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Determination of the traffic accident rate, as a function of the variables transportation, climate, weather; road axis e-28 b, Province of Pichincha, Ecuador

Determinación del índice de accidentes de transito, en funcion de las variables transporte, clima ,tiempo; eje vial e-28 b, Provincia de pichincha, Ecuador

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ABSTRACT

The Troncal de La Sierra (E35) located in the Andes Mountains, comes off at the intersection with the Quito-Cayambe Collector Road (E28B), Guayllabamba sector. Geography influences the weather and climate of the region. The meteorological parameters and monthly averages for the last 29 years were analyzed to determine the evolution of the weather, climate and its impact on traffic accidents. Finally, the accident rate was formulated based on the variables determined in this research.

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RESEUMEN

La Troncal de La Sierra (E35) ubicada en la cordillera de los Andes, se desprende en la intersección con la Vía Colectora Quito-Cayambe (E28B), sector Guayllabamba. La geografía influye en el tiempo, clima de la región. Se analizó los parámetros meteorológicos, y medias mensuales de los últimos 29 años, para determinar la evolución del tiempo, clima y su incidencia con los accidentes de tránsito. Finalmente, se formuló el índice de accidentabilidad en base a las variables determinadas en esta investigación.

Keywords / Palabras clave

Weather, Climate, E-28B, Accidents, Traffic.

Tiempo, Clima, E-28B, Accidentes, Transito.

Introduction

Ecuador is located in the northwest of the South American continent, crossed by the equatorial line (east to west) and the Andes Mountain Range, which divided into three branches: Western, Central and Eastern, runs through the entire territory from north to south. It determines three climatically well differentiated regions: Coast or Littoral and Insular; Inter-Andean and Amazonian, generating several climatic floors, from the warm humid to the icy cold of the glaciers of its snow-capped mountains and volcanoes (Fajardo, 2008).

The Troncal de La Sierra (E35) is located along its entire length in the inter-Andean valley between the western and eastern ranges of the Andes. The road, therefore, crosses the transverse Andean nodes that connect the two Andean mountain ranges to travel through the inter-Andean basins. Most of the extension of this trunk road is part of the Pan-American Highway. The exception to this generality is in the metropolitan area of the city of Quito, where the Panamerican Highway separates from the Troncal de La Sierra (E35) at the northern end of the city and then joins it again at the southern end of the city. This separation occurs specifically at the intersection with the Quito-Cayambe Collector Road - E28B (IGM, 2010), which comprises our research area.

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Throughout history, traffic accidents have been one of the main causes of deaths and serious injuries in Ecuador and in the world, which is why they have become an epidemic for society, since year after year traffic accidents have been increasing due to different factors.

Regarding traffic accidents registered in the city of Quito, province of Pichincha, Ecuador, a significant variation has been noted in terms of accidents, injuries and deaths between the years 2019 and 2021, in the year 2019 there were 7,896 traffic accidents. The SARS-CoV-2 pandemic (COVID/19), which struck the world and paralyzed transportation to a great extent in 2020, registered 5,418 accidents, in 2021 5,554 accidents were registered, which shows a slight increase with respect to the previous year, according to the statistics of the National Traffic Agency (ANT, 2022).

In terms of weather and climate, in Ecuador, the periods considered as wet season occur twice a year, the most intense between the months of February, March, April and May, with April being the most intense; the other occurs between the months of October, November, December and January, with November being the most intense. The month of September would be considered the transition between the dry and wet seasons in the study area, and the precipitation in this month corresponds to practically half of what will precipitate in the month of October (Fajardo, 2020).

Based on the historical data of traffic accidents and focused on the meteorological and climatic factor as a cause of various accidents, we will investigate the relationship between climate, weather and transportation, analyzing various aspects such as road geography, road actors, infrastructure, climatological events in which the best known are the El Niño and La Niña events, with great influence in recent years in Ecuador.

For the development of this research, information provided by the National Institute of Meteorology and Hydrology (INAMHI) from the weather stations of Tomalon, Iñaquito and Izobamba, with information for 29 years (INAMHI, 1990-2019), the National Transit Agency (ANT) and information provided by other means, has been considered.

The objective of this work is to define in the study area, road axis E28-B, the traffic accident rate that influences the so-called dry and wet seasons, which will allow characterizing these variables: climate,

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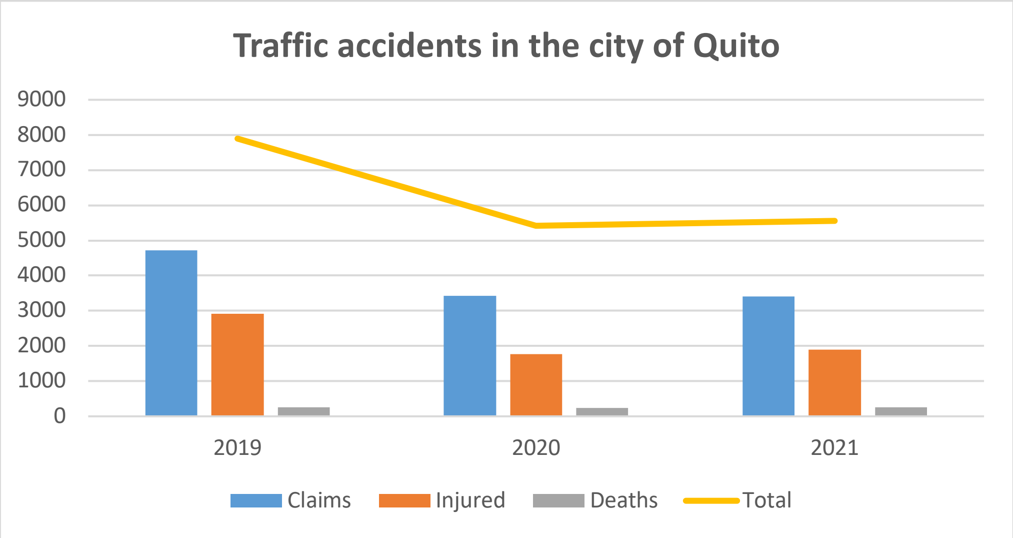
weather and transportation, highlighting the atypical years that have influenced the periods of higher accident rates in traffic accidents.

Materials and Methods

Evolution of traffic accidents years: 2019, 2020 and 2021

In the city of Quito, 7,896 traffic accidents were recorded in 2019. The SARS-CoV-2 pandemic (COVID/19), which hit the world and paralyzed transportation to a great extent in 2020, registered 5,418 accidents, in 2021 5,554 accidents were registered, which shows a slight increase with respect to the previous year, according to the statistics of the National Traffic Agency (ANT, 2022).

Graph 1. Evolution of traffic accidents in the last three years.



Note: Own elaboration, based on information obtained from the National Transit Agency (ANT).

Classification of traffic accidents, by cause and type of accident

Based on the information obtained from the National Transit Agency, statistical information was available in which traffic accidents are

