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Analysis of Climate Variability in Market Prices of Corn and Panela in Two Municipalities of The Department of Nariño

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Abstract

This study explores the effect of climate variability on corn and panela prices in two municipalities in the department of Nariño; Precipitation and temperature series from 4 IDEAM meteorological stations were analyzed during the period 2008 – 2018 in the municipalities of El Tambo and Sandoná. Based on the exploratory data analysis, a characterization of the variables was carried out for their treatment and identification of atypical values presumably linked to climate variations and speculative market structures. Through the trend analysis, the detection of changes in the climatic series was verified; In addition, the correlation of the climatic variables with the prices of the products in the national market was determined. On the other hand, principal components analysis was used, with which it was possible to reduce the information of the variables, creating two components that represent the data of the study variables, for the municipality of Sandoná these first two components explained 69, 8% accumulated of the variation of the total sample, while for the municipality of El Tambo the two components explained 67.8% of the variability of the data.

Keywords: Climate Variability, Outliers, Trend, Correlation

Introduction

Given the ever-increasing societal demand for useful and quality information on the effects of climate variability and climate change, the IPCC (2023) (Intergovernmental Panel on Climate Change), defines climate as: "the average state of the weather and, more rigorously, as a statistical description of the weather in terms of the mean values and variability of the corresponding magnitudes over periods that can range from months to thousands or millions of years." Climate is influenced by a variety of factors that are a function of latitude, distance from the sea, vegetation and the presence or absence of orographic systems and anthropic activities, it can vary over time, seasonally, annually and on longer time scales (Arango et al., 2012; Gallardo, 2023).

Colombia has numerous characteristics that intervene in the dynamics of its hydroclimatology, due to its geographical location, highlighting the influence of the atmospheric circulation of the Caribbean Sea, the Pacific Ocean and the Amazon Basin, in addition to the strong topographic barrier that constitutes the Andes Mountain range and the interaction that occurs between the soil, the soil and the environment. vegetation and atmosphere, giving rise to a complex climatic variability that is difficult to predict, making it necessary to carry out an in-depth analysis in which the dynamics of the processes that govern these variations on the different time scales are recognized (Poveda, 2004).

The ECLAC report (2020) highlights the impact of climate change on the agricultural sector in Latin America and the Caribbean, which can lead to a decrease in food production and quality and incomes, as well as rising prices in the region due to vulnerability to the effects of extreme weather events. that according to Bejarano et. In 2020, there may be socioeconomic effects on the agricultural sector during the phases of the El Niño and La Niña phenomenon, which has a strong impact on the prices of the family food basket.

Etayo-Cadavid (2023), presents a chronology of the El Niño phenomenon in Colombia, showing that the most critical periods in terms of precipitation anomalies in the annual average have been 1982 – 1983, 1997 – 1998 and 2015 – 2016, the latter being the one that generated situations of rationing and partial/total shortages of drinking water and energy in large areas of the Caribbean and Andean regions, with notorious impacts in the dry seasons due to the increase in the frequency of fires in the vegetation cover, water deficit problems that affect municipal and village aqueducts and health impacts; According to data from the Ministry of Agriculture and Rural Development for 2015, 1,185,763ha of agricultural damage was caused in 20 departments of the country, with the most affected being Atlántico (403,365ha), Córdoba (243,677ha), Nariño (108,250ha), Antioquia (92,344ha) and Casanare (67,575ha) (UNGRD, 2016).

It is true that Nariño is a department with great agricultural potential, due to its geographical location, its diverse topography that derives in a variety of climates, ranging from quality and temperate temperatures, to the cold temperatures of páramo and snow, this potential has been diminished by the presence of extreme climatic factors such as rainy seasons, the presence of frosts, etc., which lead to speculative movements in the price of agricultural products, affecting food security, which can weaken the sector, leaving farmers in a state of vulnerability (Burgos, M., et. al, 2020).

Therefore, an assessment of temperature and precipitation variability was carried out on the prices of two agricultural commodities: maize *(Zea mayz* L.*)* and panela as a by-product of sugar cane *(Saccharum officinarum* L.*)* in the municipalities of Sandoná and El Tambo in the department of Nariño in order to determine the influence of climate variability on market prices of these products.

