2017)

The analysis of the averages daily rainfall confirms the folklore of March 19, Saint Joseph day, with 11.9 mm, with the second-highest in terms of average rainfall volume (Figure 06).Over the 56-year period of record, in march 19, were 37 days with precipitation (66%), with the maximum rainfall of 127.9 mm, recorded on 2013, the second-highest daily rainfall on record for the period.

In Ceará, Brazilian northeast, this rainfall represents the last hope for the farmers who depend on it to survive, older farmers believe that if it does not rain until the day of Saint Joseph, patron of Ceará, food production will be threatened (FOLHES and DONALD, 2007). In Mato Grosso, in the second half of March, there is a great probability of having abundant precipitations, period of moderate to heavy rainfall, besides marking the beginning of the transition period for drought, deadline for planting the second crop (the first crop is planted in September). In 2017, even with the rainfall reduction, after March 19, until May 24, day of the last rainfall before the drought, the accumulated rainfall volume was 263.8 mm (16.1% of the volume yearly).

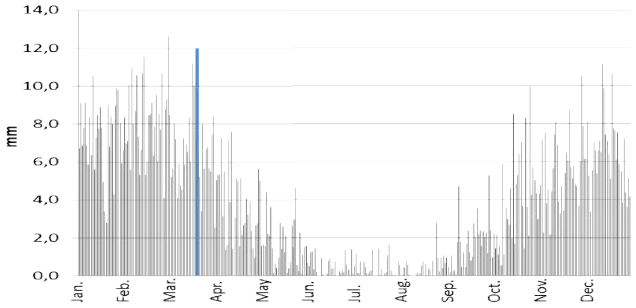

Figure 6 Average Daily Rainfall (1961-2017)

The farmers also used to predict the intensity of drought, on severity and duration, by using weather conditions of the day of Saint Joseph (AZEVEDO *et al*., 1998). For this reference, the results indicated that the chance of more intense droughts, above the historical average, in years when there were no rainfall in day of Saint Joseph was only 40.4%, a statistically significant association was not found between the no presence of rain in day of Saint Joseph and the occurrence of more intense droughts in current year ($\rho = 0.183$). In 2017, a heavy rainfall of 41.4 mm was recorded in the Saint Joseph day, but the severity and duration of drought this year were higher than the averages historical in the period.

In contrast, Silva (1997) concluded that the popular beliefs about the expected rain after the day of Saint Joseph, interpreted from available concepts and methods of meteorology and statistics, are scientifically consistent and, as a result of his work, developed a probabilistic model that allows to estimate the rainfall expected for the autumn equinox.

For Azevedo *et al*. (1998), it is likely that the Saint Joseph rain is related to the autumn equinox, when the day will last roughly 12 hours, as the sun passes directly over the equator, with more sunlight being received nearer the equator. The occurrence of a similar phenomenon in September, an increase in the average intensity daily of rainfall events, around spring equinox, may reinforce the hypothesis of the relation between these precipitations and the transitions between the seasons of the astronomical calendar. The difference between rainfall intensity in around September 23 and around March 21, beginning and the end of the rainy season, respectively, may be related the soil heat storage, from spring to summer, and the consequent return it to the atmosphere during autumn and winter.

Celebrated also in Italy and by the Italian communities in North America, the tradition of St. Joseph's Day began on the Sicily, around the year of 1268, when there was a drought that ruined harvest and caused a famine. The people prayed to Saint Joseph and prayers were answered when the famine and the drought receded (CHAKERES, 2008). In Ireland, another climate-related tradition at this time of year is associated with St. Bridget's Day, on February 1st: a bright, sunny day predicted cold, frosted nights and an extended winter, a cloudy day

predicted warming rains and an early thaw. The St. Bridget's Day announces the arrival of warmer, longer days, the first signs of spring.

Changing Moon Phases

The rare rainfall events in dry months, of June, July and August, on average, were 2.2, 1.5 e 1.9 days with precipitation, respectively. Commonly, the extreme drought phase, going from the last rain in, May or June, until the next rain, in July or August, known as the "cashew rain".

This interval between the two precipitations may be greater, with cashew rain happening in September, October, or only next year, as reported by José Barbosa de Sá, a portuguese chronicler of the 18th century who lived in colonial Cuiabá:

a drought, that there was no rain in the year, nor in the following year,until the end of one thousand seven hundred and forty-nine, has left these people in extreme misery, causing shortage of food, and not only people that suffered, but animals as well, there was not a green leaf, only ash and smoke(SÁ, 1975, p. 44).

In this landscape, the farmers use the phenomena occurring in the atmosphere, celestial objects, or the animals' behavior to predict the arrival of rainfall. Lara *et al*. (2009)found references of the residents of New Xavantina, MT, to birds that anticipate changes environmental conditions before they happen. In this period, there are references to dawn chorus of the Sabiá, national bird symbol of the Brazil, that happens when some rain may arrive (LANHI, 2010). Sick (1997) explains that birds that act in this way, according to Pedro, only vocalize the influence of climatic factors, especially air humidity, not being the cause of rain or of cold outbreak (friagem) events.

The friagem, incursions of masses of cold air with polar characteristics (cold and dry air) affecting the continent of South America, is, generally, the phenomenon responsible for the few rainfall events that occur in this period. (RICARTE *et al*., 2015). The number of rain days, in the extreme drought phase, that occurred under the influence of the friagem was 48.7% of the total rain days, confirming the prevalence of this phenomenon on the rainfall in this region.

However, when signs do not appear, the farmer has as habit to wait the next first quarter moon occur, that may favor the occurrence of rainfall, according popular references. In this sense, Ruoso (2012), evaluating the degree of climate perception of individuals living in the rural areas of Brazil, found reports of rainfall forecast associated to first quarter crescent moon and full moon.