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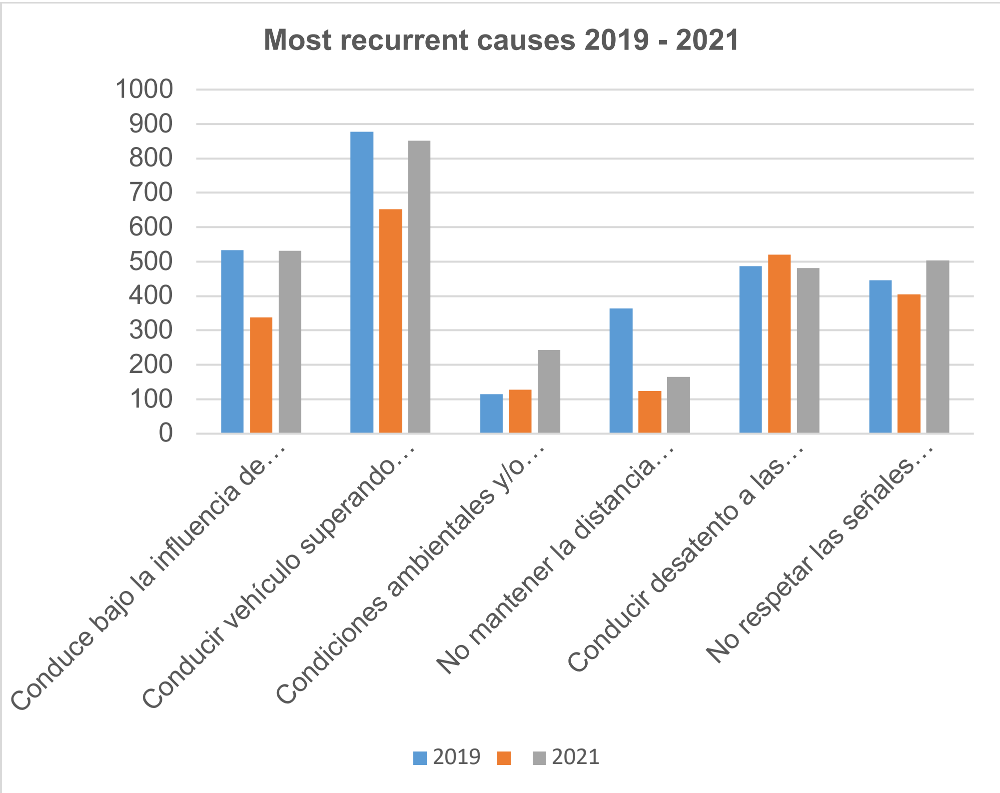
classified between 2019, 2020, 2021, by type and cause. From the information analyzed, the main causes that determine the occurrence of traffic accidents in the province of Pichincha, which is the one that has this information, were determined.

Graph 2. Evolution of traffic accidents in the last three years, by type and cause.



Note: Own elaboration, based on information obtained from the National Transit Agency (ANT).

From the above graph, the 6 most incident causes can be appreciated (based on their percentages), it is important to appreciate that regarding traffic accidents due to environmental and/or atmospheric conditions (fog, mist, hail, rain), the trend is increasing between the year 2019 to 2021, it represents a growth percentage of 50.10% ,direct consequence of the increase in precipitation of the last 2 years and is absolutely related to Climate Change and the presence of adverse

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events such as El Niño and La Niña. Failure to respect traffic signals also has a growing trend.

Table 1. *Traffic accident rate, by type and causes, period 2019-2021.*

No.	Probable causes	2019		2021	Total	% Last year	of total % of total
C6	Driving under the influence of alcohol, narcotic or psychotropic substances and/or medication.	533	339	532	1404	37,89%	12,53%
C9	Driving a vehicle exceeding the maximum speed limits.	877	652	852	2381	35,78%	21,26%
C10	Environmental and/or atmospheric conditions (fog, mist, hail, rain).	115		**243**	**485**	**50,10%**	4,33%
C11	Failure to maintain a prudent distance from the vehicle in front.				655	25,34%	5,85%
C14	Driving inattentive to traffic conditions (cell phones, video screens, food, make-up or any other distracting element).	486	520	481	1487	32,35%	13,28%
C23	Failure to respect traffic signals (stop, yield, yield the right of way, red traffic light, etc.).	446	405	**503**	1354	37,15%	12,09%

Note: Own elaboration, based on information obtained from the National Transit Agency (ANT).

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Analysis of Climatic Variables:

Three meteorological stations have been selected near the study area, which correspond to the climatology of the area and are characterized by long periods of information on temperature, precipitation and relative humidity parameters (Table 2).

Table 2. *List of weather stations for analysis.*

Stations	Temporality Series	Parameters	Period
Tomalón	29 years and 3 years (other parameters)	Precipitation Temperature, relative humidity	1990 - 2019
		Cloud cover, visibility	2019-2021
		Maximum precipitation (1990-2015)	1990 - 2015
		Daily precipitation (specific days)	Specific days
Iñaquito	29 years old	Precipitation temperature, relative humidity	1990-2019
Izobamba	29 years old	Precipitation temperature, relative humidity	1990-2019

Note: Own elaboration.

Multiannual cycle average temperature behavior.

The multiannual behavior of the monthly mean temperature in general presents a weak climatic variability, with several peaks between high and low, the largest amplitude correspond to El Niño events such as 1982-1983; 1997-1998; 2003-2004; 2015-2016; 2018/2019, others of smaller amplitude correspond to transition years and La Niña events: 1995-1996; 2007-2008; 2010-2011, 2017-2018 (Figure 1).

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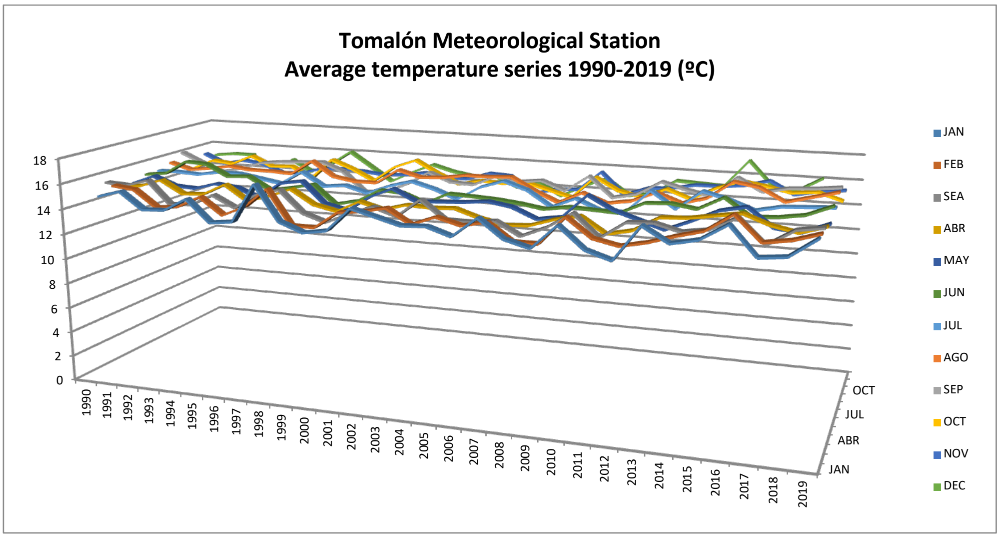
Graph 3. Multi-annual cycle curve of the monthly mean temperature, Tomalón meteorological station.



Note: Own elaboration .

Graph 4. Multi-annual cycle curve of the monthly mean temperature, Iñaquito meteorological station.

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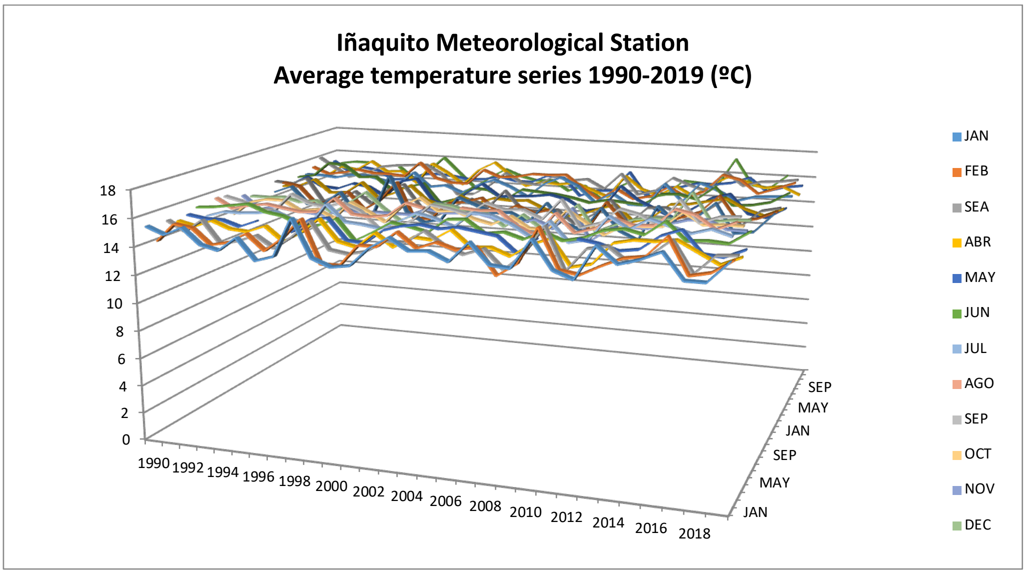

