

## **Analysis of Climate Change and Sustainable Development in Peru and Its Departments during the Year 2006 - 2018**

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### **Authors' contributions**

*This work was carried out with the participation of all the authors. The author VVD proposed and raised the research project, wrote the report and wrote the manuscript for review. The authors RRA, UQQ, ECD and JCL managed the searches of bibliographic sources, methodologies, study analysis and carried out the statistical analysis using the software. All authors read and approved the final manuscript.*

### **Article Information**

DOI: 10.9734/IJECC/2021/v11i830456

*Editor(s):*

(1) Dr. Anthony R. Lupo, University of Missouri, USA.

*Reviewers:*

(1) Balamuralithara Balakrishnan, Sultan Idris Education University, Malaysia.

(2) M. Doorasamy, University of Kwa-Zulu Natal, South Africa.

Complete Peer review History: <https://www.sdiarticle4.com/review-history/73111>

**Review Article**

**Received 10 July 2021**  
**Accepted 20 September 2021**  
**Published 23 September 2021**

### **ABSTRACT**

**Aims:** Analyze and relate the general index of climate change and sustainable development of Peru and its departments during the year 2006 - 2018.

**Study Design:** The research is not intended to deliberately manipulate the variables, therefore, it is non-experimental; is descriptive, correlational and longitudinal.

**Place and Duration of Study:** The research project was carried out in the Faculty of Forestry and Environmental Sciences of the UNCP, likewise the collection of information data was carried out during 2020 and 2021, due to the Covid19 pandemic.

**Methodology:** Two economic data, four social data and five environmental data were selected, in addition climatic data of precipitation, maximum and minimum temperature of the 24 departments of Peru were collected during the years 2006 - 2018; To estimate the climatic and sustainable indices, the Prescott-Allen methodology was applied, the interpretation and assessment scale (climate change and sustainable development) was carried out using the barometric analysis of McCarthy. Five regression models were applied [dependent variable GISD; independent variable IGCC], hypothesis testing was performed using Karl Pearson's r coefficient and p-value at 0.05.

**Results:** It is stated that Peru presents an economic sustainable index [EcSI] of 0.066 low, social sustainability [SoSI]: 0.225 medium, environmental sustainability [EnSI]: 0.282 high and general index of sustainable development [GISD] is 0.572 medium. In itself the climate index of precipitation is [CPrl]: 0.079 weak, the climate index maximum temperature [CTxl]: 0.251 severe, climate index minimum temperature [CTnl]: 0.138 weak and the general index of climate change [GICC] is 0.468 moderate. Two appropriate regression models [linear and exponential] were determined to estimate the GISD as a function of the GICC, CPrl, CTxl and CTnl.

**Conclusion:** It was found that during the year 2006 to 2018 Peru presented a low economic, social medium, high environmental situation and therefore its sustainable development is in a medium situation; while precipitation is weak, severe maximum temperature, weak minimum temperature, and therefore, climate change has a moderate impact. Likewise, it is stated that there are two linear and exponential regression models to estimate the GISD based on the GICC, CPrl, CTxl and CTnl. It is recommended to collect more climatic data and economic indicators to be able to differentiate the economic and climatic situation that Peru and departments represent during its thirteen years of development.

*Keywords: Economic; social and environmental situation of Peru; general index of climate change; general index of sustainable development; analysis and regression models.*

## 1. INTRODUCTION

Sustainable development is a carefully planned strategy to embrace growth while using resources more efficiently [1], [2], with maximum consideration of the immediate and long term benefits for our planet and human beings living in it [2], [3]. Sustainable development encourages us to conserve and improve our resource base [4], [5], gradually changing the ways in which it is developed and technologies of use [6], [7]. Countries must be able to meet their basic needs for jobs [6], food, energy, water and sanitation [7], [8]. Peru is one of the most mega diverse countries in South America [9]; where the interaction of its natural regions (coast, mountains and jungle); they offer different natural resources [10], thus providing great economic, social and environmental benefits for sustainable rural and urban human development [11]. In recent years, the country has experienced remarkable socioeconomic progress and poverty reduction [12]. Starting with the gross domestic product per capita, which during 2006 until 2018 had a rise above \$5M USD; the adequately employed population that during 2006 to 2018 is above 60%; while the population with at least one unsatisfied basic need was reduced by 30% [13]. In the social sector, the literacy rate of the population aged 15 and over presented an

average of 6.2% throughout Peru; Added to them are some negative effects, producing environmental damage, such as a 400% increase in the number of vehicles in circulation nationwide [14], as well as people affected by natural and anthropogenic impacts and events, causing urban and rural unsustainability (for example, the urban sector consumes 78% of its natural resources between renewable and non-renewable, generating 70% of greenhouse gas emissions) [15] and urbanization (for example, urban expansion into agricultural areas) has highlighted deficiencies in water supply drinking water and sanitation [16], as well as growing concerns about air pollution, urban transportation, and waste treatment and disposal [13]. On the contrary, in rural areas there are still significant challenges related to poverty alleviation and equitable access to land and water resources [17].

Climate change is having a very real impact [18], affecting not only ecosystems but also the socio-economic systems of small cities and rural communities [19], [20]. Globally, climate change is a consistent concern [21], as it is contributing to rising global temperatures [22], changes in precipitation patterns, rising sea levels, and natural hazards [19]. At the local level, the effects of climate change vary by region, and

communities experience the impacts of climate change differently and to varying degrees [18]. The impact of climate change is becoming a growing reality, not only because it produces widespread effects on the physical environment [23], [24], but also because it directly affects people's lives by threatening the economy, culture, and institutions within communities societies [25]. According to their geographical space (coast, mountains and jungle), the departments of Peru are in the most prone to suffer climatic changes [26], products of natural phenomena (phenomenon of the boy, the girl, cold, low water, frost, landslides, floods, droughts, earthquakes, etc.) [27-29]. For this reason, Peru is not alien to these different types of changes; [30] the effects of climate change have revealed the vulnerability of the Peruvian territory to climatic imbalances caused by various phenomena [31], since the occurrence of natural phenomena has been observed with greater frequency and intensity [26]; and therefore, they would be affecting the availability of the ecosystem services used by the population and consequently the development and well-being of Peruvian society in general would be compromised [32-34]. Changes such as precipitation, maximum and minimum temperature are clear evidence of the hydro-meteorological changes that occur in different departments of Peru [26], [31]; that during the years 2006 - 2018 the total average precipitation of Peru increased and decreased by  $200 \pm 500$  mm, likewise it occurred with the maximum temperature where an increase of  $0.5^{\circ}\text{C}$  occurred and the minimum temperature also rose by  $0.4^{\circ}\text{C}$  [35-36].

