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# Evaluation of the Effects of Climate Change on Agricultural Production - La Rinconada Town Center – Ancash, Peru

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**Abstract** The objective of this research is to evaluate the effects of climate change on agricultural production in the town of Rinconada in the district of Santa, Ancash, Peru. Climate change variables (Precipitation and Temperature) vs. agricultural production were analyzed. We worked with the information collected from the SENAHMI (Servicio Nacional de Methodology e Hydrology del Peru), Lima - Peru through the database of the Pisco station, the Santa Users Board, the La Rinconada Irrigation Commission and the integrated system of agrarian statistics of the Ancash region, Peru [20]. The perception of the irrigation commission of the town of La Rinconada, district of Santa, Ancash, Peru was also evaluated through a survey with questions about the effects of the 2 variables of climate change: precipitation and temperature vs agricultural production of the main crops: corn, cotton, and rice. Climate change was modeled between the periods of 2006 and 2010 and between 2011-2015, through the variables of maximum precipitation and average precipitation in comparison with the variables of planting area, yield, and agricultural production [22]. It can be concluded that it is possible to predict the planting, yield and production of the crops evaluated: corn, cotton, and rice, using only the variables of maximum rainfall, and average rainfall, and that it is necessary to keep investigating the presence of transgenic crops in the Rinconada valley.

**Keywords** Climate Change, Agricultural Production, Ancash, Peru

## 1. Introduction

Projections indicate that by 2050, the impact of climate change on agriculture could be greater, including the potential effects of extreme weather events [29]. Agro-productivity can be very vulnerable to climate variations [8]. Efficient water resources management can improve the sustainability of agricultural productivity [15]. The losses produced in water resources due to climate change are noticeable with greater vulnerability due to its current water scarcity; at higher temperatures, there is a greater runoff [25,19].

“Climate change, based on variables and variation in temperature and precipitation, can have an important impact on agricultural production” [14]. “These changes will not similarly affect all crops [11], which shows us an important link between the effects of climate change and agricultural production” [29]. Likewise, climate change is a phenomenon considered irreversible, therefore, it only remains to establish measures and strategies aimed at reducing its impact and adapting to it [18].

In South America, agricultural production is very diverse and complex. The conciliation between the food of the inhabitants and the preservation of the environment is a pending task for the social actors linked to agricultural production [3]. In Peru, with Law 29811, which entered into force in 2011, the only thing that has been done is to extend the 10-year term that transgenic seeds are not allowed to enter the country, [16]. However, in the study area, the planting of transgenic crops has increased, mainly in cotton and corn, due to their increased yield per hectare, which is why it is required in the future to transform social relations within the sciences in relation to the subjects responsible for agricultural production [10]. Given the context, in Argentina and Bolivia, the effects of climate change on crops such as corn and wheat with rainfed irrigation have been evaluated, observing their growth in production, influenced by climate change [24]. Climate change is having significant adverse impacts on smallholder farmers [9]. There are seasonal variations in maximum and minimum temperatures, which are related to the annual averages of historical precipitation data [12].

According to Abid [1], who mentions the importance of education in farmers to understand changes in climate, agricultural decisions are not always driven by climate change, but by economic factors and the importance of livelihoods, impacting crop yields. It is necessary to consider the planning of the water resource, the characteristics of each basin, the behaviours and customs of the inhabitants of the upper basin, as well as all of the users involved in the use of the water resource [2,21]. The objective of this research was to evaluate the effects of climate change from the variables precipitation and temperature. In agricultural production, through 3 main crops: Rice, corn, and cotton in the population center of Rinconada in the district of Santa, Ancash, Peru [20].

## 2. Materials and Methods

The present research was developed in two stages:

**(1) The estimation of agricultural production based on variables related to climate change**

It was related to the historical data between the years 2006-2015, for this research, and given the increase in transgenic crops in the study area since 2011, - Law 29811, it was separated for analysis into two defined periods: Between 2006-2010 and between 2011-2015, information was requested from the board of users of the Santa, the Commission of Irrigators of Rinconada and the integrated system of agrarian statistics of the Ancash region, Peru, which is represented by the maximum, minimum and average rainfall and the maximum, minimum and average temperature, vs agricultural production (ton), and the area under irrigation (has) of the main crops: rice, cotton and maize. With the information collected, multiple linear regression equations of the SPSS 25.0 software were elaborated. Two professional software curves: Expert Professional and hydrostat 2; only the six best equations were selected according to their best relationship based on the $R^2$ (coefficient of determination) between both variables.