Graph 5. Multi-annual cycle curve of the monthly mean temperature, Izobamba meteorological station**.**

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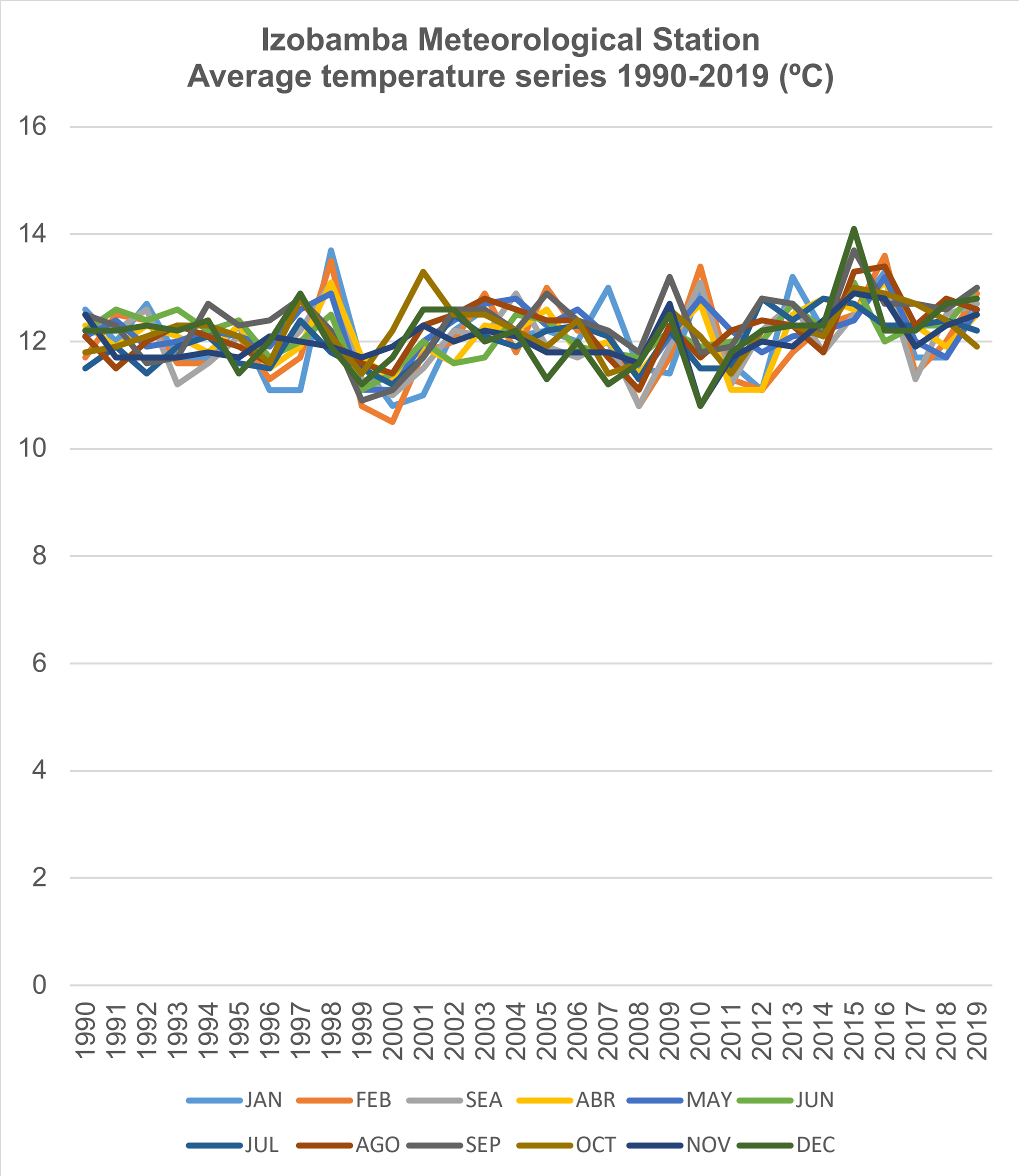

Note: Own elaboration

Multiannual cycle monthly precipitation behavior

In El Niño and La Niña events, precipitation is more intense than in normal years, and the highest peaks occur, depending on the location of the station in the study area (Graph 6).

At the Tomalon weather station the highest precipitation (above normal) occurred in the El Niño events: 1994-1995 (highest

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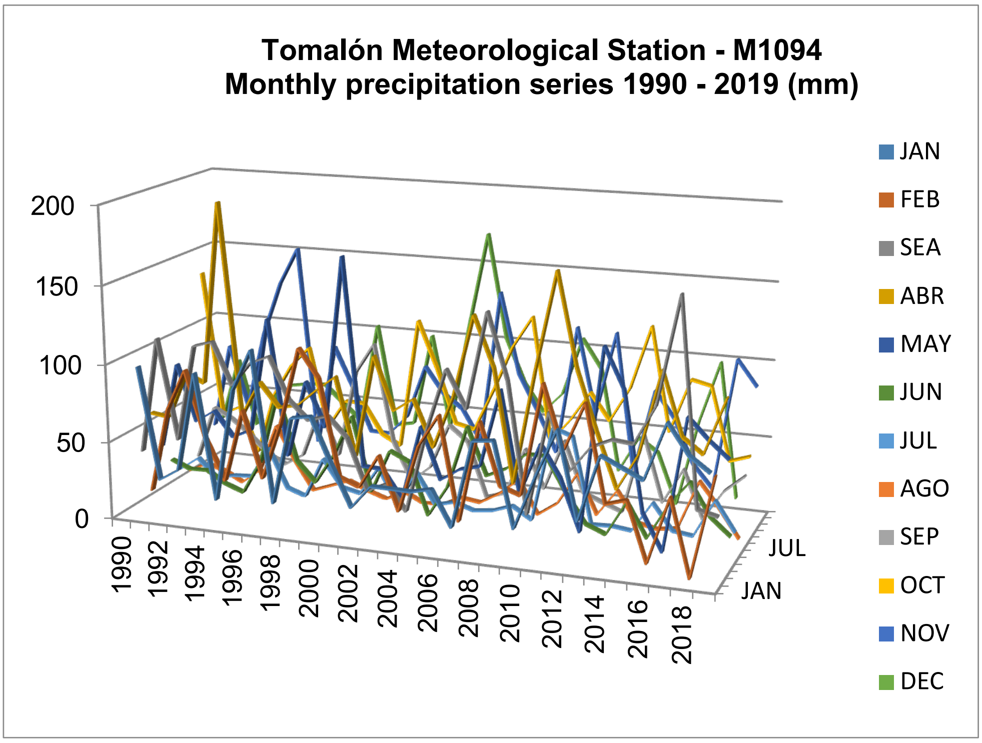
precipitation); 2002-2003; 2015-2016; and as for the La Niña event, higher precipitation even than El Niño occurs in the events of: 1998-1999, 2007-2008 (highest precipitation); 2011-2012 and 2017-2018 (the one with the lowest precipitation).

Graph 6. Multi-annual cycle curve of monthly average precipitation, Tomalón meteorological station**.**



Note: Own elaboration.

At the Iñaquito weather station, the highest precipitation (above normal) occurred in the El Niño events: 1994-1995; 1997-1998, 2002-2003; 2015-2016; and regarding the La Niña event, precipitation higher even than El Niño occurs in the events of: 2010-2011 (the one with the highest precipitation), 2016-2017, 2017-2018.

Graph 7. Multi-annual cycle curve of monthly average precipitation, Iñaquito meteorological station.