Area of Study

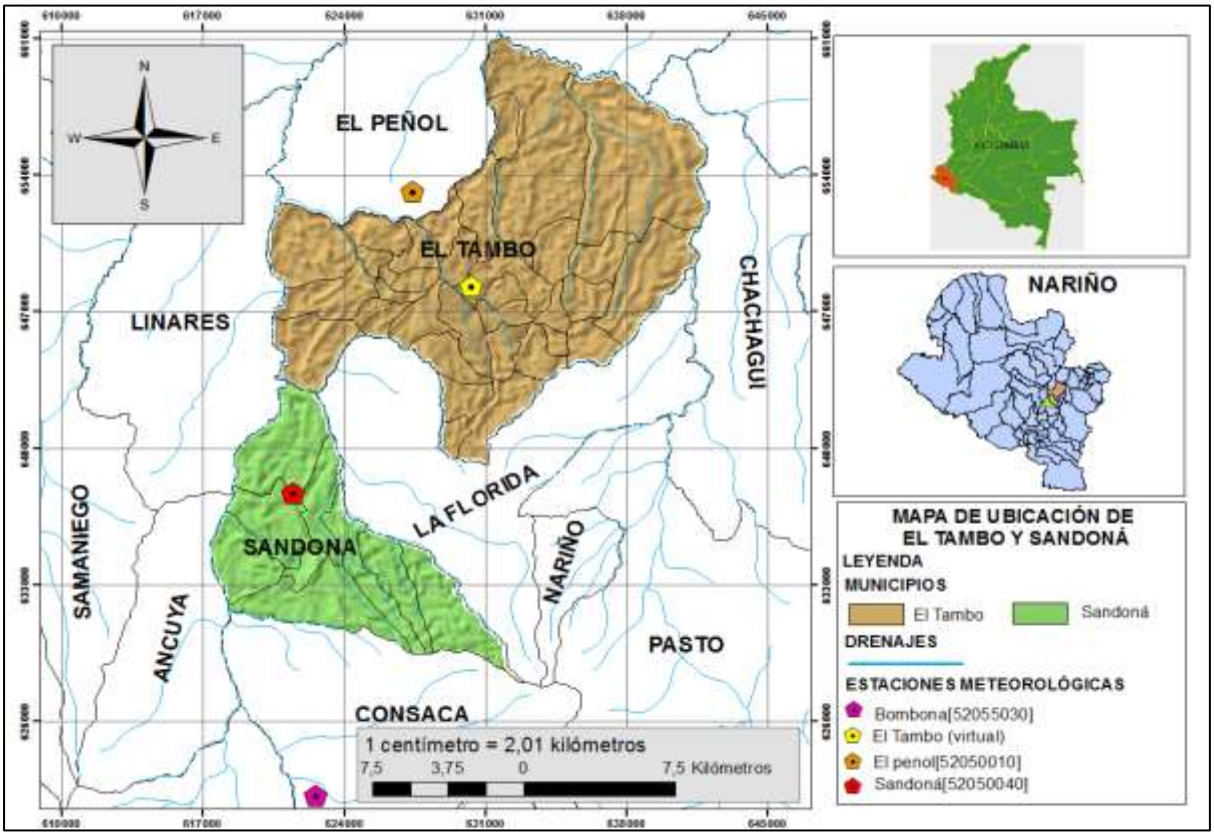
Municipality of El Tambo.

It is located to the northwest (Figure 1) in the department of Nariño, 37km from the city of Pasto. It belongs to the subregion of Guambuyaco. Its municipal seat is located at 01º 24' 47" north latitude and 77º 23' 53" west longitude, with an altitude range that goes from 641 m.a.s.l. to 2,592 m.a.s.l. and a total extension of 1271 km2, the rural area occupies 1024^{km2} (Mayor's Office of El Tambo, 2016); It has a relative humidity of 60%, an average annual rainfall of 1,199mm and an average temperature of 18ºC. Its inhabitants depend economically on agriculture and livestock, with the main production products being: beans, corn, coffee, onions, bananas, sugar cane, tomatoes (El Tambo Mayor's Office, 2020).

Municipality of Sandoná

It belongs to the Western subregion (Figure 1), its municipal seat is located on the Paltapamba plateau, with an altitude range that goes from 830 m.a.s.l. to 3,200 m.a.s.l. and at a distance of 48 km from the city of Pasto. Its surface area is 101Km2, of which 95.6Km2 are part of the rural sector, with an average temperature of 19.8ºC (Mayor's Office of Sandoná, 2020). Its inhabitants live mainly from agricultural activity, highlighting products such as sugar cane, coffee and other crops such as corn and beans on a smaller scale. In addition, the production and marketing of Toquilla Straw products is highlighted (Mayor's Office of Sandoná, 2020).