Climate change and sustainable development have been addressed in largely separate circles in both research and policy [24], [37]. However, there are strong links between the two in both areas [38]. Although climate change is one of the most important symptoms of "unsustainability" [39], it is remarkable how little the discussion on Climate Change has influenced Sustainable Development or vice versa [40-41]. Thinking about climate change in a sustainable development framework requires broadening the focus of the analysis and examining the intersection points between seemingly disparate issues [42]. Making these connections will require change. Climate change and sustainable development have been pursued as largely separate discourses; this has led to difficulties in establishing strong working links between the research and policy communities [43]. Despite

having good and bad sustainable and climate indicators, Peru still needs to overcome a series of "challenges", derived from institutional weaknesses and lack of sustainability [12], [44]; to this is added the poor management and planning of different departmental entities [11]. In order to measure all these positive and negative effects of Peru and its departments, we used the sustainable development index and the climate sustainability index [2], [45-46]. One of the key questions of the sustainable and climate index is how organizations in developing countries are achieving their urban and rural development [1], [2], [42]; therefore, the following research leads us to evaluate the sustainable and climate index of Peru during the years 2006 to 2018 as well as to design regression models between both research topics.

## 2. MATERIALS AND METHODS

### 2.1 Place of Research

To estimate the effect of climate change on sustainable development, each of the 24 departments of Peru was selected. Where departmental data are different: maximum temperature, minimum temperature, precipitation, economic, social and environmental values.

## 3. METHODOLOGY

### 3.1 Description General of Data

According to the indicators, dimensions and research variables, the data collection is summarized in Table N°01.

### 3.2 Structure Variables

$$DV = \int [M(IV)_{1,2,3,4,5}] \quad (1)$$

Where: "DV": is the composite indicator [dependent variable], " $f[M_{1,2,3,4,5}]$ ": functions of the regression models and "IV": dimensions of the independent variables.

$$V_{[GISD/GICC]} = [D_1, D_2, D_3] \quad (2)$$

$$D_{[EcSI;SoSI;EnSI/CPri;CTxI;CTnI]} = [I_1, I_2, \dots, I_n] \quad (3)$$

Where: variable

$V_{[GISD: \text{General Index of Sustainable Development}]}$  is  
 $GICC: \text{General Index of Climate Change}]$

determined according to its three dimensions

[D<sub>1,2,3</sub>]. So too, D<sub>[EcSI: Economic Sustainable Index]</sub>,  
 D<sub>[SoSI: Social Sustainable Index]</sub>,  
 D<sub>[EnSI: Environmental Sustainable Index]</sub>,  
 D<sub>[CPrI: Climatic Precipitation Index]</sub>,  
 D<sub>[CTxI: Maximum Temperature Climatic Index]</sub>,  
 D<sub>[CTnI: Minimum Temperature Climatic Index]</sub>, which will  
 be decisive in the collection of data by the  
 indicators [I<sub>1,2,...,n</sub>].

### 3.3 Mathematical Models for Estimating the Results [Variables, Dimensions and Indicators]

In order to estimate the normalized values of each indicator, weighting of the dimensions, sum of variables and the total sum of the sustainable indices and climate change, the Prescott-Allen [47] manual was used as well as other research sources, encompassing some sources of similar research [48-49].

- Normalization of sub-indicators of economic sustainability

$$EcN[1; 2]_{it} = \frac{Ec[1; 2]_{it} - Ec[1; 2]_{nin_t}}{Ec[1; 2]_{max_t} - Ec[1; 2]_{min_t}} \quad (4)$$

- Normalization of sub-indicators of social sustainability

$$SoN[1; 2; 4]_{it} = \frac{So[1; 2; 4]_{it} - So[1; 2; 4]_{nin_t}}{So[1; 2; 4]_{max_t} - So[1; 2; 4]_{min_t}} \quad (5i)$$

$$SoN[3]_{it} = \frac{So[3]_{it} - So[3]_{nin_t}}{So[3]_{max_t} - So[3]_{min_t}} \quad (5ii)$$

- Normalization of sub-indicators of environmental sustainability

$$EnN[1; 3; 4; 5]_{it} = \frac{En[1; 3; 4; 5]_{it} - En[1; 3; 4; 5]_{nin_t}}{En[1; 3; 4; 5]_{max_t} - En[1; 3; 4; 5]_{min_t}} \quad (6i)$$

$$EnN[2]_{it} = \frac{En[2]_{it} - En[2]_{nin_t}}{En[2]_{max_t} - En[2]_{min_t}} \quad (6ii)$$

- Normalization of sub-indicators of climate change

$$CcN[1; 2]_{it} = \frac{Cc[1; 2]_{it} - Cc[1; 2]_{nin_t}}{Cc[1; 2]_{max_t} - Cc[1; 2]_{min_t}} \quad (7i)$$

$$CcN[3]_{it} = \frac{Cc[3]_{max_t} - Cc[3]_{it}}{Cc[3]_{max_t} - Cc[3]_{min_t}} \quad (7ii)$$

- Weighting of normalized data in economic sustainability indicators

$$EcW[1; 2]_{it} = EcN[1; 2]_{it} * Wec_{[1;2]} \quad (8)$$

- Weighting of normalized data in social sustainability indicators

$$SoW[1; 2; 3; 4]_{it} = SoS[1; 2; 3; 4]_{it} * Wso_{[1;2;3;4]} \quad (9)$$

- Weighting of normalized data in the indicators of environmental sustainability

$$EnW[1; 2; 3; 4; 5]_{it} = EnS[1; 2; 3; 4; 5]_{it} * Wen_{[1;2;3;4;5]} \quad (10)$$

- Weighting of normalized data in climate change indicators

$$CcW[1; 2; 3]_{it} = CcN[1; 2; 3]_{it} * W[p, tx, tm]_{[1;2;3]} \quad (11)$$

- Economic sustainability index

$$EcSI_{it} = EcW1_{it} + EcW2_{it} \quad (12)$$

- Social sustainability index

$$SoSI_{it} = SoW1_{it} + SoW2_{it} + SoW3_{it} + SoW4_{it} \quad (13)$$

- Environmental sustainability index

$$EnSI_{it} = EnW1_{it} + EnW2_{it} + EnW3_{it} + EnW4_{it} + EnW5_{it} \quad (14)$$

- General index of sustainable development

$$GISD_{it} = EcSI_{it} + SoSI_{it} + EnSI_{it} \quad (15)$$

- General index of climate change

$$GICC_{it} = CcW1_{it} + CcW2_{it} + CcW3_{it} \quad (16)$$

Where i: for a given department [average/total], t: at a given time [year]; weighting factor Wec<sub>[1,2]</sub>: for economic sustainability 0.10, Wso<sub>[1,2,3,4]</sub>: for social sustainability 0.10, Wen<sub>[1,2,3,4,5]</sub>: for

environmental sustainability 0.08,  $W[p]_{[1]}$ : for precipitation 0.3,  $W[tx]_{[2]}$  for maximum temperature 0.4 and  $W[tm]_{[3]}$  for minimum temperature 0.3.