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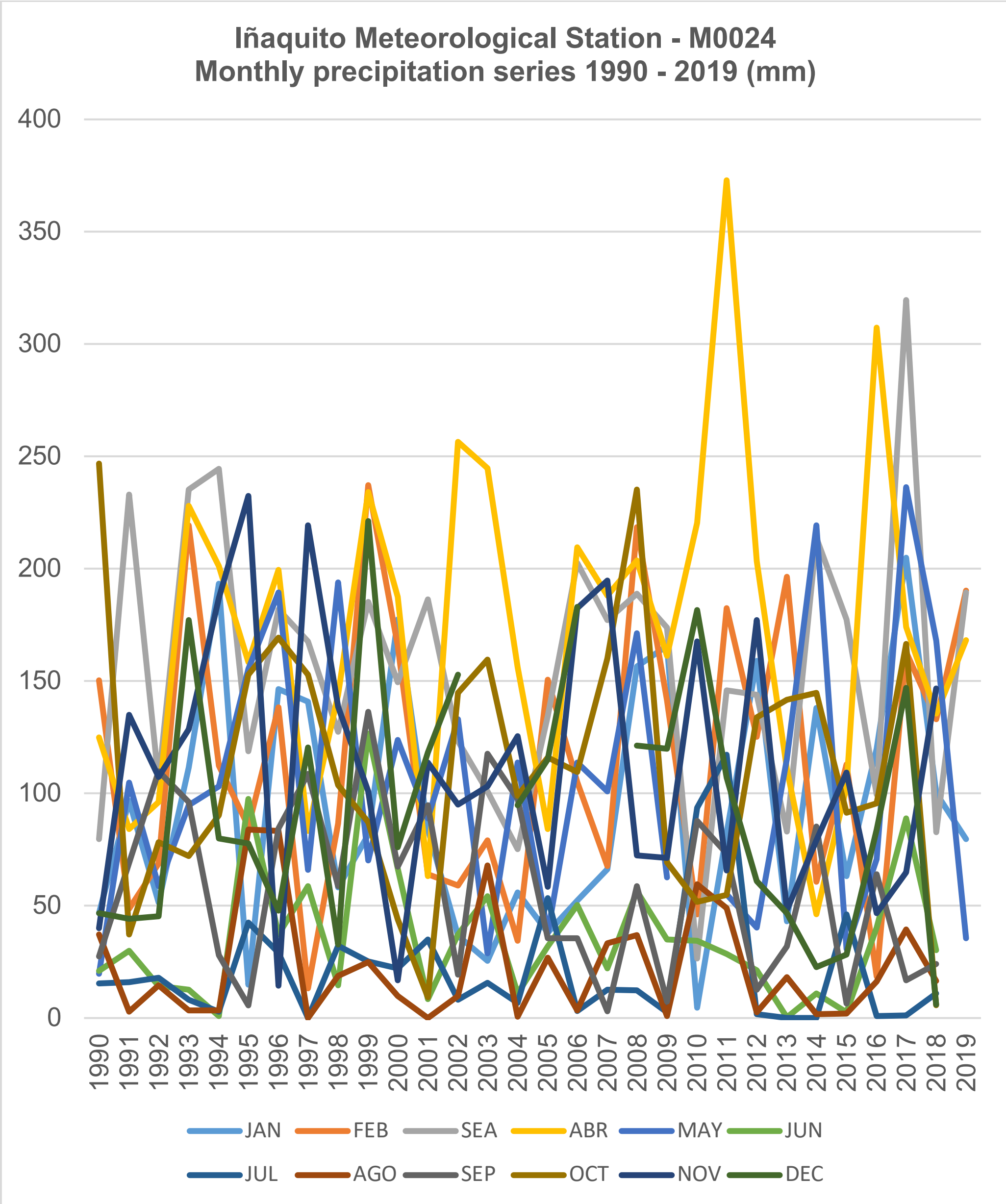

Note: Own elaboration.

At the Izobamba weather station, the highest rainfall (above normal) occurred in the El Niño events: 1997-1998, 2015-2016; and with regard to the La Niña event, rainfall higher even than El Niño occurs in the events of: 2007-2008 (the one with the highest rainfall), 2010-2011, 2016-2017, 2017-2018.

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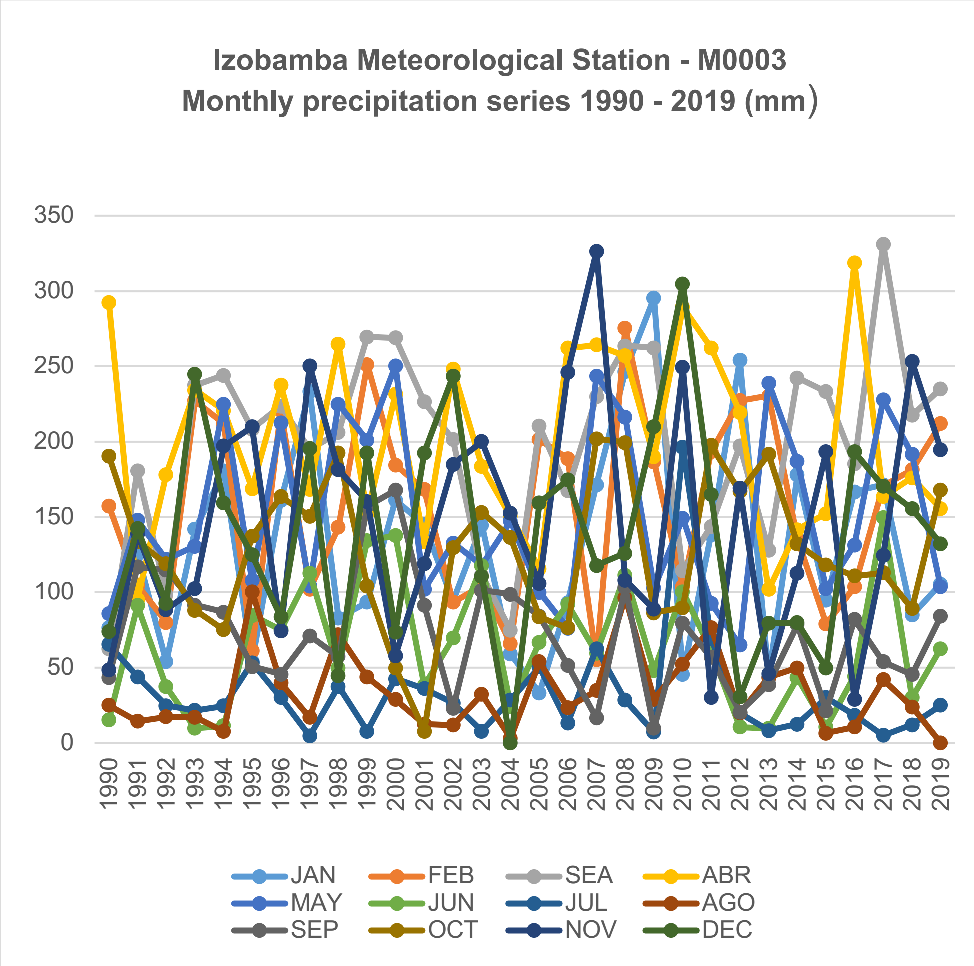
Graph 8. Multi-annual cycle curve of average monthly precipitation, Izobamba meteorological station**.**



Note: Own elaboration.

From the analysis carried out, the highest precipitation values were obtained during the El Niño and La Niña events, being La Niña the one characterized by intensities even higher than those of El Niño during the study period.

Multiannual cycle relative humidity behavior.