To analyze this popular references, the number of rain days during the dry season, that occured on the day, day before or after, of a primary moon phases were counted. Thus, 107 rain days were recorded, but only 51 of these records were not under the influence of friagem. The distribution of these records in each primary moon phases is shown in table 1.

Table 1 Rain days, in dry season, in each primary moon phases (1961 - 2017)

	Full Moon	Third Quarter	New Moon	First Quarter
Rain days	9	10	11	21

Despite the predominance of rainfall in first quarter moon, according to the popular reference, not possible to reject the null hypothesis, that the result could have occurred by chance alone ($\rho = 0.048$), according significance level adopted. According to Camuffo (1999), the weather changes which can be predicted by simply looking at the Moon have a low probability of success: For this reason farmers should be advised to follow other, more reliable methods of forecasting. Nevertheless, sing time variation of daily precipitation data as a function of some moon particular cycles, some studies have showed that gravitational tides affect heavy rainfalls more than moderate rainfalls. (BRADLEY *et al*., 1962; ADDERLEY and BOWEN, 1962; BRIER and BRADLEY, 1964; CEVOLANI *et al*., 1986). According to Camuflo (1999), the most effective mechanisms for lunar influence on the climate seems to be attributed to the modulation in the gravitational field with changes in transport of heat as a consequence of the tidal movement of the water masses. The proximity of the moon to the Earth, according to Kohyama and Wallace (2016), creates bulges in the planet's atmosphere that creates imperceptible changes in the amount of rain that falls below.

Cashew Rain

First rain after a long span of dry weather, this rain play important role in the growth and development of fruit, and so it received its name, Cashew Rain. Plant phenology may help to understand this reference, once this is a winter flowering species, but almost all the flowering occurs during July, although some flowering does occur over 5 month period, and fructification occurs 7 days after pollination (BARROS, 1988). Somewhat similar reference occurs elsewhere on the planet, as in the case of the wild plum, an important food in central Australia, integral part of the central Australian Aboriginal culture and traditions. Fruit is only ever produced after rain, and rain events in central Australia are not common, or African fruit, baobab, which starts growing weeks before the start of the rainy season.

Cashew Rains for the period were 13 occurrences in the month of July, 17 occurrences in the month of August, and 14 occurrences in September, with 25% of occurrences under the influence of masses of cold air. However, this rain do interrupt the drought, but does not indicate its end, marking final drought period, with daily mean temperature in 27.1 °C and a daily maximum temperature of 40.0 °C or higher, for days in a row, and daily mean air relative humidity in 60% and an air relative humidity minimum of 20.0%.

Despite name, single, two or three rains are a normal occurrence, sometimes on successive days. In 2017, there were two rainfall events in August, one on the 14th and the other on the 20nd. Cashew rain that occurred on the 14th was 26.9 mm, without influence of masses of cold air, on third quarter moon phase. The 2017-2018 wet season started around second half of September.

August is known for the difficult days it brings, according to region native beliefs, by the associated conditions of elevated temperatures, low relative humidity, high winds and lack of rain all contribute to increased fire danger (SOUZA *et al*., 2012a) and the possibility of acid rain.

Pleiades the Return of Rains

After the rain of the cashew, the farmer observes, in the nature, an indication the return of the rainy season. A known reference by the tribal communities of Mato Grosso region, the Pleiades, are an open cluster in the constellation of Taurus, 7 blue stars, grouped and distinct, which, due to a high visibility, gained a special place in many ancient cultures (HERRMANN, 1975).
The rising of these stars announced to ancient populations a special period of the year or the starting of a new season, dry or rainy (SPARAVIGNA, 2008). In French Guiana, for example, natives greet their return on the horizon, because it coincides with the beginning of the dry season (LANKFORD, 2007). These stars were known since old times, by several cultures all around the world, including the Maori and Australian Aborigines, Chinese, Maya and Aztec and the Native people of North America (SPARAVIGNA, 2008).

The Bororo Indians of the Mato Grosso celebrated the heliacal rising of the Pleiades (AkiriDóge) because this astronomical event marked the onset of the dry season (LÉVI-STRAUSS, 1973). Their disappearance (JóruBútu), in the west, which occurs about the middle of May, marked the onset of the dry season (Table 02). The reappearance of the Pleiades on the eastern horizon soon after sunset in September constitutes the passing of a year and signals the start of the rainy season (ANDREWS, 2004). To Aboriginal Australians, like the Bororo, roughly in late November, the Pleiades were signaling and initiating rainy season (ANDREWS, 2004).

Table 2 The annual cycle of the Pleiades

Pleiades Invisible		**Rises at Dawn**			**Pleiades Seen in Night Sky**				**Sets atDusk**	
May	June	July	Aug.	Sept.	Oct.	Dec.	Jan.	Feb.	Mar.	Apr.

Lankford, 2007

The temporal coincidence between the appearance and disappearance of the Pleiades with the alternation of rainfall and drought, according Verdet (1987), is enough for native consider this constellation as cause of seasonal rhythms of the water regime, causal relationship and, at the same time, as "why".

CONCLUSION

There are no quantitative measurements, presented in this paper, that would allow unquestionable identification most of popular references of rainfall prediction. However, it is notable that these popular references have been noticed before historical weather records were available. Thus, it is possible these references describes, approximately, earlier climatic conditions, which occurred at different times, in this area.

Beyond recover the traditional knowledge, so that it perpetuates itself, he use of such references combined with modern weather forecasts can provide a more useful basis for public understanding of these predictions, once these references do not limit in trying to predict the weather, but also provide an understanding of the relationship existing between population and the natural environment.

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