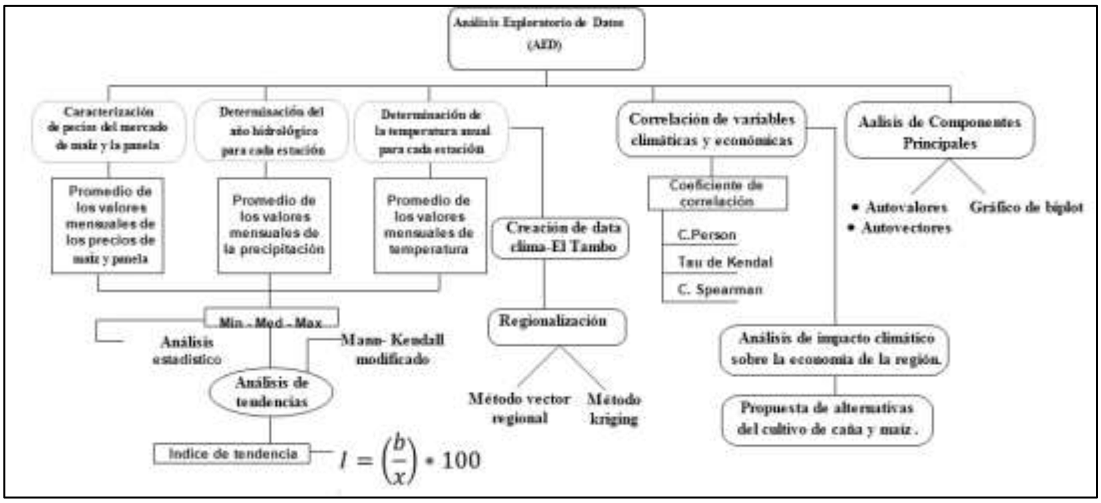
Figure 1. *Location of the municipalities and weather stations used for this study.*



Materials and Methods

The daily series of temperature and precipitation data from all stations were organized and monthly, as was the economic variable; An exploratory data analysis and statistical analysis of the records of the climatic variables was performed for the determination of trends, correlation of the variables, and the analysis of principal components as shown in Figure 2.

Figure 2. *Methodological process. In the original language of Spanish*



Data Used

The selection of the stations was made taking into account the criteria Harvey et al., (2012):

- The sites represent near-natural conditions (less than 10% modification over natural conditions).
- Absence of significant regulations or deviations upstream of the measuring station (less than 5% of the regulated area).
- A minimum of 20 years of hydrological data.
- Highly accurate data logs.

The daily precipitation and temperature data series were analyzed for the period 2008 – 2018 (11 years), information from open data from IDEAM (Institute of Hydrology, Meteorology and Environmental Studies). For the temperature data of the municipality of El Tambo it was necessary to create climate data through the New_LocClim_1.10 program, also using temperature data from nearby stations and interpolating them with the Kriging method in the ArcGIS 10.8 software. Corn prices were obtained through SIPSA Wholesale Price Bulletins and panela prices were obtained through FEDEPANELA. Table 1 shows the selected stations with precipitation data and minimum, average, and maximum monthly temperature.

Table 1.23

Season	Municipality	Elevation (m.s.n.m.)	Lat. (N)	Long. (W)	PP_{min}	PP_{med}	PP_{max}
El peñol [52050010]	El Peñol	1.620	1° 27' 14''	-77° 24' 00''	0	93,5	287,9
Sandoná [52050040]	Sandoná	1.779	1° 11' 24''	-77° 16' 48''	0	112,1	325
					tP_{min}	tP_{med}	tP_{max}
El Tambo	El Tambo	1.720	1° 24' 47"	-77°23'53"	16,1	18,44	20,3
Bomboná[52055030]	Season	Municipality	Elevation	Lat. (N)	Long. (W)	PPmin	PPmed

Note: General information from meteorological and rainfall stations in the municipality of El Peñol, Sandoná, El Tambo and Consacá, precipitation (mm) and temperature (°C) variables, period 2008 – 2018.

Exploratory Data Analysis (AED)

It provides simple methods for organizing and preparing data, detecting flaws in design, and collecting, processing, and evaluating missing data, such as identifying outliers (Salvador & Gallardo, 2003). In this research, a general analysis of the initial data (errors and inconsistencies) was carried out, using box plots at 95% confidence. These graphs provided information on the minimum, average, and maximum values for each station, quartiles, median, existence of outliers, and distribution symmetry obtained in the InfoStat software. As well as evaluating trends and jumps in the TREND software with the modified Mann-Kendal test, verified with Student's T.

Determination of the hydrological year

The hydrological series was used by averaging the monthly values for all seasons. The hydrological year is the twelve-month period comprising a complete hydrological cycle, starting from the month in which the lowest values are observed. It allowed us to observe the variations in precipitation and temperature, the maximum and minimum peaks, and the seasonal variations of the series.

Calculation of precipitation and minimum, average and maximum temperature

To calculate the minimum, average and maximum series, the main series was disaggregated, from which the minimum, mean and maximum values for each month during the period analyzed were extracted.

Trend Analysis

The non-parametric test based on the modified Mann-Kendall T range (MKm) was used, which minimizes the problems associated with differentiating between natural variability and data trends (Blain, 2013).