### 3.4 Regression Models and Hypothesis Contracting Test

According to equation number one (1), five classic regression models were designed to determine the influence of climate change on sustainable development [46], these models are the following:

$$y = a_1 \pm a_2 \cdot x_1 \pm a_3 \cdot x_2 \pm a_4 \cdot x_3 \pm a_5 \cdot x_4 \pm \varepsilon \quad (17)$$

$$y = a_1 \pm a_2 \cdot \ln x_1 \pm a_3 \cdot \ln x_2 \pm a_4 \cdot \ln x_3 \pm a_5 \cdot \ln x_4 \pm \varepsilon \quad (18)$$

$$y = a_1 \pm a_2 \cdot x_1^2 \pm a_3 \cdot x_2^2 \pm a_4 \cdot x_3^2 \pm a_5 \cdot x_4^2 \pm \varepsilon \quad (19)$$

$$y = a_1 \cdot x_1^b \pm a_2 \cdot x_2^b \pm a_3 \cdot x_3^b \pm a_4 \cdot x_4^b \pm \varepsilon \quad (20)$$

$$y = a_1 \cdot e^{x_1} \pm a_2 \cdot e^{x_2} \pm a_3 \cdot e^{x_3} \pm a_4 \cdot e^{x_4} \pm \varepsilon \quad (21)$$

Where equation (17) is a linear model, (18) logarithmic model, (19) polynomial model, (20) potential model, (21) exponential model;  $y$ : dependent variable [GISD] and  $x_{[1,2,3,4]}$ : are independent variables [GICC, CPrl, CTxl, CTnl],  $[a_{[1,2,3,4,5]}]$  and  $[b]$  are estimated parameters (using the InfoStat software) To establish the best adjusted model for the regression between both variables, the Akaike Information Criteria [AIC] [50] and Bayesian [BIC] [51] were applied [52]. For the association between the research variables [GISD] and [GICC] and the other variables, the analysis of correlation and hypothesis Karl Pearson [ $r$ ] (using the R-Studio software).

## 4. RESULTS AND DISCUSSION

### 4.1 Sustainable Economic, Social, Environmental Index of the Departments of Peru during 2006 - 2018

The economic sustainability index [EcSI] that integrates the per capita gross domestic production and the adequately employed population of the 24 departments showed that Moquegua, Madre de Dios, Lima, Arequipa and Ica are departments with a high economic sustainability index with a higher value to 0.15;

while Amazonas, Cajamarca and Puno present values lower than 0.05. The social sustainability index [SoSI] that comprises at least one basic need, the sanitation service literacy rate and the mortality rate of the 24 departments, asserts that Lima, Moquegua, Tacna and Ica are departments with a high social sustainability index with high value. greater than 0.35; while Puno, Ucayali and Huancavelica present values lower than 0.15. The environmental sustainability index [EnSI] that lists the consumption of charcoal or firewood, reforested areas, impoverished homes due to natural disasters and the pollution of automobile parks in the 24 departments, states that Moquegua, Pasco, Lambayeque, Cajamarca Ancash, Tacna and Tumbes are departments with a high social sustainability index with a value higher than 0.25; while Loreto presents values less than 0.1.

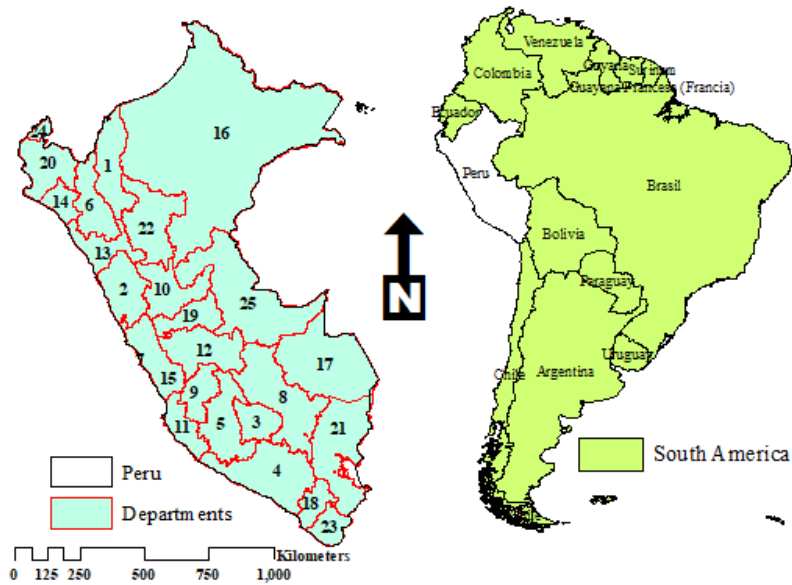
Analyzing sustainability is a way of understanding the urban and rural human development of a certain place, this is expressed through its economic, social and environmental situation, and better through different periods or years; As can be seen in Fig. 2 at the departmental level, the environmental sustainable index and the social sustainability index are higher than the economic sustainability index, this means that the economic situation of the departments of Peru is low, while their environmental status it is suitable for departmental development.

### 4.2 General Index Analysis of the Sustainable Development of the Departments of Peru

The maps in Fig. 3 affirm the final temporal situation of the 24 departments of Peru during the years 2006 - 2018; where the average economic sustainability index [EcSI] of the Department of Moquegua is 0.18 indicating a very high value, on the contrary, the departments of Cajamarca 0.02, Amazonas 0.02, Huánuco 0.01, Huancavelica 0, Ayacucho 0.02, Apurímac 0.02 and Puno 0.02 they have very low rates due to little economic development in these departments. Likewise, the average social sustainability index [SoSI] of Lima 0.4, Ica 0.32, Arequipa 0.35, Moquegua 0.36 and Tacna 0.37 indicate very high values; while the department of Huancavelica 0.06 has a very low average, due to the high number of emigration to other departments. Also the average environmental sustainability index [EnSI] of Lima 0.23 and Loreto 0.18 are very low, showing a high

environmental neglect in these departments. And finally, the average general index of sustainable development [GISD] in Moquegua 0.82 is very high, while Huancavelica 0.35 and Loreto 0.34

show the lowest averages, since in these departments there are no communication routes, there is little development in health and education.



**Fig. 1. Location of the map of Peru and its departments**

Where 1: Amazonas, 2: Ancash, 3: Apurímac, 4: Arequipa, 5: Ayacucho, 6: Cajamarca, 7 and 15: Callao and Lima, 8: Cusco, 9: Huancavelica, 10: Huánuco, 11: Ica, 12: Junín, 13: La Libertad, 14: Lambayeque, 16: Loreto, 17: Madre De Dios, 18: Moquegua, 19: Pasco, 20: Piura, 21: Puno, 22: San Martín, 23: Tacna, 24: Tumbes and 25: Ucayali. Note, the departments of Lima and Callao were joined to form a single data