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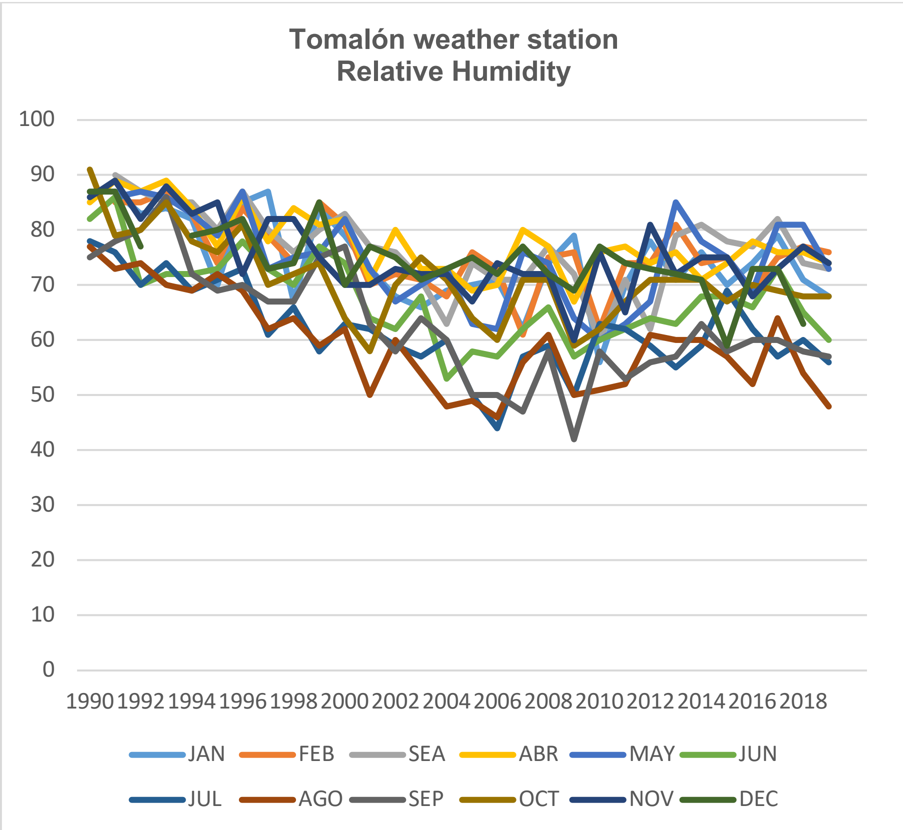
From the analysis carried out in the period 1990-2019 with respect to the relative humidity parameter of the meteorological stations under study, the multiannual behavior curves are shown.

Graph 9. Multi-annual cycle curve of monthly relative humidity, Tomalon weather station.



Note: Own elaboration.

Graph 10. Multi-annual cycle curve of monthly relative humidity, Iñaquito meteorological station**.**

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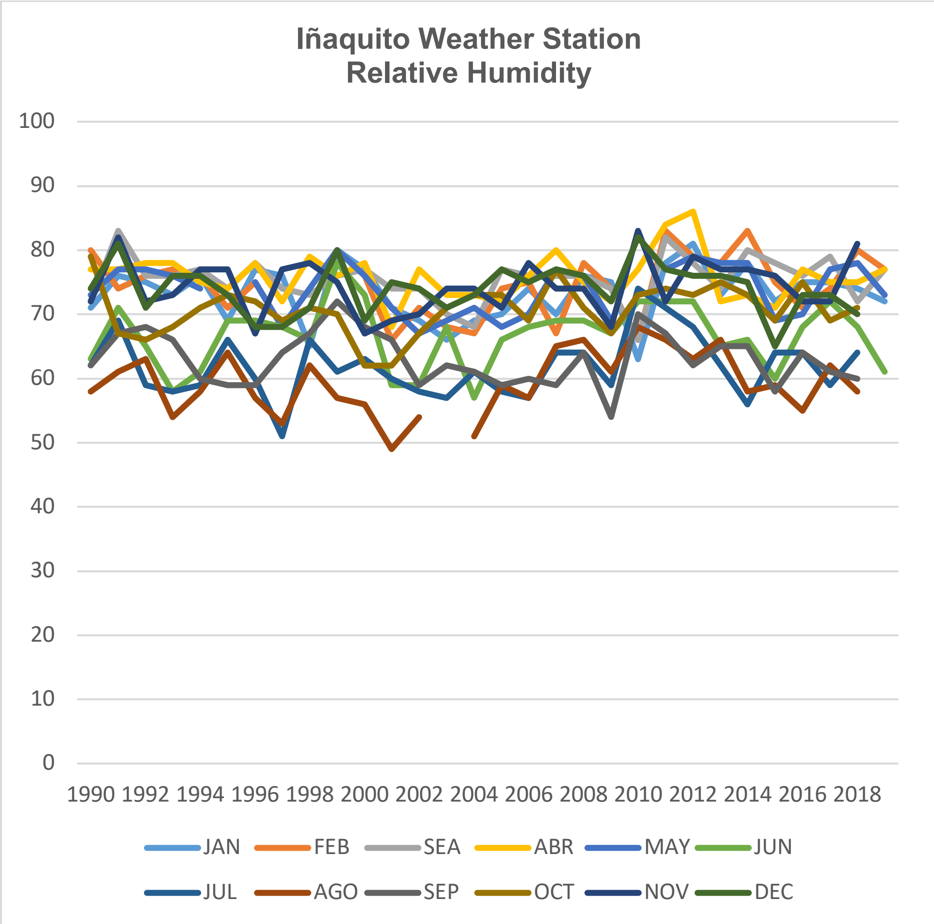

Note: Own elaboration. ** There are certain periods in which information was not available, so there are cuts in these curves, but the trend is not changed.

Graph 11. Multi-annual cycle curve of monthly relative humidity, Izobamba meteorological station.

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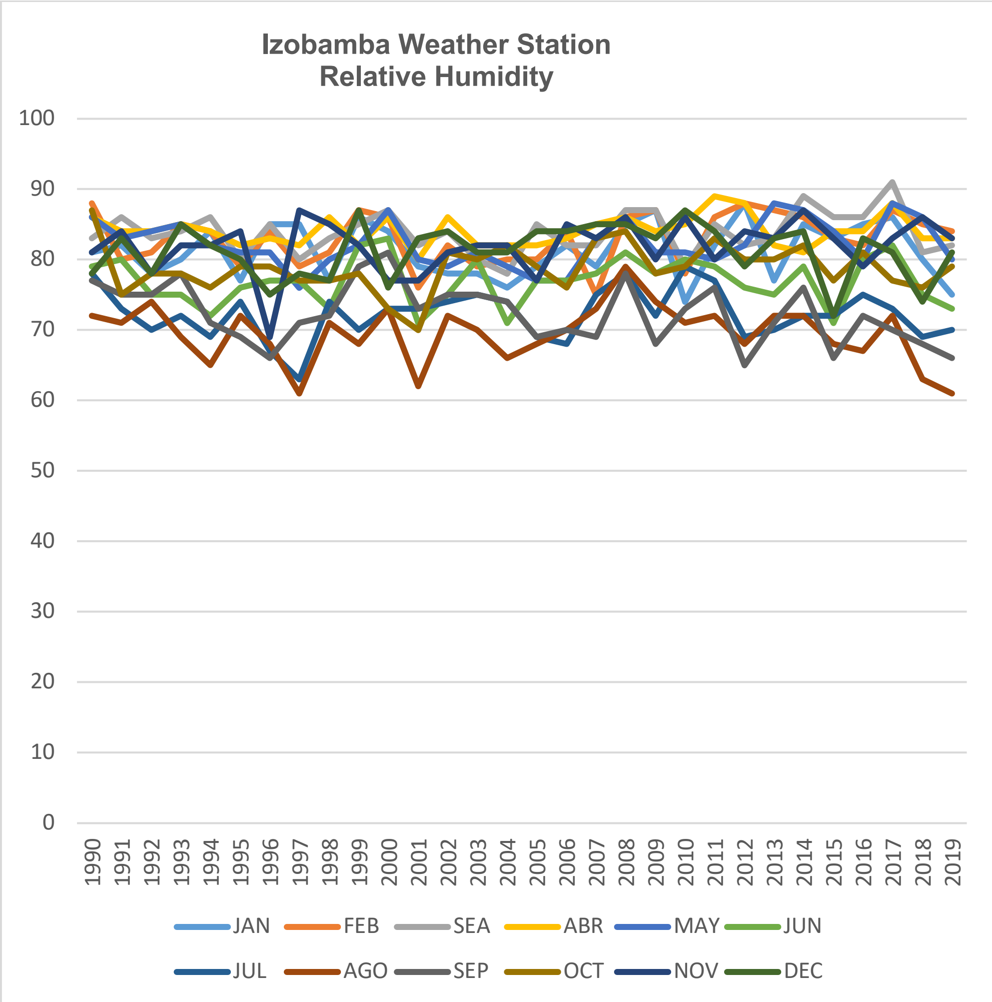

Note: Own elaboration.