Correlation of variables

The parametric and non-parametric tests of Pearson, Kendall and Spearman were applied, with which the level of linear association between the variables under study was determined. When the variables present a linear correlation, predictions can be made, but it is limited to making inferences about the cause of the correlation (Morales & Rodríguez, 2016).

Principal Component Analysis

Principal component analysis (PCA) was used to reduce the dimensionality of climate data and product prices, which allows extracting the most important information from a multivariate dataset, compressing a multivariate dataset while keeping only the information that is considered important (reducing the dimensionality of the data), simplifying the description of a dataset, and analyzing the structure of observations and variables (Polanco, 2016).

Results and Discussion

Geographical characterization of the stations used

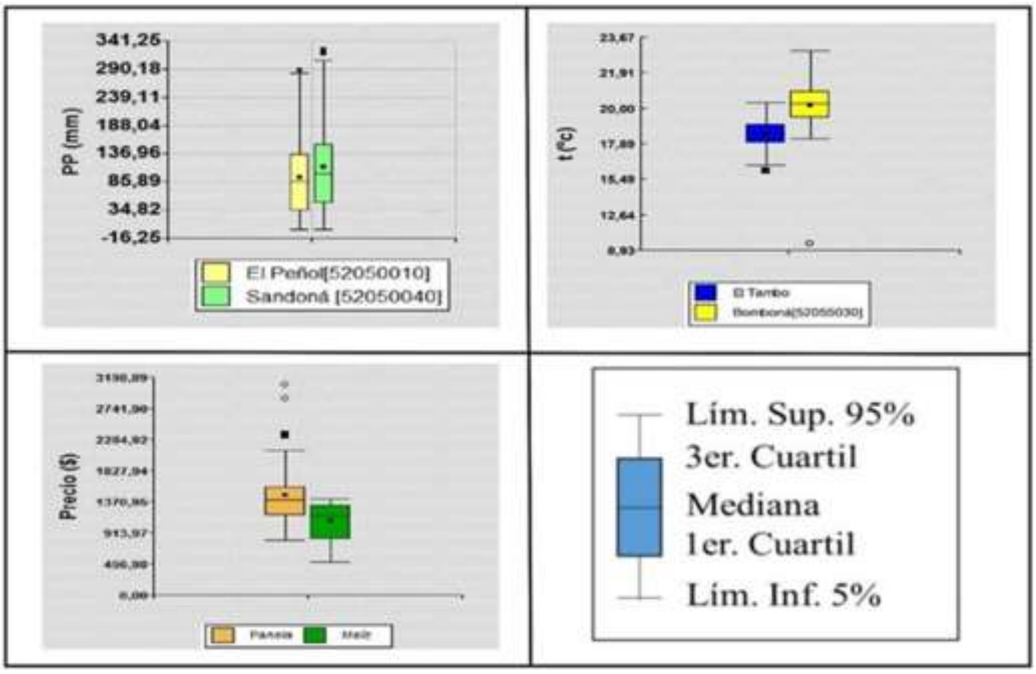
The information obtained from IDEAM was analyzed from daily precipitation and temperature data with a common period from January 1, 2008 to December 31, 2018 (11 years).

Exploratory Data Analysis (AED)

Box Plots

Box plots were made to detect outliers. Figure 3 shows the distribution of data for each station's variable, as well as the market prices of corn and panela within the 95% confidence interval. The El Peñol [52050010] and Sandoná [52050040] stations for the precipitation variable present outlier values above the maximum value, the prices of panela also present outliers above the maximum value, as for the temperature variable there are outliers below the minimum value in the Tambo virtual station, because they exceed the interquartile range.

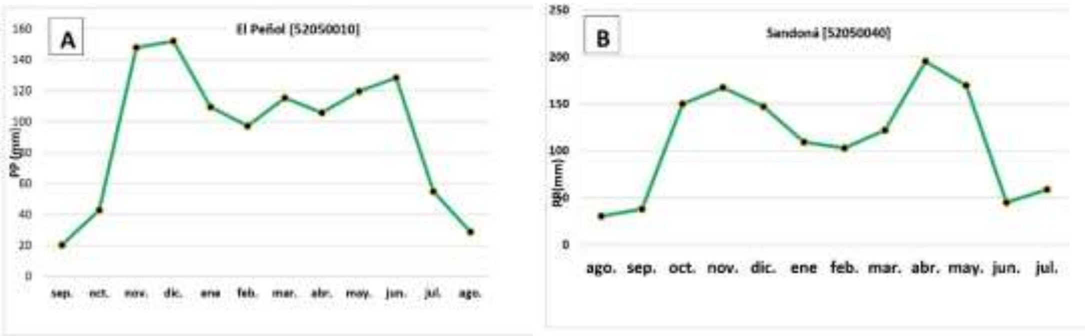
Figure 3. *Box charts for detection of outliers and distribution of data on precipitation, temperature and price variables in the corn and panela market. In the original language of Spanish*



Precipitation characterization

The hydrological year was determined by taking the averages of the monthly values for the stations El Peñol [52050010] and Sandoná [52050040] presented in Figure 4. According to Jaramillo (2005), for this region (southern zone), which are latitudes below 3° North, there is a markedly dry season from mid-June to mid-September and a rainy season from October to June, with small dry "summer" seasons in February and March.

