Effects of climate change on the resources of the rural ecosystem, a view from farmer perspectives

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Abstract. This paper presents the results obtained from the categorization of the social representations of farmer groups on the effects of climate change on the biodiversity of their farms, developed in a rural area of the Colombian Andes. A mixed methodology was used throughout the analysis of the behavior of rainfall and temperature between the years 2010-2017 and the implementation of an open survey on 144 farmers, of which its data was analyzed using descriptive and inferential statistics through descriptive estimators and an analysis of variance and multiple comparison mean tests, respectively. Furthermore, a qualitative analysis, supported by Corbin and Strauss’ Grounded Theory, was carried out on 18 farmer families using semi-structured interviews. The hypothesis testing determined the existence of significant differences between the mean temperatures of the years observed when obtaining a value of \(F_c = 3.50\), highly significant at 1%, and a value of \(F_c = 2.79\), significant at 5%, \(P<0.05\), for the mean rainfall. In the descriptive analysis, farmers’ perception of the negative effects of climate change was evident in the decrease in the availability of water from natural sources (80.6%), deterioration in water quality (50.0%), variations in rainfall intensity (82.0%) and in local bimodal rainfall patterns (79.0%). The inferential analysis determined that the proportion of farmers reporting a disappearance of species due to intense heat or rainfall differs significantly from the level of \(p<0.05\), over those who reported that these conditions have not caused variations in flora and fauna. The qualitative analysis verified the effects of climate change on rural biodiversity resources, which were expressed in 4 emerging categories: 1) Biodiversity resources in the process of extinction, 2) resilient resources, 3) emerging biodiversity, and 4) new agricultural business opportunities. The findings reveal that from a farmers’ perspective climatic variations are affecting species of fauna and flora in rural communities.

1. Introduction

The effects of climate change on the environment are generated by the pressure on the environmental conditions for survival and reproductive of species, shifting the climatic niches, which forces the species to adapt or disappear depending on its phenotypic plasticity, capacity for evolution and ability to adapt in the same environment or spread to colder areas. [1]. However, the uncertainty in the trend of current environmental changes does not allow us to effectively assess the rates of displacement, adaptation and phenotypic plasticity of flora and fauna species [2] in order to reduce their depopulation. Likewise, alterations in the weather patterns of climatic cycles are generating differences in flowering, pollination, reproduction and eclosion patterns of species [3], which result in altered interactions between species in disrupted scenarios [4] due to the degeneration of symbiotic
relationships, the disappearance of natural enemies of control, or the invasion of new species and pests.

The research carried out during 2017 and 2018 was aimed at classifying the effects of climate change on the rural ecosystem, from farmer representations in the Municipality of Bochalema, Norte de Santander, Colombia.

The findings of the study are relevant and pertinent to the academic and scientific communities due to the endogenous and multimethodic angle of their approach, which contribute to the understanding of socio-environmental phenomena from the perspective of local actors, with the possibility of forming participatory intervention models that would mitigate the impacts of climate change on the biodiversity of ecosystems and human communities.

2. Materials and methods

The methodological approach used was a mix of data capture and analysis based on the quantitative approach, using descriptive statistics for the organization and presentation of the data, as well as inferential statistics for the survey analysis and extrapolation of conclusions (inferences) of the population; in the qualitative area, the data reduction process of the theory of basis [5] was applied for the interpretation of the interviews. In rural villages, 144 small-scale farmers were approached and 18 key informants in farm families were interviewed. In relation to the climatological analysis, the average annual temperatures and precipitations during the 2010-2017 period were taken from the Blonay station of “Centro Nacional de Investigaciones de Café (Cenicafé)”, located in the Municipality of Chinchota, Colombia, at 1,250 meters above sea level, within the geographical area of influence of the community under study.

For the inferential analysis, we used an analysis of variance and the tests of multiple comparison means via the Equation (1):

\[ y_{ij} = \mu + \tau_i + \varepsilon_{ij}, \] (1)

where \( i = 1, 2, 3, 4, 5, 6, 7, 8 \), and \( j = 1, 2, 3, \ldots 12 \); so \( y_{ij} \) = response observed in the \( i \)-th year of the \( j \)-th month; \( \mu \) = population mean of the observed response estimated by the sample mean; \( \tau_i \) = variation, on the response observed for the \( i \)-th year; \( \varepsilon_{ij} \) = random error associated with each observed response; \( y_{ij} \), and assume normal and independent, with average zero and variance of zero. \( \sigma^2 \), \( \varepsilon_{ij} \sim \text{NID}(0; \sigma^2) \).

According to the evaluated response, a hypothesis contrast was developed to determine the significance of the effect, which is expressed as Equation (2):

\[ H_0: \mu_1 = \mu_2 = \cdots = \mu_8 \]
\[ H_1: \mu_i \neq \mu_j \quad (i \neq j) \] (2)

The null hypothesis \( H_0 \) indicates that the averages of the observed responses are the same for all data points.