**Table 1. Physical, chemical and biological properties of experimental soil (0-20 cm)**

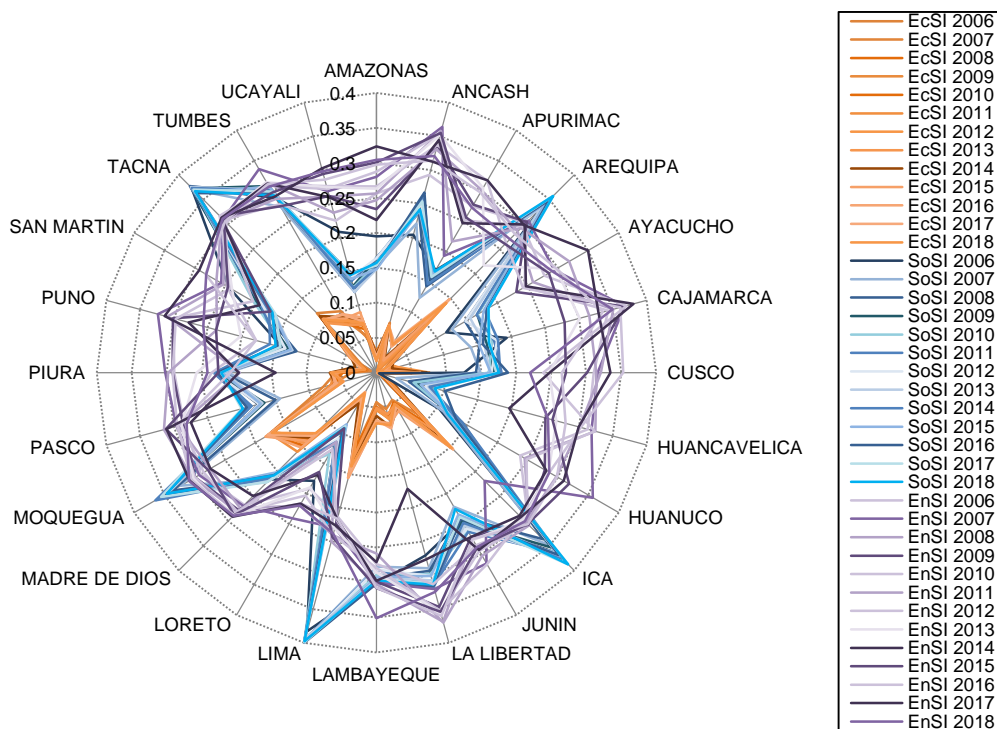
Variable	Dimension	Indicator
GISD: General Index of Sustainable Development	EcSI: Economic Sustainability Index	Ec1: Per Capita Gross Domestic Product. Ec2: Properly employed population.
	SoSI: Social Sustainability Index	So1: Population with at the least one basic need unmet So2: Illiteracy rate of the population aged 15 and over years' old. So3: Population with access to improved sanitation services So4: Infant mortality rate.
	EnSI: Environmental Sustainability Index	En1: Proportion of the population in households that uses charcoal or firewood to prepare their food. En2: Reforested area. En3: People affected by the occurrence of emergencies, due to the impact of natural and anthropic events. En4: Vehicle fleet in circulation nationwide. En5: Homes destroyed by the occurrence of emergencies caused by natural and anthropic events.
	CPri: Climate Index of Precipitation	Cc1: Total annual precipitation. Annual data in millimeters (mm).
	CTxl: Climate Index maximum Temperature	Cc2: Annual average maximum temperature Annual data in degrees centigrade (°C).
GICC: General Index of Climate Change	CTnl: Climate Index minimum Temperature	Cc3: Annual average minimum temperature. Annual data in degrees centigrade (°C).

\* To estimate the General Index of Climate Change, meteorological data [annual precipitation data (mm), annual maximum and minimum temperature data (°C)] were collected with the support of public institutions [SENHAM: National Meteorology and Hydrology Service [35], IDESEP: SENAMHI Spatial Data Infrastructure - Peru] of each department during the year 2006 to 2018 [36]. To estimate the General Index of Sustainable Development, economic, social and environmental data were collected from public institutions [INEI: National Institute of Statistics and Information [13], SERFOR: National Forest and Wildlife Service [16], INDECI: National Institute of Civil Defense [15], MTC: Ministry of Transport and Communications] [14]. Data collection was determined for each of the 24 departments of Peru, in addition the union of the department of Callao and Lima formed one

**Table 2. Scale of valuation of Sustainable Indices and Climate Change**

	Interpretation	EcSI	SoSI	EnSI	GISD
General index of sustainable development	Very Low	0.000-0.039	0.000-0.079	0.000-0.079	0.00-0.19
	Low	0.040-0.079	0.080-0.159	0.080-0.159	0.20-0.39
	Medium	0.080-0.119	0.160-0.239	0.160-0.239	0.40-0.59
	Tall	0.120-0.159	0.240-0.319	0.240-0.319	0.60-0.79
	Very Tall	0.160-0.200	0.320-0.400	0.320-0.400	0.80-1.00
General index of climate change	<b>Interpretation</b>	<b>CPri</b>	<b>CTxi</b>	<b>CTni</b>	<b>GICC</b>
	Very Weak	0.000-0.059	0.000-0.079	0.000-0.059	0.00-0.19
	Weak	0.060-0.199	0.080-0.159	0.060-0.199	0.20-0.39
	Moderate	0.120-0.179	0.160-0.239	0.120-0.179	0.40-0.59
	Severe	0.180-0.239	0.240-0.319	0.180-0.239	0.60-0.79
	Very Severe	0.240-0.300	0.320-0.400	0.240-0.300	0.80-1.00

\*Barometric and interpretive analysis of sustainable development and climate change. Source taken from Prescott-Allen [47] and McCarthy [23]



**Fig. 2. Temporal analysis of the Economic, Social and Environmental Sustainability of the 24 departments of Peru, during the years 2006 – 2018**

Descriptive statistical data analysis. [EcSI: 2006 – 2008]: Average: 0.066, Typical error: 0.003, Median: 0.060, Standard deviation: 0.047, Sample variance: 0.002, Kurtosis: -0.338, Coefficient of skewness: 0.713, Range: 0.182, Minimum: 0.001, Maximum: 0.183. [SoSI: 2006 – 2018]: Average: 0.225, Typical error: 0.005, Median: 0.206, Standard deviation: 0.093, Sample variance: 0.009, Kurtosis: -1.021, Coefficient of skewness: 0.297, Range: 0.396, Minimum: 0.004, Maximum: 0.400. [EnSI: 2006 – 2018]: Average: 0.282, Typical error: 0.003, Median: 0.289, Standard deviation: 0.045, Sample variance: 0.002, Kurtosis: 1.543, Coefficient of skewness: -0.839, Range: 0.288, Minimum: 0.092, Maximum: 0.380.