Figure 4. *Hydrological year for stations **A** El Peñol [52050010], **B** Sandoná [52050040]. In the original language of Spanish*



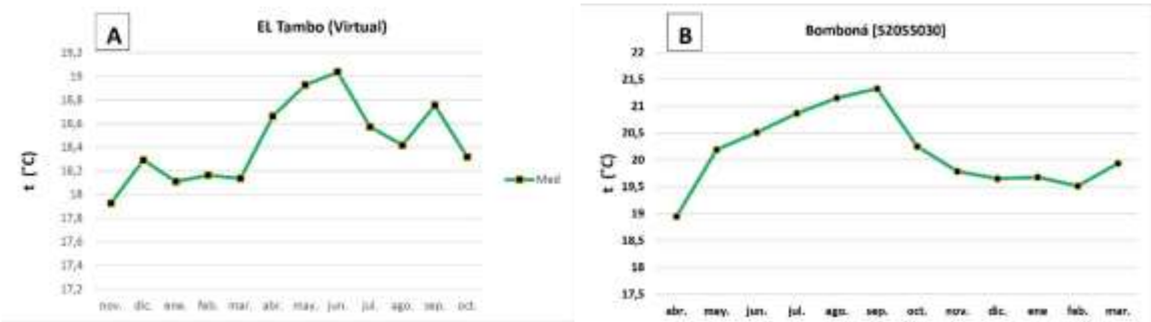
Note: The El Peñol Station has the highest peak of precipitation in December and the Sandoná [52050040] station has a maximum in the month of April, for both seasons there are two rainy periods.

It was evidenced that the rainfall regimes are of the bimodal type for the two mentioned seasons, so that this zone has an equatorial mountain climate, characteristic of the southern Andean region influenced by the Intertropical Confluence Zone - ITCZ, (Cortés, 2010). This information was used as input for the analysis of price correlation in both corn and panela.

Temperature Characterization

Figure 5 shows the temperature data (°C) from the El Tambo (virtual station) and Bomboná [52055030] stations. At the El Tambo station (Figure 5A) it is observed that it has a notorious peak in the month of June with a value of 19.03ºC and a minimum for the month of November with a value of 17.92ºC. The Bomboná station [52055030] (Figure 5B) has a maximum in September with 21.32°C and a minimum in April with 18.94°C.

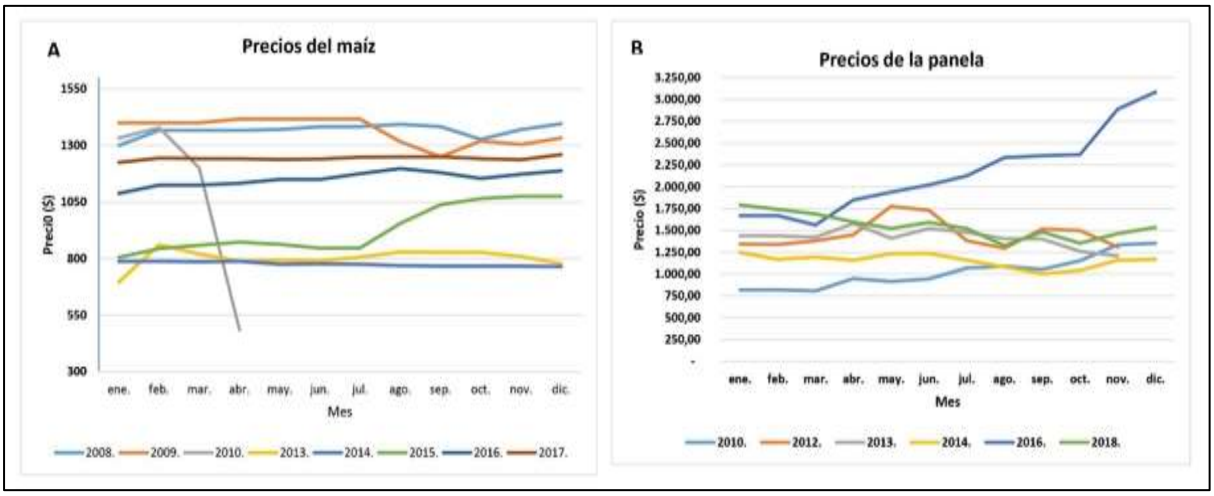
Figure 5. *Temperature for stations **A** El Tambo (Virtual) and **B** Bomboná [52055030]. In the original language of Spanish*



Characterization of market prices for maize and sugarcane (panela)

Figure 6 shows the market prices per kilogram for corn (Figure 6A) and panela (Figure 6B). The maximum price of corn in the period analyzed is in April, May, June and July 2009 with a price of $1,417 and the lowest in April 2010, with a value of $485. In Figure 6B, the minimum price of panela is in March 2010, with a value of $807.2 and the highest price for December 2016 with a value of $3085.