**(2) The Perception of the Commission of Irrigators of the Population Center of Rinconada (CRR), district of Santa, Ancash, Peru**

Formed by a total population of 267 users, from which 102 people were statistically selected who are part of the sample, farmers, technical staff of the irrigation committees, the irrigation commission and the Board of Users of the Santa Valley. This population sample, it was evaluated the farmer ́s perception of the climate change for which a survey was carried out, which was initially validated through a sample, of 30 people in the district of Cullpa Alta Huancayo, Peru, this instrument comprised five items: “Totally disagree, disagree, neither agree nor disagree, agree, and totally agree, this was validated by the expert judgment by five specialists, before being applied” [25,27,7].

The survey was carried out in 2020, the farmers of Rinconada were consulted with four questions to have a perception about these effects of the variable climate change on agricultural production: If they know the consequences that high temperatures have generated in the installed crops, if the presence of climate change harms the agricultural production of corn, cotton, and rice, which are the most important crops in the scope of the Rinconada irrigation commission.

## 3. Results

**(1) Estimation of agricultural production based on variables related to climate change**

The link of the three main crops installed in the CRR with the climate change variables was analyzed: Precipitation = P and temperature = T, obtaining the following results in Table 1.

Table 1 shows that the maximum average temperature and the highest sowing of the corn crop occurred in 2015. The minimum average temperature was recorded in 2008, with respect to production (ton) of corn. The highest production was recorded in 2014, and the lowest in 2013, the highest production in cotton (ton) in 2011 and the lowest in 2015, and the highest production (ton) in rice occurred in 2015.

**Table 1.** Annual evaluation of the relationship of climate change variables vs agricultural production of the population center of Rinconada-Ancash, Peru. Source: [20]

| N ° | Tmin | Tmax | Tprom | Pmin | Pmax | Pprom | Corn | | | Cotton | | | Rice | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Seed (Ha) | Rend (kg/ha) | Prod. (ton) | Seed (Ha) | Rend (kg/ha) | Prod (ton) | Seed (Ha) | Rend (kg/ha) | Prod (ton) |
| 2006 | 7,6 | 30,7 | 21,52 | 0,06 | 1,51 | 0,46 | 236.4 | 7,000 | 1,655 | 562.4 | 3,783.10 | 2,127.62 | 132.9 | 7,449.70 | 990.07 |
| 2007 | 8,21 | 30,78 | 20,74 | 0 | 0,78 | 0,3 | 368.37 | 7,100 | 2,615 | 538.26 | 3,085.50 | 1,660.80 | 120.61 | 7,810.30 | 942.00 |
| 2008 | 12,04 | 30,69 | 20,78 | 0,04 | 2,02 | 0,56 | 536.65 | 7,050 | 3,783 | 691.71 | 3,762.60 | 2,602.63 | 222.43 | 7,705.90 | 1,714.02 |
| 2009 | 7,96 | 30,28 | 21,39 | 0 | 11,38 | 1,35 | 853.22 | 7,035 | 6,002 | 203.76 | 3,555.60 | 724.49 | 407.38 | 9,544.00 | 3,888.03 |
| 2010 | 8,9 | 31,9 | 21,42 | 0,06 | 3,06 | 0,61 | 809.7 | 7,250 | 5,870 | 524.15 | 2,959.90 | 1,551.43 | 242.24 | 9,734.00 | 2,357.96 |
| 2011 | 7,25 | 30,48 | 20,68 | 0 | 1,91 | 0,48 | 713.12 | 7,320 | 5,220 | 555.52 | 2,976.20 | 1,653.34 | 148.88 | 9,878.00 | 1,470.64 |
| 2012 | 12,59 | 31,49 | 21,66 | 0 | 1,25 | 0,4 | 527.12 | 7,340 | 3,869 | 550.88 | 3,186.30 | 1,755.27 | 192.51 | 9,857.00 | 1,897.57 |
| 2013 | 12,22 | 30,93 | 21,18 | 0 | 11,83 | 1,96 | 689.46 | 7,850 | 5,412 | 553.25 | 3,233.30 | 1,788.82 | 163.71 | 10,020.00 | 1,640.37 |
| 2014 | 13,26 | 30,51 | 21,72 | 0 | 1,85 | 0,52 | 763.1 | 8,100 | 6,181 | 428.6 | 2,938.50 | 1,259.44 | 264.75 | 9,868.00 | 2,612.55 |
| 2015 | 13,41 | 30,97 | 22,52 | 0 | 3,65 | 0,72 | 989.28 | 7,925 | 7,840 | 158.06 | 2,852.40 | 450.85 | 387.78 | 9,587.90 | 3,718.00 |