The interpretation of the qualitative data was developed based on the grounded theory in [5], by reducing the data taken from the interviews, coded and put into 4 emerging categories allowed the reconstruction of the guiding threads to the representations of the key informants.

3. Results and discussion

3.1. Analysis of climatic behavior

The annual mean temperatures analyzed [6] (Table 1) by the hypothesis tests, which are the product of the results of the Analysis of Variance, determined the existence of significant differences between the mean temperatures for the various years (in at least one of the years) observed by obtaining a value of
**Table 1.** Trends in average temperatures.

| Year | Average | Deviation | Variation coefficient | Minimum | Maximum | Average c. interval (95%) | Inferior | Superior |
|------|---------|-----------|-----------------------|---------|---------|--------------------------|---------|----------|
| 2010 | 20.93   | 0.7362    | 3.52                  | 19.7    | 22.1    | 20.46                    | 21.39   |          |
| 2011 | 20.03   | 0.6824    | 3.41                  | 18.6    | 20.7    | 19.59                    | 20.46   |          |
| 2012 | 20.33   | 0.6412    | 3.15                  | 19.0    | 21.1    | 19.92                    | 20.73   |          |
| 2013 | 20.72   | 0.6492    | 3.13                  | 19.8    | 21.4    | 20.30                    | 21.13   |          |
| 2014 | 20.77   | 0.5646    | 2.72                  | 19.8    | 21.8    | 20.41                    | 21.13   |          |
| 2015 | 21.15   | 0.6502    | 3.07                  | 20.3    | 22.4    | 20.74                    | 21.56   |          |
| 2016 | 21.11   | 0.7204    | 3.41                  | 19.7    | 22.0    | 20.65                    | 21.57   |          |
| 2017 | 20.69   | 0.9453    | 4.57                  | 19.1    | 21.9    | 20.09                    | 21.29   |          |

Table 2 presents trends in average rainfall [6]. The hypothesis and analysis of variance tests determined a value of $F_c = 2.79$, significant at 5%, $P < 0.05$, so the null hypothesis is rejected, i.e. rainfall differs by at least two years from the eight years observed. During the 8-year period of climatological records, there was some variability in the variables of temperatures (increasing tendencies) and rainfall (decreasing tendencies) that influence physiological processes due to hydric and thermal stress [7], infestation of pests and diseases [8], reproduction, flowering and fruit filling [9].

**Table 2.** Trends in average rainfall.

| Year | Average | Deviation | Variation coefficient | Minimum | Maximum | Average c. interval (95%). | Inferior | Superior |
|------|---------|-----------|-----------------------|---------|---------|---------------------------|---------|----------|
| 2010 | 198.44  | 127.59    | 65.08                 | 0.6     | 397.4   | 114.98                    | 277.12  |          |
| 2011 | 228.44  | 160.02    | 70.05                 | 58.5    | 613.3   | 126.77                    | 330.12  |          |
| 2012 | 141.85  | 130.70    | 92.14                 | 18.1    | 393.5   | 58.81                     | 224.89  |          |
| 2013 | 113.42  | 104.30    | 91.95                 | 25.9    | 371.8   | 47.16                     | 179.69  |          |
| 2014 | 100.63  | 88.81     | 88.26                 | 6.4     | 272.6   | 44.20                     | 157.05  |          |
| 2015 | 73.61   | 50.86     | 69.10                 | 11.5    | 176.8   | 41.29                     | 105.93  |          |
| 2016 | 105.63  | 89.66     | 84.88                 | 8.2     | 321.5   | 48.66                     | 162.59  |          |
| 2017 | 121.63  | 70.46     | 57.93                 | 53.8    | 257.2   | 76.86                     | 166.39  |          |

With regards to the average rainfall data in Table 2, it can be observed that 2011 had the highest rainfall (228.44 mm), due to the winter wave that hit the country at the end of 2010 and in the beginning of 2011. The year with the lowest rainfall was 2015 (73.61 mm). In general, there is a trend towards an annual decrease in rainfall from 2011. The variation coefficient shows a moderate variability, which indicates abundant rainfall in some years and little rainfall in others. The reliability intervals reveal a large difference of the first 3 years with respect to the remaining 5 years analyzed.

The previous discoveries correspond with studies carried out by [10] in Yucatán, Mexico, after finding a high and positive perception of the producers on the changes in the climate due to increments, and extreme changes, in the temperatures and rainfall, decrease of rain frequency, increase in drought periods and impact on the daily lives of families; [11] in Botswana, Africa, they reported that farmers perceived increases in average annual temperature, increase in hot days, decrease in...
rainfall and rainy days; [12] in Nepal they say that people have begun to feel the impacts of climate change through the decrease in water sources, loss of agricultural crops and the attack of new pests, diseases and weeds on their crops.; [13] affirm that 95% of small farmers in Central America are experiencing the effects of rising temperatures, unpredictable rains and extreme weather events and the incidence of pests and diseases and; [14] Chinchiná, Colombia, found increases of 1.4 °C and solar brightness by 14% and a 44% reduction in rainfall during the first quarter of 2010.