Figure 6. *Market prices of corn and panela in the municipalities of Sandoná and El Tambo. **A.** Prices for maize **B.** Prices for panela. In the original language of Spanish*



Trend Analysis

Table 2 summarizes the results of the trend analysis with the non-parametric Mann-Kendall test, for the stations of Sandoná (Sandoná [52050040], Bomboná [52055030]), El Tambo (virtual) and El Peñol [52050010] and the prices per kilo in the corn and panela market.

Table 2 *Note: The*

PPmax	Municipality			
	(m.a.s.l.)		El Tambo	
	Mann-Kendall	valor-p (bilateral)	Mann-Kendall	El Peñol [52050010]
El Peñol	1.620	1° 27' 14''	-77° 24' 00''	0
93,5	287,9	Sandoná [52050040]	Sandona	1.779
1° 11' 24''	-77° 16' 48''	0	112,1	325
Panela	0,377	< 0,0001	0,377	< 0,0001

tP *min* se evaluó con alfa de 0.05. Se presenta en azul una tendencia positiva, en rojo la tendencia negativa y en blanco no existe una tendencia. H0: No existe una tendencia en la serie. HA: Existe una tendencia en la serie

In the municipality of Sandoná, the variables of temperature and prices of panela showed a positive trend in the Mann-Kendall test with a P-value of less than 0.0001 each, presenting a significance in the temperature series and prices of panela. For the variables of precipitation and maize prices, there is no trend because the P-value exceeds the alpha significance level of 0.05. In the municipality of El Tambo, the variable of panela prices also showed a positive trend in the Mann-Kendall test with a P value of less than 0.0001, presenting a significance in the prices of panela, for the variables of precipitation, temperature and corn prices, the results are not statistically significant. for a 95% confidence level.

The temperature variable at the Bomboná station [52055030]) in the analyzed period shows a positive trend, this is due to the fact that in recent years the average temperature of the country increased 0.8°C, with the average temperature in Colombia being 22.2 °C (IDEAM, 2017). The behavior of this variable in Colombia is influenced by the positive trend due to the increase in the global concentration of GHGs and the occurrence of the El Niño phenomenon, with notable increases in the average annual temperature in the country's regions (Etayo-Cadavid, M. 2023).

Panela prices have also had a positive trend, according to Fedepanela, (2016) sugarcane withstands high temperatures for a maximum period of 3 months, however, this crop when exposed to long periods of drought and high temperatures begins to present reductions in yields for panela production. In 2016 the drought caused by the El Niño phenomenon decreased the cultivation of sugarcane at the national level, causing a 40% drop in the production of panela at the national level, this causes a decrease in the supply of the product and an increase in the price of the product, in this case that of panela.

Figure 7 shows that the precipitation variable in both municipalities decreases in the trend graph for the period analyzed, the trend for the station (Sandoná [52050040], decreases -3.92%, while for the El Peñol station [52050010] decreases -1.48%. For the temperature variable in the municipality of Sandoná, the Bomboná station [52055030], increases by 1.15% and in the municipality of El Tambo (virtual) increases by 0.00043%. As for corn prices in the study area, it decreased -2.69% and panela prices increased by 5.33%.

Correlation of variables

To determine if the correlation between the variables is significant, the P-value was compared with the level of significance of the variables of temperature-corn, temperature-panela, precipitation-maize, and precipitation-panela at 90%, 95%, and 99% (Table 3) in the municipalities of Sandoná and El Tambo.

Figure 7. *Trend graphs of the variable's precipitation, temperature and prices/kg of panela and corn in the municipalities evaluated. In the original language of Spanish*