Tmin =Minimum temperature. Tmax = Maximum temperature. Tprom = Average temperature. Pmin = Minimum precipitation. Pmax = Maximum precipitation. Pprom = Average precipitation. Siem: plant. Ren= performance.

Prod= Production [20].

**Table 2.** Evaluation of the correlation between climate change variables Vs agricultural production, for the period 2006-2010

| Variables | Corn | | | Cotton | | | Rice | | |
|---|---|---|---|---|---|---|---|---|---|
| | Seed (Ha) | Rend (kg/ha) | Prod. (ton) | Seed (Ha) | Rend (kg/ha) | Prod (ton) | Seed (Ha) | Rend (kg/ha) | Prod (ton) |
| Tmax | | **0.84** | | | | | | | |
| Pmax | **0.64** | | **0.62** | **0.76** | | **0.6** | **0.95** | **0.57** | **0.96** |
| Pprom | | | **0.6** | **0.73** | | **0.63** | **0.94** | **0.53** | **0.92** |

**Table 3.** Evaluation of the correlation between climate change variables vs. agricultural production, for the period 2011-2015

| Variables | corn | | | cotton | | | rice | | |
|---|---|---|---|---|---|---|---|---|---|
| | Siem (Ha) | Rend (kg/ha) | Prod. (ton) | Siem (Ha) | Rend (kg/ha) | Prod (ton) | Siem (Ha) | Rend (kg/ha) | Prod (ton) |
| **Tprom** | | | | 0.75 | | 0.68 | 0.87 | 0.62 | 0.87 |

**Table 4.** Multiple regression equations that evaluate the relationship between the variables climate change (P = precipitation and T = temperature) vs agricultural production of the population center of Rinconada-Ancash, Peru

| Relationship | Equation | Type | Determination coefficient $R^2$ | Program |
|---|---|---|---|---|
| Climate Change (X) *vs* Rice sowing (Y) | y=-90.9894+43.7774*Pmax+ 12.6623*Pprom | Lineal Multiple | 0.95 | Hidroesta2 |
| Climate Change (X) *vs* Rice sowing (Y | y=1108.0947+959.0667*Pmax - 2875.0556*Pprom | Lineal Multiple | 0.97 | Hidroesta2 |
| Climate Change (X) *vs* Rice sowing (Y | y=689.0234252-64.3588814*Pmax | Lineal | 0.76 | Hidroesta2 |
| Climate Change (X) *vs* Rice sowing (Y | $y=644.8373*Pmax^{0.3451}*Prom^{-1.1520}$ | Potencia mutiple | 0.54 | Hidroesta2 |
| Climate Change (X) *vs* Rice sowing (Y | $y=-307.4824579+88.1647676*P_{max}$ | Lineal | 0.64 | Hidroesta2 |
| Climate Change (X) *vs* Rice sowing (Y) | $y=5678.1840+3728.0246*P_{max}-18913.9126*P_{prom}$ | Lineal Multiple | 0.83 | Hidroesta2 |

Source: [18,20] 2006- 2010

From Table 2, it is observed that in the period from 2006 to 2010, the best correlation is between average precipitation and rice production, and the lowest correlation between average precipitation and rice yield, it is also observed that the maximum precipitation and average have a great influence on planting and production of installed crops.

From Table 3, it is observed that in the period from 2011 to 2015, the best correlation is between average temperature and rice sowing and production, and the lowest correlation between average temperature and rice yield.