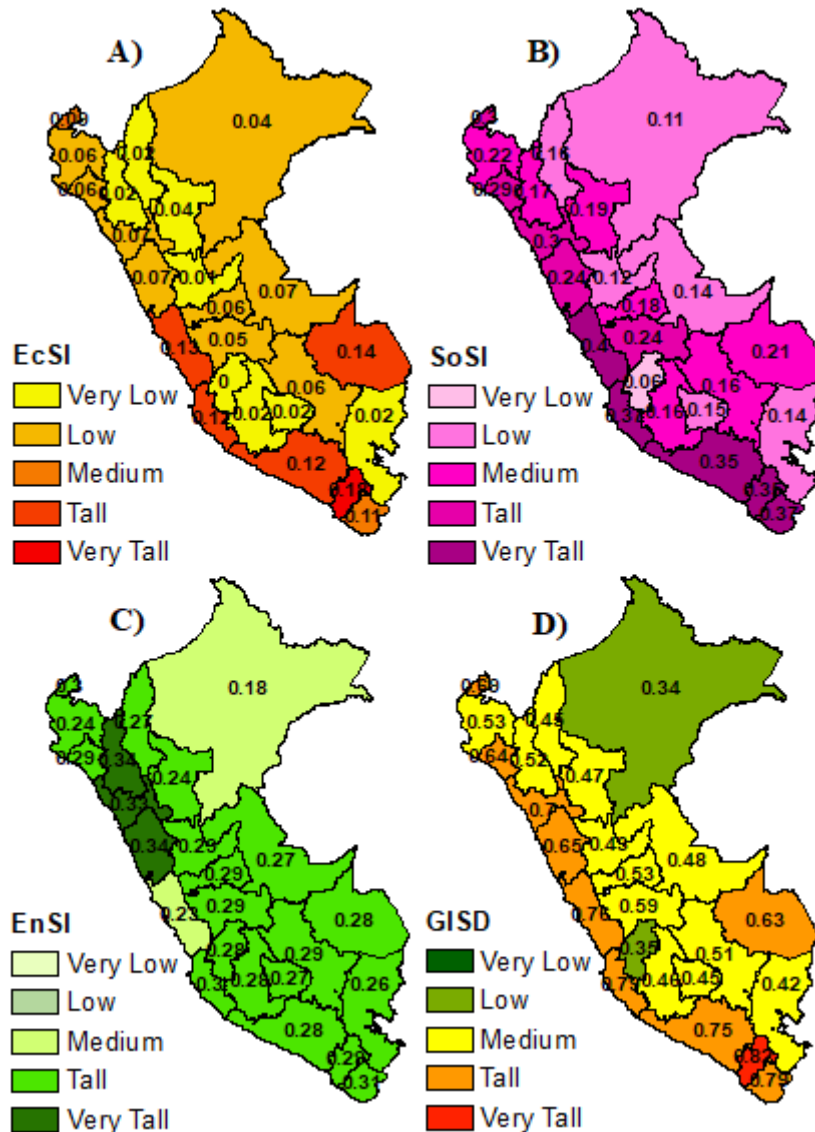
**4.3 Climate Index, Precipitation, Maximum and Minimum Temperature of the Departments of Peru during 2006 – 2018**

According to the information carried out (Fig. 4) we can show that the climatic precipitation index

[CPri], of the 24 departments affirmed that Madre de Dios, Loreto and Amazonas are departments with a climatic index of high precipitation with a value higher than 0.2; while Tacna, Arequipa, Ica, Lambayeque, La Libertad, Lima and Moquegua present values lower than 0.05. Likewise, the maximum temperature climatic

index [CTxI], of the 24 departments stated that Loreto, Madre de Dios, Piura, Ica, Tumbes, Ucayali and San Martin are departments with a maximum temperature climatic index with a value higher than 0.3; while Puno, Arequipa and Huancavelica present values lower than 0.15. And the minimum temperature climatic index

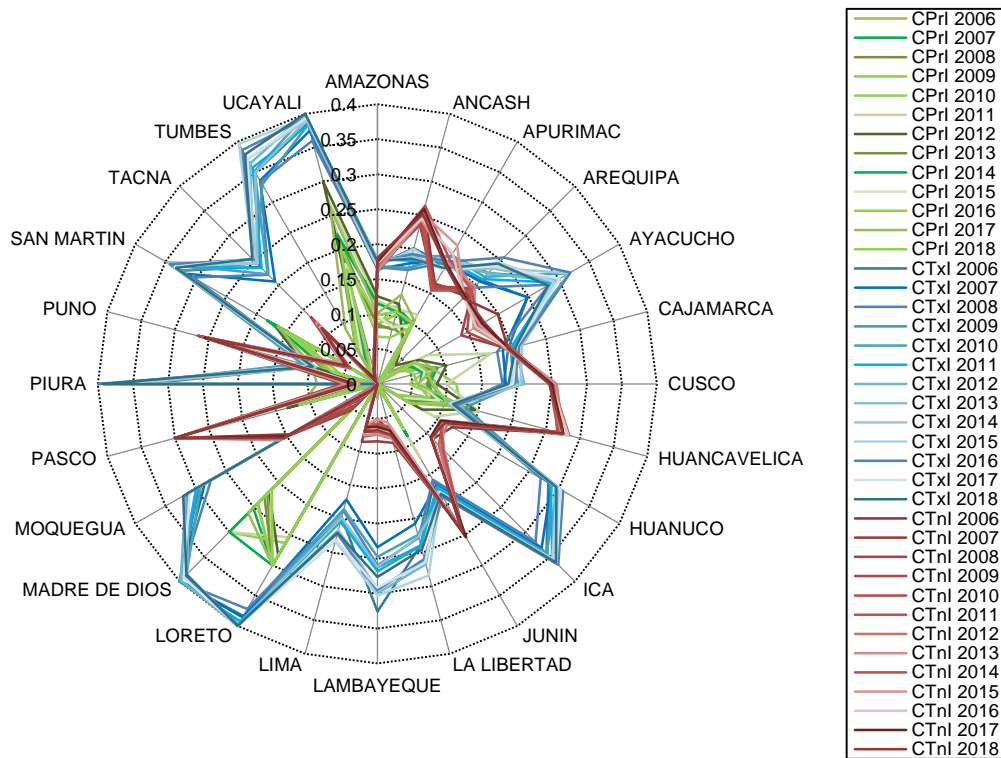
[CTnI] of the 24 departments confirmed that Puno, Pasco, Ancash and Huancavelica are departments with a minimum temperature climatic index with a value higher than 0.25; while Loreto, Madre de Dios, Tumbes and Ucayali present values lower than 0.05.