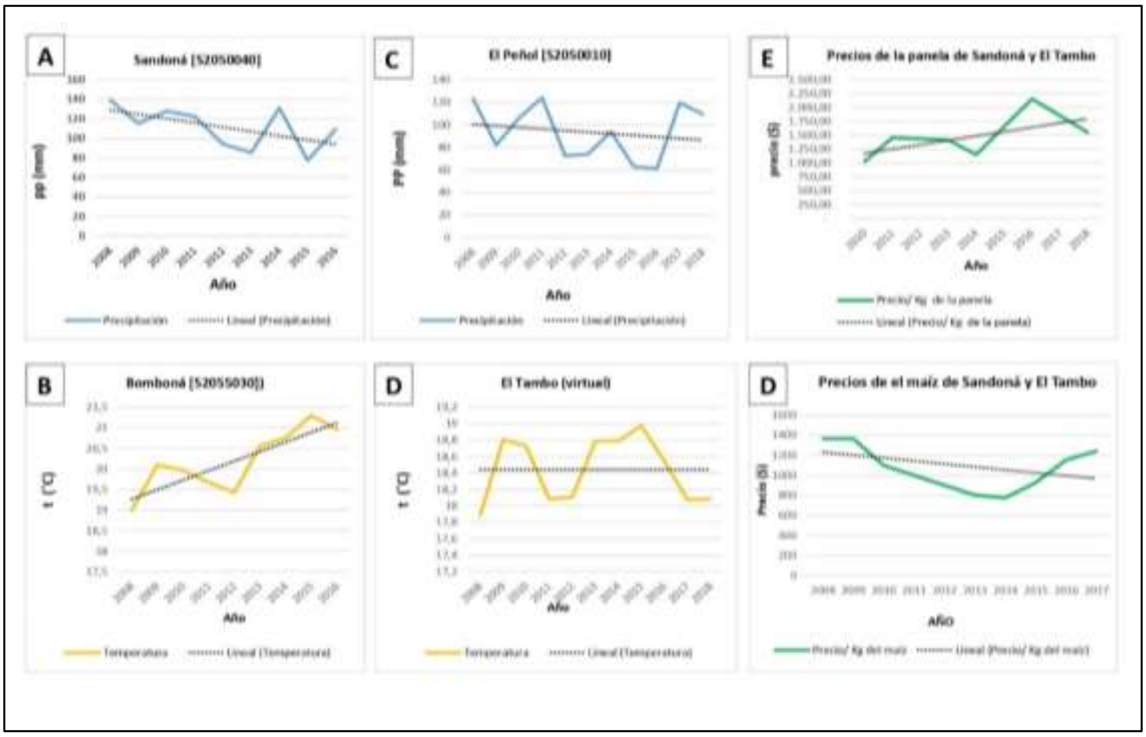


Table 3 shows the degree of correlation between the variables, as determined by Pearson's test, Kendall's Tau test, and Spearman's test. In the case of Sandoná, the temperature-corn relationship in the three tests presented a negative value (red) and a P-value that is close to the significance level of 0.01, according to (Ortega et al., 2009), rejecting the null hypothesis (H0), concluding that there is a high correlation in the temperature-corn series.

In the case of Temperature – Panela, Precipitation – Corn and Precipitation – Panela there is no correlation since the P-value is higher than the level of significance proposed for this analysis. In the municipality of El Tambo, the relationship between the temperature-maize variables in Pearson's test presented a significant negative value (red) and a P-value that approaches the significance level of 0.01, which allows us to identify a high significant correlation. For the Kendall and Spearman tests, a mean negative value (pink) was obtained, which with the P-value approaches the significance level of 0.05, concluding that there is a mean correlation in the related variables. In the case of the temperature-panela variables, only Pearson's test showed a low negative correlation (light pink), since the P-value is close to the degree of significance 0.1, the other variable relationships do not present a correlation.

Table 3 *90%*

	tPmax	El Tambo		El Tambo		1.720	
	-77°23'53"	**16,1**	**18,44**	**20,3**	**Bom boná [520 5503 0]**	**Consacá**	**1.493**
	-77° 16' 12''	9,6	20,15	23	0,003	-0,402	0,001
1° 06' 36''	Temperature-Panel	-0,012	0,934	0,045	0,643	0,098	0,495
	Precipitation- Corn	0,04	0,736	0,009	0,913	0,015	0,903
	Precipitation- Panela	-0,027	0,847	-0,07	0,45	-0,096	0,484
	THE DAM						
	Temperature-Corn	-0,281	0,008	-0,174	0,018	-0,267	0,012
Variable	Temperature-Panel	-0,201	0,095	-0,133	0,109	-0,18	0,136
	Precipitation- Corn	0,158	0,143	0,077	0,288	0,111	0,303

Precipitation- Panela	0,009	0,94	0,005	0,956	Variable	Munici pality

Negative	Sandona	El Tambo
Mann-Kendall		Precipitation
-0,092		-0,049
0,408		0,423

Note: the negative trend is presented on a red scale (red for 99%) and the positive trend on a blue scale (dark blue for 99%) for each case, with white for stations that do not show a trend. H0: There is no correlation in the series. HA: There is a correlation in the series