To perform the descriptive and inferential calculations, 20 multiple linear regression equations were initially selected from the Hidroesta 2 software and the two specialized professional software. Finally, only the six best equations were validated, showing a better regression between climate change and the planting and agricultural production of three main crops: rice, cotton, and corn (Table 3).

In Table 4, it is observed that the relationship between climate change vs. rice production (0.97) achieved a greater $R^2$, and the relationship between climate change and cotton production achieved a lesser $R^2$(0.54).

Table 4 shows the six best validated equations to evaluate climate change through its variables (P= Precipitation and T= temperature) vs. agricultural production, leaving us with the equations that achieved a better relationship between climate change vs. planting of corn, rice and cotton; with which the best $R^2$ values were obtained, between climate change with sowing and agricultural production. Likewise, a better $R^2$ was achieved, between climate change vs. cotton production (0.97) and the lowest $R^2$, between climate change vs. corn planting (0.54).

With the data collected from the climate change variables: maximum and average precipitation during the years 2016 and 2017, the information on agricultural production was expanded.

**Table 5.** Annual evaluation of the relationship of climate change variables vs agricultural production of the population center of Rinconada-Ancash, Peru

| | | | | | | | Corn | | | Cotton | | | Rice | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N ° | Tmin | Tmax | Tprom | Pmin | Pmax | Pprom | Siem (Ha) | Rend (kg/ha) | Prod. (ton) | Siem (Ha) | Rend (kg/ha) | Prod (ton) | Siem (Ha) | Rend (kg/ha) | Prod (ton) |
| 2006 | 7,6 | 30,7 | 21,52 | 0,06 | 1,51 | 0,46 | 236.4 | 7,000 | 1,655 | 562.4 | 3,783.10 | 2,127.62 | 132.9 | 7,449.70 | 990.07 |
| 2007 | 8,21 | 30,78 | 20,74 | 0 | 0,78 | 0,3 | 368.37 | 7,100 | 2,615 | 538.26 | 3,085.50 | 1,660.80 | 120.61 | 7,810.30 | 942.00 |
| 2008 | 12,04 | 30,69 | 20,78 | 0,04 | 2,02 | 0,56 | 536.65 | 7,050 | 3,783 | 691.71 | 3,762.60 | 2,602.63 | 222.43 | 7,705.90 | 1,714.02 |
| 2009 | 7,96 | 30,28 | 21,39 | 0 | 11,38 | 1,35 | 853.22 | 7,035 | 6,002 | 203.76 | 3,555.60 | 724.49 | 407.38 | 9,544.00 | 3,888.03 |
| 2010 | 8,9 | 31,9 | 21,42 | 0,06 | 3,06 | 0,61 | 809.7 | 7,250 | 5,870 | 524.15 | 2,959.90 | 1,551.43 | 242.24 | 9,734.00 | 2,357.96 |
| 2011 | 7,25 | 30,48 | 20,68 | 0 | 1,91 | 0,48 | 713.12 | 7,320 | 5,220 | 555.52 | 2,976.20 | 1,653.34 | 148.88 | 9,878.00 | 1,470.64 |
| 2012 | 12,59 | 31,49 | 21,66 | 0 | 1,25 | 0,4 | 527.12 | 7,340 | 3,869 | 550.88 | 3,186.30 | 1,755.27 | 192.51 | 9,857.00 | 1,897.57 |
| 2013 | 12,22 | 30,93 | 21,18 | 0 | 11,83 | 1,96 | 689.46 | 7,850 | 5,412 | 553.25 | 3,233.30 | 1,788.82 | 163.71 | 10,020.00 | 1,640.37 |
| 2014 | 13,26 | 30,51 | 21,72 | 0 | 1,85 | 0,52 | 763.1 | 8,100 | 6,181 | 428.6 | 2,938.50 | 1,259.44 | 264.75 | 9,868.00 | 2,612.55 |
| 2015 | 13,41 | 30,97 | 22,52 | 0 | 3,65 | 0,72 | 989.28 | 7,925 | 7,840 | 158.06 | 2,852.40 | 450.85 | 387.78 | 9,587.90 | 3,718.00 |
| 2016 | 8,22 | 28,5 | 26,1 | 0 | 7 | 0,28 | 374.68 | 6736.17 | 2,524 | 647.43 | 2028.11 | 1313.07 | 400.98 | 17498.66 | 7016.55 |
| 2017 | 10,15 | 30,65 | 21,79 | 0,014 | 4,2 | 0,69 | 577.70 | 7054.43 | 4,075 | 491.09 | 3407.66 | 1673.47 | 283.59 | 11115.95 | 3152.39 |