**Fig. 3. Analysis of Sustainable Development [Economic, Social and Environmental] final average of the 24 departments of Peru during the years 2006 - 2018**

*Descriptive statistical data analysis. [EcSI]: Average: 0.066, Typical error: 0.010, Median: 0.058, Standard deviation: 0.047, Sample variance: 0.002, Kurtosis: -0.232, Coefficient of skewness: 0.742, Range: 0.172, Minimum: 0.004, Maximum 0.176. [SoSI]: Average: 0.225, Typical error: 0.019, Median: 0.200, Standard deviation: 0.094, Sample variance: 0.009, Kurtosis: -1.041, Coefficient of skewness: 0.368, Range: 0.331, Minimum: 0.065, Maximum: 0.396. [EnSI]: Average: 0.282, Typical error: 0.007, Median: 0.285, Standard deviation: 0.034, Sample variance: 0.001, Kurtosis: 2.257, Coefficient of skewness: -0.863, Range: 0.161, Minimum: 0.181, Maximum: 0.342. [GISD]: Average: 0.572, Typical error: 0.030, Median: 0.529, Standard deviation: 0.145, Sample variance: 0.021, Kurtosis: -1.153, Coefficient of skewness: 0.209, Range: 0.481, Minimum: 0.336, Maximum: 0.817*





**Fig. 4. Temporal Climatic analysis of Precipitation, Maximum Temperature and Minimum Temperature of the 24 departments of Peru, during the years 2006 - 2018**

*Descriptive statistical data analysis. [CPrI: 2006 – 2018]: Average: 0.079, Typical error: 0.005, Median: 0.068, Standard deviation: 0.081, Sample variance: 0.007, Kurtosis: 0.949, Coefficient of skewness: 1.220, Range: 0.300, Minimum: 0.000, Maximum: 0.300. [CTxI: 2006 – 2018]: Average: 0.251, Typical error: 0.006, Median: 0.244, Standard deviation: 0.101, Sample variance: 0.010, Kurtosis: -0.284, Coefficient of skewness: -0.394, Range: 0.400, Minimum: 0.000, Maximum: 0.400. [CTnI: 2006 – 2018]: Average: 0.138, Typical error: 0.005, Median: 0.137, Standard deviation: 0.093, Sample variance: 0.009, Kurtosis: -1.264, Coefficient of skewness: 0.100, Range: 0.300, Minimum: 0.000, Maximum: 0.300*

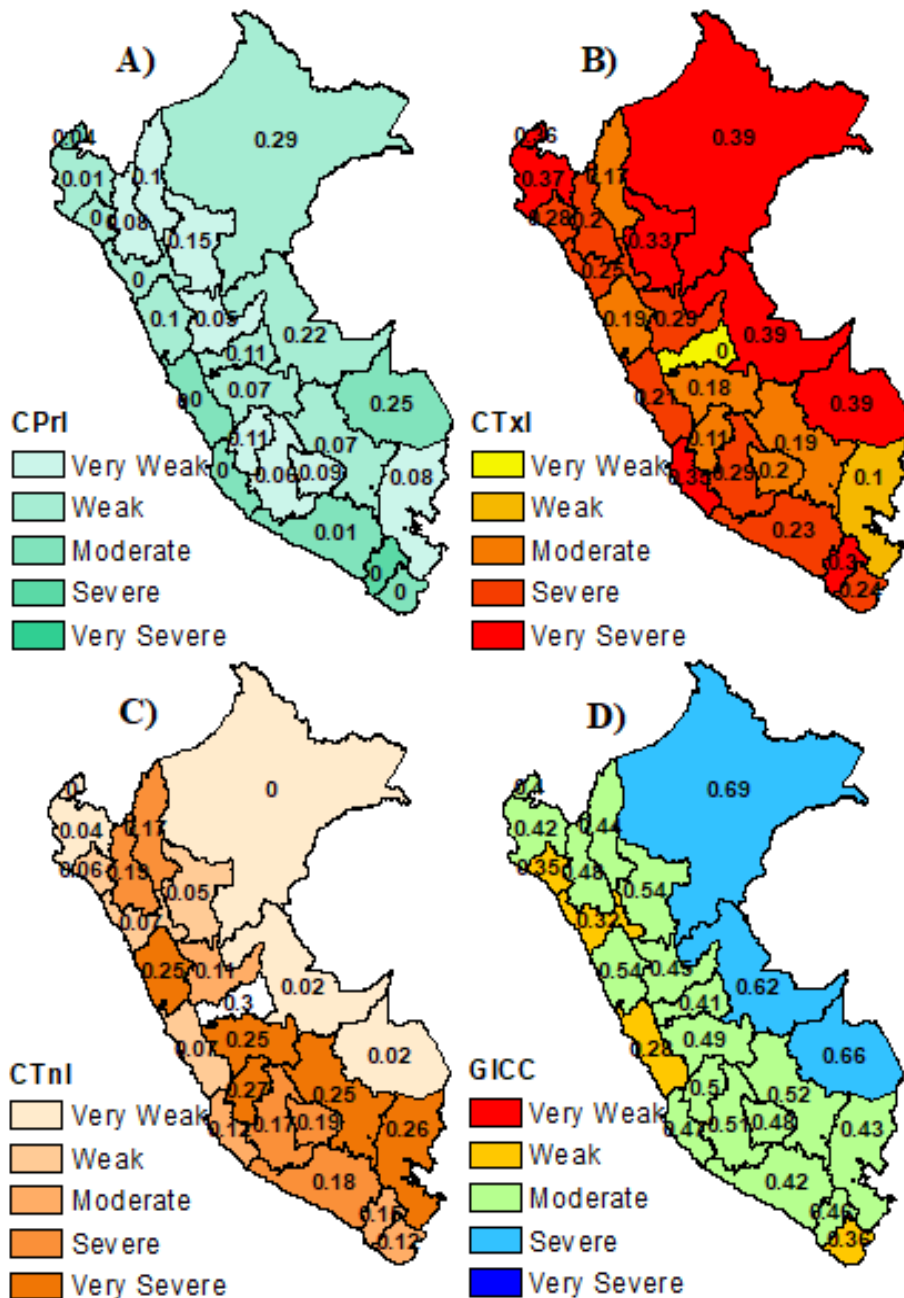
Climate change will always present dynamic changes according to industrial, anthropogenic activities and natural environments according to their geographical and temporal space, that is why its indicators such as temperature and precipitation and other elements are in various changes, as can be seen in Fig. 4, where the maximum temperature is higher than the precipitation, likewise higher than the minimum temperature recorded by each department in Peru. Although we must remember that, according to the geographical space of Peru, such as the coast, mountains and jungle, it presents totally different environments, that is why its hydro-meteorological indicators are totally different and this could be concluded that Peru is one of the most affected by the climate change, not because of the registered values but because of the same geographic space and its topography.

#### 4.4 General Index Analysis of Climate Change in the Departments of Peru

The average analysis of the results of the climatic indices that occurred during the years 2006 - 2018 can be represented in Fig. 5, where it can be stated that the average climate precipitation index [CPrI] of Lambayeque 0, La Libertad 0, Lima 0, Ica 0, Moquegua 0 and Tacna 0, with very weak values where rainfall is very scarce or null; while Loreto 0.29 and Madre de Dios 0.25 have very severe values, that is, they are departments with the highest precipitation averages. Furthermore, the maximum temperature climatic index [CTxI] average of Loreto 0.39, Ucayali 0.39 and Madre de Dios 0.39 with very severe values; while Pasco 0, it has a very weak value. Also the average minimum temperature climatic index [CTnI] of Tumbes 0 and Loreto 0, with very weak values; while Pasco 0.3 with a very severe average value. And finally the general climate change

index [IGCC] average for Loreto 0.69, Ucayali 0.62 and Madre de Dios 0.66, with severe

values, where tropical forests are very fragile in the face of climate change.