Relative humidity in the Tomalon station varies between 40 and 90%, Iñaquito between 50 and 90% and Izobamba between 60 and 90% (it rains every month of the year).

Results

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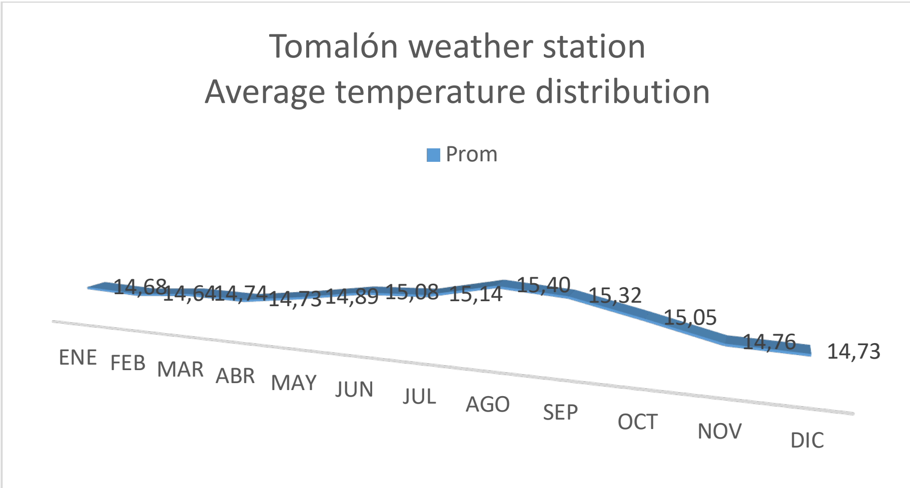
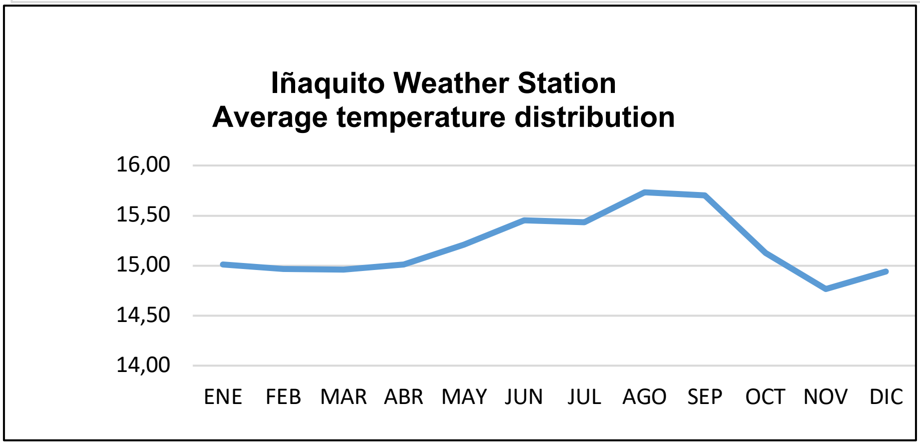
Characterization of temperature and precipitation distribution curves.

Mean, maximum and minimum absolute temperature distribution curves.

The distribution curves of the meteorological stations of Tomalón, Iñaquito and Izobamba were obtained from the analysis period: Tomalón, Iñaquito and Izobamba :

Graph 12. Average monthly temperature distribution curves, Tomalón, Inaquito, Izobamba weather stations.





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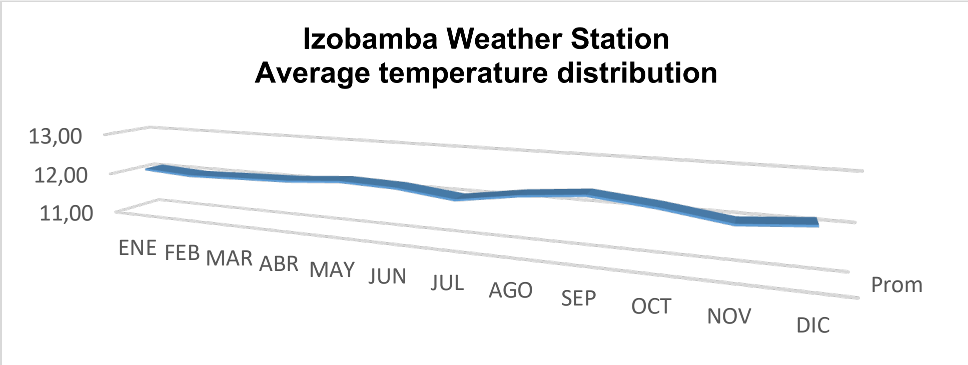

Note: Own elaboration

The dry season is very well defined in the Tomalon and Iñaquito weather stations; however, the behavior of the temperature in the Izobamba station is less well defined, mainly due to the fact that this sector receives rainfall throughout the year.

Precipitation distribution curves.

In the meteorological stations of: Tomalón, Iñaquito and Izobamba, it can be observed that all the precipitation distribution curves show a similar behavior, in which the two wet temperate and one dry season can be clearly visualized, Figure 11.

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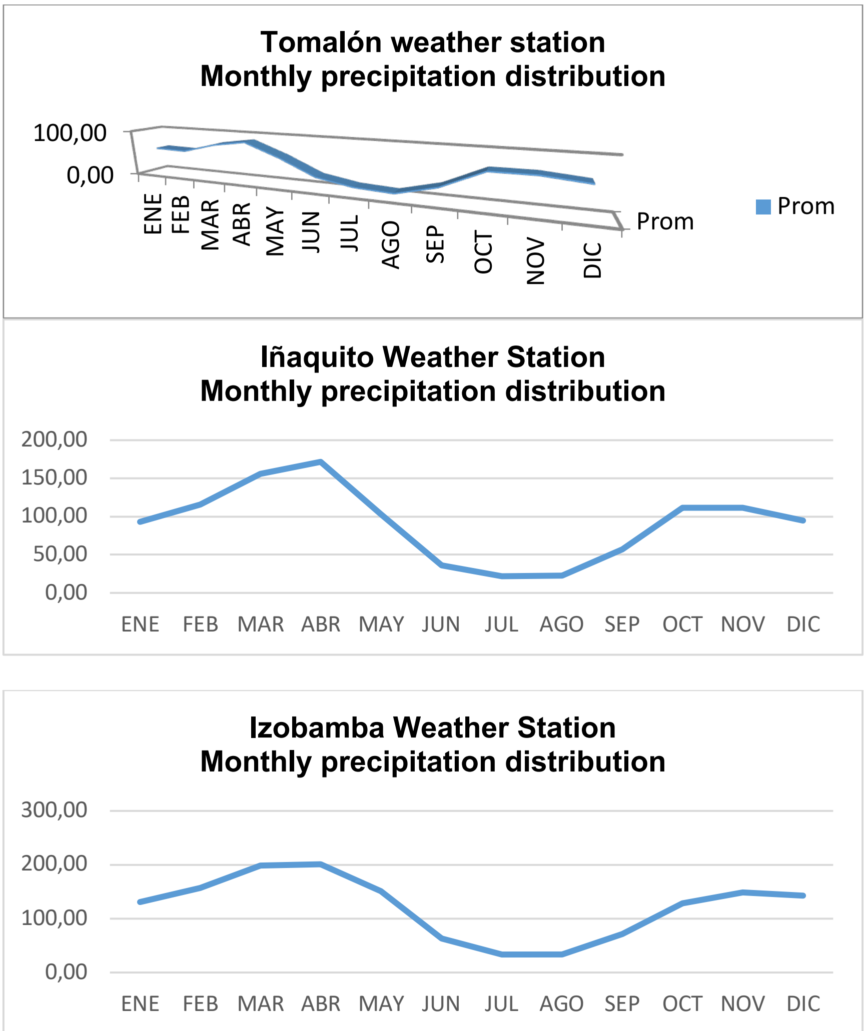
Graph 13. Distribution curves of average monthly precipitation, Tomalón, Inaquito, Izobamba weather stations.