Source: [20]

Tmin =Minimum temperature. Tmax = Maximum temperature. Tprom = Average temperature. Pmin = Minimum precipitation. Pmax = Maximum precipitation. Pprom = Average precipitation. Siem: plant. Ren= performance.

Prod= Production [20].

**Table 6.** Answers to the questionnaire on the relationship between the variable climate change (variables P and T) and agricultural production in the population center of Rinconada-Áncash, Peru

| N° | Questions | 1: Strongly disagree | | 2: Disagree | | 3: Neither agree nor disagree | | 4: Agree | | 5: Totally agree | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Find out about the consequences of high temperatures on crops. | 19 | 18.63 | 7 | 6.86 | 1 | 0.98 | 59 | 57.84 | 16 | 15.69 |
| 2 | Do you consider that the presence of climate change is detrimental to maize production? | 16 | 15.69 | 3 | 2.94 | 2 | 1.96 | 59 | 57.84 | 22 | 21.57 |
| 3 | Do you consider that the presence of climate change is detrimental to the agricultural production of cotton? | 15 | 14.71 | 4 | 3.92 | 2 | 1.96 | 59 | 57.84 | 22 | 21.57 |
| 4 | Do you consider that the presence of climate change is detrimental to rice production? | 16 | 15.69 | 6 | 5.88 | 1 | 0.98 | 45 | 44.12 | 34 | 33.33 |

Source: [20]

**(2) Perception of the irrigation committee of the Rinconada (CRR), district of Santa, Ancash, Peru**

From Table 6, there is a greater number of people who agree and totally agree on the harmful consequences generated by high temperatures on corn, cotton and rice crops, and there is a smaller number that there are even those who disagree and consider that the presence of climate change is harming agricultural cotton production.

# 4. Discussion

Of the six equations chosen and validated to evaluate climate change (maximum precipitation and average precipitation) vs. agricultural production, for the period 2006-2010, a better $R^2$ was achieved between climate change vs. rice production (0.97), it has a better $R^2$ between climate change vs cotton production (0.54). It shows us a variation in the impact of climate change (variation in precipitation = P and temperature = T), in agriculture in different seasons and climatic zones of different latitudes of the world [26]. These farmer adaptation measures are very important to prepare for the presence of climate change [28]. According to López [14], “climate change, shows us important impacts on agricultural production in various Caribbean countries” [4].

The perception of indigenous communities in the world and in Mexico has been investigated, in the presence of climatic alterations due to concrete actions carried out [8]. “Global climate change affects the entire hydrological cycle; therefore, adaptation measures must consider the possible effects on its various components” [5,23,6].

The impacts of climate change on family farming must be evaluated through a relevant and contextualized model of indicators that considers and assesses the particularities of agricultural productive units. “Finally, [19], climate-smart agriculture is an important requirement for improving yields and production quality”. “We must be prepared for the next challenges to combat the impact of climate change, and ensure food security not only for humans, but for all living things” [13].

It was possible to validate that there is an $R^2$, which has allowed us to expand of two years of information: 2016 and 2017. Likewise, it is necessary to continue investigating the subject, taking into account for a longer period of time to the variables of climate change: precipitation, temperature, including the effects of the presence of transgenic crops in Peru, and that are related to agricultural production, such as: Funding, crop prices in the market and the customs of the farmers of the Rinconada Irrigation Commission.

# 5. Conclusions

It is possible to predict the sowing, yield, and production of the main crops of rice, cotton and corn, using the variables of maximum /average rainfall, and it is necessary to continue investigating the subject in the presence of transgenic crops in the Rinconada Valley., including other variables such as economic financing, crop prices in the market and the customs of the farmer of the Rinconada Irrigation Commission.

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