**Fig. 5. Climate Change Analysis [Precipitation, Maximum Temperature and Minimum Temperature] final average of the 24 departments of Peru during the years 2006 - 2018**  
 Descriptive statistical data analysis. [CPrI]: Average: 0.079, Typical error: 0.016, Median: 0.073, Standard deviation: 0.080, Sample variance: 0.006, Kurtosis: 1.301, Coefficient of skewness: 1.271, Range: 0.292, Minimum: 0.001, Maximum: 0.292. [CTxI]: Average: 0.251, Typical error: 0.021, Median: 0.242, Standard deviation: 0.102, Sample variance: 0.010, Kurtosis: -0.020, Coefficient of skewness: -0.447, Range: 0.394, Minimum: 0.000, Maximum: 0.394. [CTnI]: Average: 0.138, Typical error: 0.019, Median: 0.137, Standard deviation: 0.094, Sample variance: 0.009, Kurtosis: -1.273, Coefficient of skewness: 0.106, Range: 0.298, Minimum: 0.002, Maximum: 0.300. [GICC]: Average: 0.468, Typical error: 0.020, Median: 0.464, Standard deviation: 0.099, Sample variance: 0.010, Kurtosis: 0.434, Coefficient of skewness: 0.414, Range: 0.412, Minimum: 0.277, Maximum: 0.688

#### 4.5 Sustainable Development Index and Climate Change Index 2006 – 2018

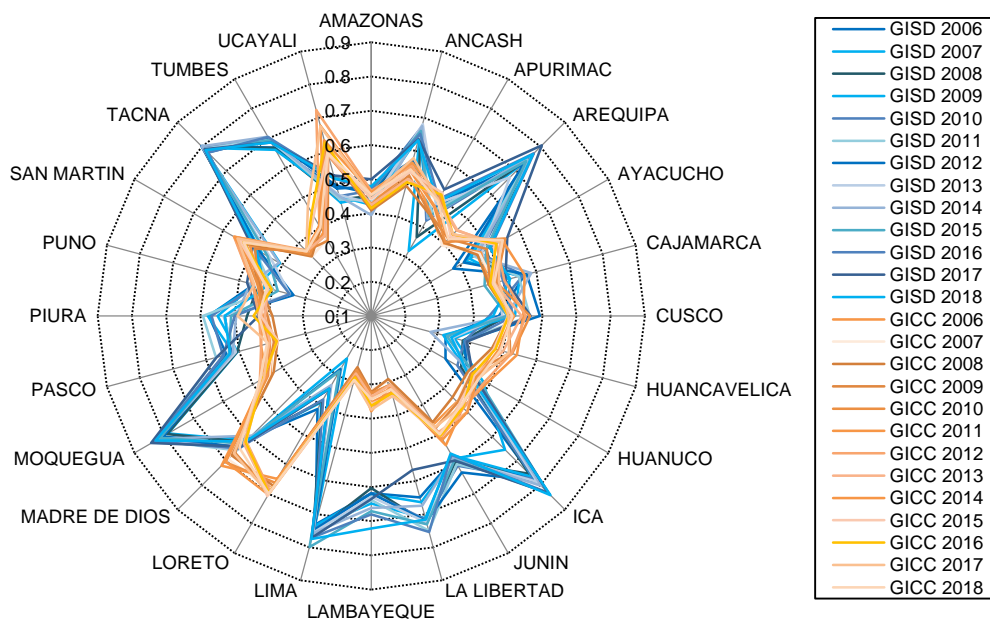
The sustainable and climatic changes that the departments of Peru suffered temporarily can be observed in Fig. 6, where the general sustainable development index [CPrI], of the 24 departments showed that Tacna, Arequipa, Ica, Lima and Moquegua are departments with an index general sustainable development with a value higher than 0.7; while Huancavelica, Loreto and Puno present values lower than 0.5. The general climate change index [GICC], of the 24 departments, it was shown that Loreto, Madre de Dios and Ucayali are departments with an index that generates climate change with a value higher than 0.6; while Tacna, Lima, Lambayeque and La Libertad present values lower than 0.4.

Temporarily we can observe (Fig. 6) that the general index of sustainable development is a little higher than the general index of climate change, in addition that the GISD and GICC values obtained by each department do not reach the same level, so we can affirm that the situation Climate of each department is totally different from its sustainable development, we

also inform that according to its natural resources in its geographical space, each department has different basic needs and these needs may be related to sustainable indicators and this could be related to change climate, and this will be discussed in the next point.

#### 4.6 Regression Analysis between Climate Change vs Sustainable Development and Regression Models

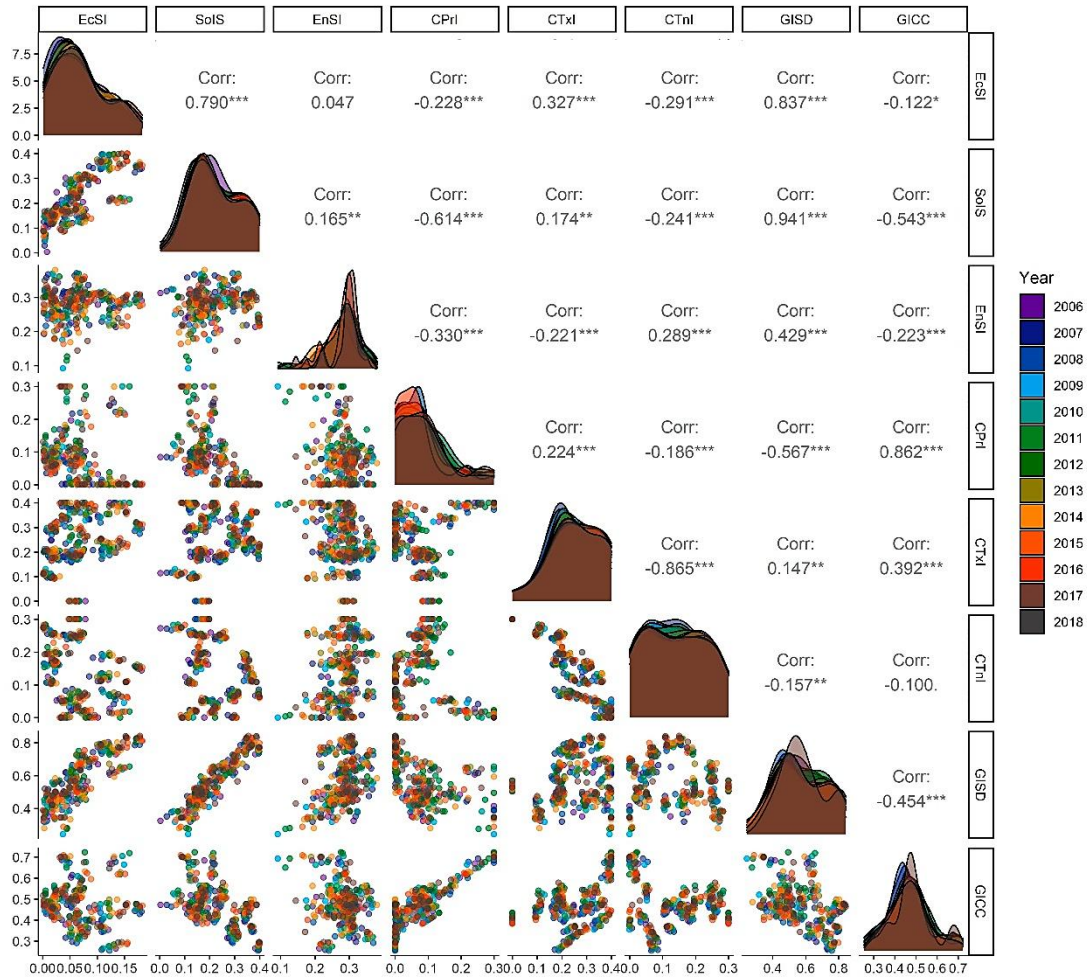
The multiple correlation matrix between the variables (Fig. 7) states that there are 13 positive relationships and 15 negative relationships, where we can say that SoSI is highly related to EcSI  $r = 0.79$ , GISD  $r = 0.94$ , CPrI  $r = -0.61$  and GICC  $r = -0.54$ ; while EcSI only presented a high relationship with SoSI  $r = 0.79$  and GISD  $r = 0.83$ ; CPrI also presented a high relationship with SoSI  $r = -0.61$  and GICC  $r = 0.86$ ; likewise CTxI only presented a high relationship with CTnI  $r = -0.86$ ; on the other hand GISD is highly related to EcSI  $r = 0.83$ , SoSI  $r = 0.94$  and CPrI  $r = -0.56$ ; likewise, GICC presented a statistical relationship only with two dimensions, SoSI  $r = -0.54$  and CPrI  $r = 0.86$ ; and, finally, EnSI did not present high relationships with the other variables.