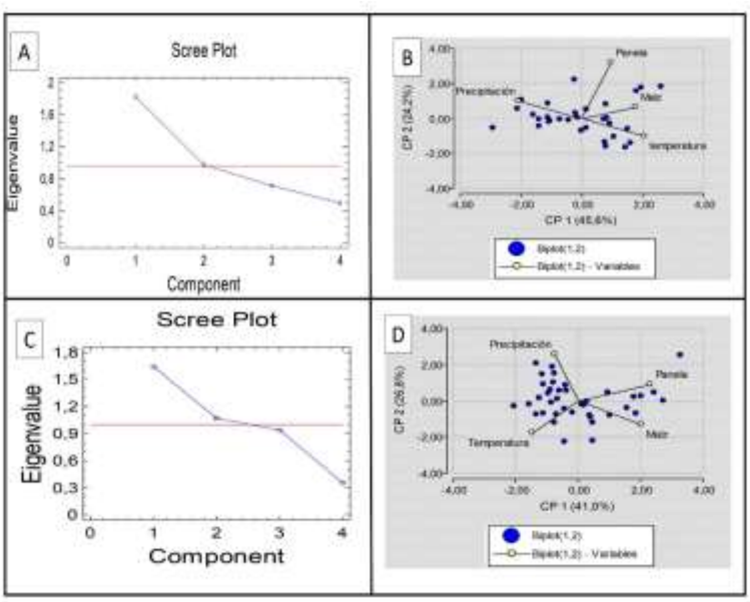
Saldarriaga, (2016) in the study of temperature variability in the productivity and prices of agricultural products (evidence in Peru), determined that a greater variability of temperature increases the prices of these products between 3.5% and 4%. Contrasting these results with the correlations yielded for this study, it can be inferred that the temperature in both municipalities negatively influences corn prices.

Principal Component Analysis (PCA)

The main component analysis allowed the reduction of the four original variables in the municipality of Sandoná and El Tambo, the PCA eigenvalues for the four variables in the municipality of Sandoná, showed that the first component explained 45.6% of the variation (Figure 8B), with a value of λ = 1.82 and the second component explained 24.2% with λ = 1. These first two components accounted for 69.8% of the cumulative variation in the total sample.

In the municipality of El Tambo, the first component explained 41% of the variation (Figure 8D), with a value of λ = 1.63, and the second component explained 26.8% with λ = 1.07. The two components explained 67.8% of the variability in the data. Therefore, it can be considered that for the two municipalities, the PCs found explained most of the variation between the variables.

Figure 8. *Principal Component Analysis Charts obtained from the archiving of data on temperature, precipitation, prices of corn and panela in the market with standardized data. In the original language of Spanish*



Note: ***A.*** *Sedimentation graph of the variables of the municipality of Sandoná.* ***B****. Biplot graph of the variables of the municipality of Sandoná* ***C****. Sedimentation graph of the variables of the municipality of El Tambo.* ***D****. Biplot graph of the variables of the municipality of El Tambo.*

From component number three, in both municipalities the self-value begins to be less than unity. Figures 8A and 8C show the sedimentation graph of the components, which is also often used as a graphic contrast to determine the number of components to be retained; according to this criterion, it is adopted by resorting to the first two components, which are located prior to the sedimentation zone, understanding this as the part of the graph in which the components begin not to present strong slopes (Bernal et al., 2004).

On the other hand, Rivera et al., (2017) in their work Multivariate Statistics Techniques for the Typification of Livestock Production Systems, the associations between variables according to the angles of the vectors that represent them, it can be inferred that variables with acute angles indicate positive correlations, obtuse angles correspond to negative correlations and right angles indicate that there is no correlation between the variables. In graph 8B, the vectors that represent an acute angle are the temperature in relation to the prices of corn and panela, which infers that there is a positive correlation, which significantly influences the temperature variable on the prices of corn and panela in the municipality of Sandoná.

In the municipality of El Tambo, in graph 8D, the vectors of both the temperature and precipitation variables form an obtuse angle with the prices of corn and panela, corresponding to a negative correlation between the variables. Temperature and precipitation are variables that do not constitute significant variation in the prices of corn and panela.

Conclusion

The econometric estimates indicate that the temperature variable presents a negative correlation with the variables of the prices of the products studied in the municipalities of Sandoná and El Tambo, this infers that the impacts of the variability of the environmental temperature negatively affects production and yield, although it should be clarified that this factor is not the only one that influences agriculture, There are other variables such as soil, work, technology, pests, diseases, improved seeds, among others, but it is not the analysis of this study. In perspective, greater temperature variability in the future is likely to generate a food insecurity scenario due to an increase in food prices. In this research, no significant results were found in the precipitation variable, since the correlations in the Pearson, Kendall and Spearman tests against the prices of corn (dry grain) and sugarcane (panela) in the results, are higher than the level of significance proposed for this analysis; However, this variable is fundamental for the growth and yield of the crops studied, so an excess or deficit of rainfall affects the physiological processes of corn and sugarcane that go from planting to physiological maturity.

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