3.2. Effects of climate change on rural biodiversity

With regards to the effects of climate change on biodiversity, 65.3% of the producers surveyed consider that the effects of heat, prolonged droughts or intense rains have caused the disappearance and 47.0% the emergence of new species of flora and fauna on their farms (Table 3).

| Parameter                  | Representations of farmers | Percentage (%) |
|----------------------------|----------------------------|----------------|
| Availability of water      | Water depletion in water sources | 80.6          |
|                            | Decreased amount of water   | 61.0           |
|                            | Decrease in water quality   | 50.0           |
| Variation in rainfall      | Changes in rainfall intensity | 82.0          |
|                            | Variations in rainfall patterns | 79.0        |
| Local biodiversity         | Disappearance of species of wild flora and fauna | 65.3          |
|                            | Emergence of new species of flora and fauna | 47.0          |

The descriptive analysis revealed farmers' opinions on the climatic factors that are altering the local biodiversity, including the availability of water due to prolonged droughts in communities that result in depletion of water sources (80.6%), a decrease in water quantity (61%) and a deterioration in water quality (50.0%); variations in rainfall caused by changes in rainfall intensity (82.0%) and variations in bimodal local rainfall regimes (79.0%). In the inferential analysis, the null hypothesis was rejected, which indicates that the proportion of farmers who declared the disappearance of species due to the effects of the intense heat or rains experienced in the region differs significantly to the level of p<0.05, from the proportion of those who reported that these weather, heat and rain conditions have not caused variations in flora and fauna.

The qualitative study, product of the application and analysis of 18 interviews with farmer families, 4 categories emerged: 1) Biodiversity resources in the process of extinction: With rising temperatures and decreasing rainfall, native species have begun to disappear from the area. Among the plant species in extinction are: coffee, leaf vegetables, lulo and high-altitude fruit trees, mastuerzo, guinchos, pardillos, figs, mosses and wild ferns; And among the animal species: sloths, bird species, armadillos, squirrels, possums, maricotes, fleas, chapetones, deer and foxes; 2) resilient resources: Farmers have observed the resistance of some animal and plant species to climatic variations. Vegetable species: citrus, grasses, ixoras, heliconias, pines, roosts; Animal species: snakes, parrots and parakeets, mosquitoes and mosquitoes); 3) emerging biodiversity: This circumstance is presented by the presence of new climatic conditions that favor the growth and development of species coming from hot climates. Plants: cocoa, pineapple, citrus, tomato; Animals: mosquitoes, ants, ticks, snakes, alcaravanes, herons and ducks; 4) new agricultural business opportunities: Farmers are identifying new businesses to replace their traditional ventures. These include beekeeping, fish, meat cattle, citrus crops, avocado, bean, macadamia, sacha inchi, tomato and corn.

Authors have found that the disappearance, migrations and resilience of wild plants and animals due to the effects of climatic variations threatens biodiversity and the functioning of ecosystems [15], modifies the distribution and survival patterns of species [16] and, at the same time, generates new opportunities for rural communities [17]. On small-scale farms, global warming causes changes in temperatures and rainfall patterns that result in locations currently suitable for some crops ceasing to be suitable for planting [18] when basic sustainability conditions change the distribution and production of vulnerable plant species [19]. In the area under study, freshwater systems are being
significantly affected by climate change in ecosystem services and human livelihoods [20], forcing farmers to generate empirical adaptation actions in a scenario that is difficult to predict because it is a dynamic process, highly complex [21] and characterized by high climate uncertainty [22].

4. Conclusions

Statistical analysis of the behavior of climatic variables of temperatures and precipitations show significant levels with values of \( F_c = 3.50, \) to 1%, \( P < 0.01, \) and of \( F_c = 2.79, \) significant at 5%, \( P < 0.05, \) respectively. There are revealing trends towards an increase in average temperatures and a decrease in average rainfall, constituting variables that are influencing the life cycles of local biodiversity by pushing for the disappearance of species, climate resilience, immigration and emigration of plants and animals from warmer or colder climates, respectively, and the supply of new business for farmers.

Farmers are shaping social representations around the effects of climate change on the biodiversity of their farms. The negative impacts are associated with prolonged droughts in communities that cause water depletion in water sources (80.6%), decrease in water quantity (61%) and deterioration in water quality (50.0%); variations in rainfall caused by changes in rainfall intensity (82.0%) and variations in local bimodal rainfall regimes (79.0%). 65.3% thought that climatic variations affect biodiversity through the extinction of local fauna and flora species and 47.0% thought that new climatic conditions facilitate the migration of species from warmer ecosystems. These assessments were confirmed in the qualitative analysis by categorizing them as endangered, resilient, emerging and new business species.

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