Note: Own elaboration.

In general, the curves of the analysis show a complex harmonic movement, with a lag between the months of January and February; it can be seen in the case of the Tomalon station, that the lowest values of the curve generally interpolate with the 24-hour maximum precipitation curve.

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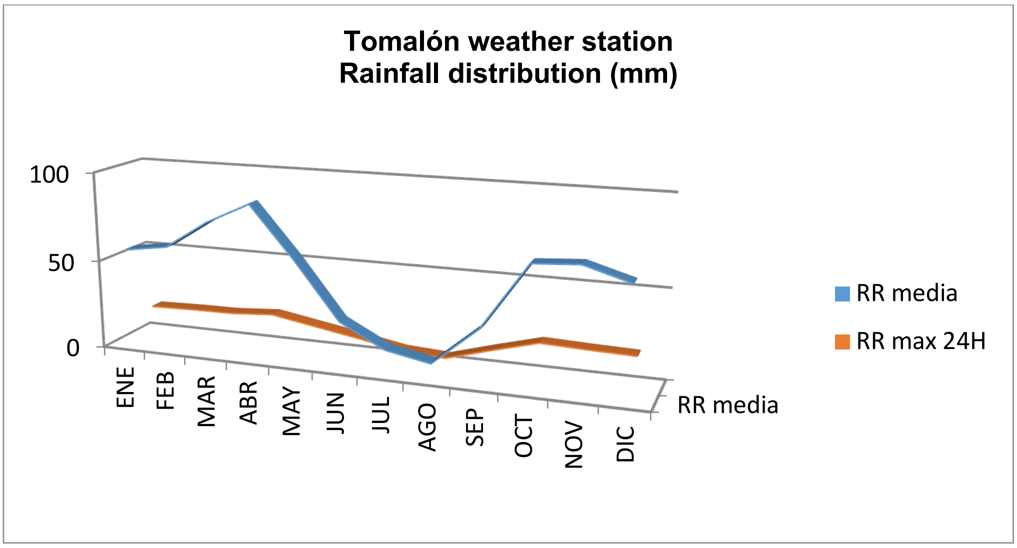
Graph 14. Distribution of average monthly precipitation, maximum 24-hour precipitation, Tomalón weather station.



Note: Own elaboration.

Regarding the curve analysis, the system presents complex harmonic oscillations during the 12 months of the year, two increasing and one decreasing periods of approximately 4 months each; in general it has elongations Xi or movements along independent directions; CRR ARR , which would represent the precipitation amplitudes in the two identified increasing periods and BRR precipitation amplitude decreasing period; where,{wi}i=1,....,n {{displaystyle \leftbrace \omega _{i}rightbrace _{i=1,....,n}} are the eigenfrequencies of the system, { Øj }i=1,...,n {displaystyle \leftlbrace \omega _{i}rightrbrace _{i=1,...,n}} en {displaystyle \leftlbrace \phi _{i}rightrbrace _{i=1,...,n}}} the initial phases (Fajardo, 2020).

The characteristic equation (1) is represented by the following formula:

$x(t) = \sum_{j=1}^{n} C_{RRj}$. ARRj . BRRj . cos(wjt+Øj) (Equation 1)

Determination of the traffic accident rate as a function of the weather.

Correlation between rainfall distribution curve and traffic accidents on the study road:

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The Municipal Traffic Agency provided information regarding the most common traffic accidents that have occurred on the E-28 B road, relating them to different factors, including climate, information that is summarized in the following table:

Table 3. *Traffic accidents related to climatic factors.*

Date	Time	Range	Cause	Siniestro	Type of accident
24/02/2019	19:30	18:00 A 20:59	Lack of attention while driving	3 vehicles affected: 1 killed, 1 injured, 3 retained	Angular side impact
2/3/2019	6:15	**6:00 A 8:59**	Climatic Factor	1 vehicle affected: 1 retained	Lane loss
3/3/2019	17:00	15:00 A 17:59	Climatic Factor	2 vehicles affected: 1 injured, 2 detained	Angular side impact
1/4/2019	15:35	15:00 A 17:59	Climatic Factor	1 vehicle affected: 1 deceased, 1 retained	Lane loss
15/11/2019	3:20	**3:00 A 5:59**	Lack of attention while driving	1 vehicle affected: 1 deceased, 1 retained	Lane loss
15/04/2020	9:00	9:00 A 11:59	Climatic Factor	2 vehicles affected: 2 retained	Crash
10/6/2020	5:25	**3:00 A 5:59**	Climatic Factor	1 vehicle affected: 1 retained	Lane loss
19/06/2020	7:35	**6:00 A 8:59**	Climatic Factor	1 vehicle affected: 2 injured, 1 retained	Lane loss
20/08/2020	5:45	**3:00 A 5:59**	Climatic Factor	2 vehicles affected: 2 retained	Rear-end collision

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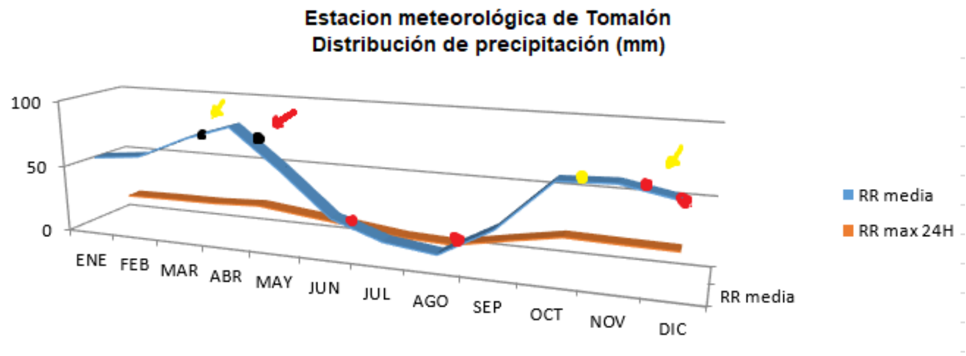
19/11/2020	6:35	**6:00 A 8:59**	Climatic Factor	1 vehicle affected: 1 retained	Loss of track
19/11/2020	7:45	**6:00 A 8:59**	Climatic Factor	1 vehicle affected: 1 deceased	Crash
25/12/2020	18:20	18:00 A 20:59	State of intoxication	3 vehicles affected: 3 retained	Loss of track
26/12/2020	8:50	**6:00 A 8:59**	Climatic Factor	1 vehicle affected: 1 deceased, 1 retained	Lane loss
31/12/2020	21:00	21:00 A 23:59	Pedestrian recklessness	1 vehicle affected: 1 injured, 1 retained	Hit-and-run (with people)
4/3/2021	22:00	21:00 A 23:59	Driving inattentive to traffic conditions	1 vehicle affected: 2 injured, 1 retained	Crash
20/03/2021	6:00	**6:00 A 8:59**	Climatic Factor	1 vehicle affected: 2 deceased2, 1 injured, 1 immobilized	Lane loss
16/10/2021	16:40	15:00 A 17:59	Climatic Factor	1 vehicle affected: 1 retained	Lane loss
29/10/2021	16:00	15:00 A 17:59	Excessive speed	2 vehicles affected: 1 injured, 2 retained	Lane loss
2/11/2021	8:10	**6:00 A 8:59**	Climatic Factor	2 vehicles affected: 2 retained	Lane loss

Note: Own elaboration, based on information obtained from the National Transit Agency (ANT).

From the information obtained, it was determined that 52.63% of the traffic accidents were due to loss of lane, 15.79% to crash, 10.53% to loss of lane, 10.53% to lateral and angular collision, 5.26% to rear-end collision and 5.26% to hit-and-run collision, all of which are related to the weather factor. Another very important aspect to mention is that 52.63% of the traffic accidents occurred in the range of 3:00 to 8:59 hours.