**Fig. 6. Temporal analysis of the General Index of Climate Change and General Index of Sustainable Development of the 24 departments of Peru, during the years 2006 – 2018**  
 Descriptive statistical data analysis. [GISD: 2006 – 2018]: Average: 0.572, Typical error: 0.008, Median: 0.559, Standard deviation: 0.146, Sample variance: 0.021, Kurtosis: -1.031, Coefficient of skewness: 0.124, Range: 0.600, Minimum: 0.243, Maximum: 0.843. [GICC]: Average: 0.468, Typical error: 0.006, Median: 0.463, Standard deviation: 0.100, Sample variance: 0.010, Kurtosis: 0.171, Coefficient of skewness: 0.418, Range: 0.468, Minimum: 0.254, Maximum: 0.723

According to the methodology proposed for the regression models between GISD and GICC, in table 3 we can mention the best fit regression equation, where the estimated parameters as well as the Akaike and Bayesian information

criteria affirm that the GICC mayor's variables, CPri, CTxl, CTnl will help determine the impact of sustainable development GSD dependent variable.



**Fig. 7. Relationship matrix between the General Index of Climate Change [EcSI, SoSI, EnSI] and the General Index of Sustainable Development [CPri, CTxl, CTnl]**

Where corr: is the correlation coefficient between the variables. Resultados del análisis del nivel de significancia: \*\*\*  $p < 0,001$ ; \*\*  $p < 0,01$ ; \*  $p < 0,05$ .

**Table 3. Regression model and statistician for estimating the general index of sustainable development based on the general index of climate change, precipitation, maximum and minimum temperature**

Eq.	Estimated Parameters						MS Error	AIC	BIC
	a0	a1	a2	a3	a4	b			
17	0.61*	1034.76	-1034.91	-1034.47	-1035.90	-	0.01	-463	-441
18	1.0E-03	1.0E-03	1.0E-03	1.0E-03	1.0E-03	-	1.1E39	27841	27864
19	0.66*	-0.68*	-0.06	1.21*	-1.32	-	0.02	-415	-393
20	0.01	0.42*	4.2E-03	-0.04	0.01	-0.35*	0.01	-427	-401
21	-0.46*	0.51*	0.85*	0.35*	-	-	0.01	-454	-435

Where Eq.: model or regression equation;  $a_{[0,1,2,3,4]}$  and b: coefficient of the regression models; MS Error: Mean Square Error; AIC: Akaike Information Criterion; BIC: Bayesian Information Criterion. Significance test for regression coefficients \* $P < 0.05$

The results of Table 3, determined each regression model is appropriate for the research objective, where we can mention that the line equation to estimate the general index of sustainable development based on the climatic dimensions can be said to have obtained an information criterion Akaike and Bayesian superior to the other models, but only one of its regression coefficients is significant at  $p < 0.05$ ; on the other hand, the logarithmic regression model was also deficient to estimate sustainable development since its statistical values are insufficient for said model; Likewise, the exponential model presented three significant regression coefficients for said regression, but its AIC and BIC presented low values; This also happens with the exponential regression model where two of its regression coefficients are significant, but its AIC and BIC are deficient values; and finally the exponential regression model presented better regression coefficients but its information criteria Akaike and Bayesian were in second place; therefore we can affirm that only two equations are possible to choose to determine the sustainable development response based on the climate change indicators for Peru and its departments. Where the two equations would be as follows:

$$\begin{aligned} \text{GISD} &= 0.61 + 1034.76 * \text{GICC} - 1034.91 * \text{CTnI} \\ &\quad - 1034.47 * \text{CTxI} - 1035.9 * \text{CPrI} \\ \text{GISD} &= 0.51 * e^{\text{CTnI}} + 0.85 * e^{\text{CTxI}} + 0.35 * e^{\text{CPrI}} \\ &\quad - 0.46 * e^{\text{GICC}} \end{aligned}$$

Where clearly different parameters and regression coefficients are observed; and properly said equations could be applied in different departments of Peru.

## 5. CONCLUSION

Peru presents different sustainability indicators according to the different geographical spaces and available natural resources, where the economic situation is low, the social situation is medium, the environmental situation is high and therefore its sustainable development is in a medium situation; while the climatic indicator in precipitation is weak, the maximum temperature is severe, the minimum temperature is weak and therefore its climate change presents a moderate impact. Likewise, the linear and exponential regression model is qualified to estimate the GISD based on the GICC, CPrI, CTxI and CTnI. Likewise, we can recommend the use of more sustainable indicators in the social and economic state, where more climatic indicators also

participate, such as atmospheric pressure, solar radiation, wind, etc., since many factors also influence the rural and urban development of many departments of Peru. It is recommended to extract more climatic data such as humidity, solar radiation, wind, etc., in order to demonstrate that there is the influence of climate change on sustainable indicators. Likewise, it is recommended to extract more economic indicators, the gross value of production and total economic collection may already exist to be able to differentiate the economic situation that Peru represents and its departmental levels during its thirteen years of development.

## ACKNOWLEDGEMENTS

A special thanks to the public institutions of each department of Peru, for providing us with the information required for the present investigation; as well as a conglomerate of people for their outstanding collaboration in the field interviews. A special thanks to the National University of the Center of Peru, for its collaboration in the research.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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DOI: 10.1177/0049124104268644.

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