Based on the distribution curve of average monthly precipitation and maximum 24-hour precipitation at the Tomalón weather station, it was correlated with the data provided by the AMT, determining the critical points of traffic accidents, which coincide with the peaks of maximum precipitation in the wet season (April, November) and the peaks of maximum 24-hour precipitation in the dry season.

Graph 15. Correlation between average monthly rainfall, maximum 24-hour rainfall, traffic accidents, E35 North road.



	2019				2021

Note: Own elaboration

The information found allows us to establish the following criteria:

The points of accidentability of traffic accidents coincide fully with the months of highest rainfall in Ecuador in the two humid climates, which correspond to the months of March, April and November.

Traffic accidents have undergone a progressive increase since 2019, with the year 2021 recording the highest number of traffic accidents due to weather effects.

The year 2020, considered the year of the COVID 19 pandemic, in which some restrictions were placed on the mobility of vehicles, presents a special peculiarity, when analyzing the curve we can observe that traffic accidents, unlike previous years, occur in the middle of the dry season.

It is very relevant for the research to analyze that these critical points of traffic accidents during the dry season coincide exactly with the interrelation of the maximum 24-hour rainfall curve. These are the exact points of accidentability.

When there is a dry season and an unusual 24-hour rainfall, the road becomes a mirror due to the effects of radiation, and this coincidence of critical points is what can cause skidding, vehicle lane slides, among others.

It is important to analyze precipitation during the hours of traffic accidents, which occur precisely in the hours between 03H00 and 08H59, favorable for this aspect, considering that relative humidities are at the highest limits of their distribution.

Determination of meteorological variables that affect the occurrence of traffic accidents due to climatic factors.

Once it was possible to demonstrate the occurrence of traffic accidents in the so-called critical points characteristic of the two wet and dry seasons identified above, and based on the data on the occurrence of traffic accidents on the E-28 B road, daily data on precipitation, cloud cover and visibility were provided, taking as a reference the hours and accident rates identified by the AMT, as shown in the following table:

Table 3. *Traffic accidents, by meteorological variables.*

Date	Range	Cause	Veh.	pp	pp 24 hours	Cloudiness	Visibility
24/02/2019	18:00 A 20:59	Lack of attention while driving		nil	nil	nil	nil
02/03/2019	6:00 A 8:59	Climatic Factor	1	3,8	0		
03/03/2019	15:00 A 17:59	Climatic Factor		0.9	0		18-8
01/04/2019	15:00 A 17:59	Climatic Factor	1	1.9	0		

15/11/2019	3:00 A 5:59	Lack of attention while driving	1	14.9	nil	nil	nil
15/04/2020	9:00 A 11:59	Climatic Factor		5,2*	12.9		
10/06/2020	3:00 A 5:59	Climatic Factor	1	0	0.3		
19/06/2020	6:00 A 8:59	Climatic Factor	1	1,1	1,1		
20/08/2020	3:00 A 5:59	Climatic Factor		2,2	2.4		
19/11/2020	6:00 A 8:59	Climatic Factor	1	0	13.6		1
19/11/2020	6:00 A 8:59	Climatic Factor	1	0	13.6		1
25/12/2020	18:00 A 20:59	State of intoxication		2.6	0.1	nil	nil
26/12/2020	6:00 A 8:59	Climatic Factor	1	0	7.4	nil	nil
31/12/2020	21:00 A 23:59	Pedestrian recklessness	1	0.3	6.3	5	5
04/03/2021	21:00 A 23:59	Driving inattentive to traffic conditions	1	0.2	2.4		
20/03/2021	6:00 A 8:59	Climatic Factor	1	2.3	2.3		
16/10/2021	15:00 A 17:59	Climatic Factor	1	4.3	2.1	nil	nil
29/10/2021	15:00 A 17:59	Excessive speed		6.2	1.4	5	
02/11/2021	6:00 A 8:59	Climatic Factor		0	0	nil	nil

Note: Own elaboration. ** pp: precipitation; nil: no information available.

The information found allows us to establish the following criteria:

The main cause of the traffic accidents reported in the table above was the presence of precipitation (rain), which correlated with the exact precipitation values obtained from the Tomalon meteorological station (Tabacundo).

On the days identified as having less precipitation, it was possible to observe the presence of rain in the 24 hours prior to the range considered, which determines the presence of humidity that possibly influenced the landslides, loss of lanes, among others.

Another very important factor in our research characterizes the analyzed days as high cloudiness or cloudy days, characterized mainly

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by skies between 6 or 8 octaves of cloudiness (partially and totally cloudy).

Another meteorological parameter analyzed was visibility. Traffic accidents occurred precisely when visibility was less than 20 m, and when visibility was less than 5 m, resulting in fatal accidents (death).

A.T. = K pp ⇔ A.T. α pp (Equation 2)
A.T. traffic accidents; pp: precipitation; α: directly proportional.
K≥1: this factor is increased by several factors:
K+0.25 (Road factor): Inadequate road culture: C9, C6, C14, C23, C11 (causes identified in table No. 1).
K+0.25: (Weather factor) pp; pp 24 hours, Visibility less than 20%.
K+0.50: Road Factor and Climate Factor

Conclusions

The road axis (E35) is located along its entire length in the inter-Andean valley between the western and eastern mountain ranges of the Andes, in the metropolitan area of the city of Quito, the Pan-American Highway comes off at the intersection with the Quito-Cayambe Collector Road - E28B. The presence and influence of the Andes Mountains modifies the climate of the region, causing this road to be characterized by a very particular climatology, which essentially affects the occurrence of traffic accidents.

The occurrence of the El Niño and La Niña events that affected Ecuador influenced the increase in temperature values (the El Niño event had a greater incidence) and with respect to increases in precipitation (the La Niña event had a greater incidence). The average temperature in the three selected meteorological stations maintained a constant variability with much smaller variation intervals.

Relative humidity values at the two study stations vary between 40 and 90 %, with the highest values being recorded during the wet seasons. For the Izobamba station, the values vary between 60 and 90 %.

The curves obtained with respect to the distribution of normal multiannual precipitation show a complex harmonic movement, with harmonic oscillations during the 12 months of the year, two increasing

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periods (wet season) and one decreasing period (dry season) of approximately 4 months each. The definition of the dry and wet seasons is essentially defined in the study area by the presence of precipitation; the influence of temperature on the definition of these periods is minimal, and it does not vary greatly during the year.

The periods considered as wet season occur twice a year, the most intense between the months of February, March, April and May, with April being the most intense; the other occurs between the months of October, November, December and January, with November being the most intense. According to the analysis carried out, it is possible to determine the existing incidence between the weather factor and the occurrence of traffic accidents. It was established that the months with the highest number of accidents occur during the two wet seasons, which correspond to the months of March, April and November (those with the highest incidence) and October and December (with the lowest impact).

Regarding the dry season, the months with the highest accident rate are June and August, which correspond to mostly dry transition months, but with constant rainfall 24 hours a day (these are the points of interception between average and maximum rainfall). An accident rate was determined for traffic accidents, the incidence of which is directly proportional to inadequate road safety, and with respect to precipitation, this is influenced by the amount of rainfall at the time of the accident and the precipitation in the 24 hours prior to the accident (due to the conditions of the road after the event). In addition, the highest occurrence increases when visibility was less than 20 m, precisely when this was in ranges below 5 meters, resulting in fatal accidents (death).

In addition to the aforementioned, the increase in traffic accidents was evidenced as a function of the climate factor (Table No. 1). In this regard, it can be determined that 50% is due to inadequate road safety (causes C9, C6, C14, C23, C11) and the other 50% is due to the climate factor.

A discovery of relevance in this research, refers to the fact that in 2020, is when more traffic accidents due to weather factor occurred, despite the fact that the vehicle restriction was applied to be the year of COVID 2019 pandemic, precisely accidents are recorded in the dry season (lower rainfall, lower relative humidity, higher rainfall 24 hours), for

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this analysis in future research it will be important to incorporate other parameters such as solar radiation and air pollution indexes.

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