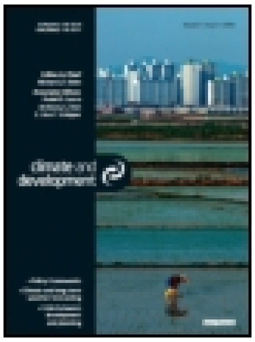

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Climate and Development

ISSN: 1756-5529 (Print) 1756-5537 (Online) Journal homepage: http://www.tandfonline.com/loi/tcld20

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To cite this article: Mariana G. Barrucand, Carolina Giraldo Vieira & Pablo O. Canziani (2016): Climate change and its impacts: perception and adaptation in rural areas of Manizales, Colombia, Climate and Development, DOI: 10.1080/17565529.2016.1167661

To link to this article: http://dx.doi.org/10.1080/17565529.2016.1167661

Climate and Development, 2016
http://dx.doi.org/10.1080/17565529.2016.1167661

RESEARCH ARTICLE

Climate change and its impacts: perception and adaptation in rural areas of Manizales, Colombia

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(*Received 5 February 2015; accepted 13 January 2016*)

Tropical social-ecological systems are highly vulnerable to climate change, given the limited natural climate variability in the tropics. Tropical rural populations, with livelihoods dependent on agriculture, are particularly vulnerable to climate variability and changes. To develop climate change social communication, plan and implement adaptation, it is necessary to understand regional/local climate process, risks and opportunities. It is also important to understand how local populations perceive such changes and adapt their livelihoods. Limited information is available on climate change perceptions in tropical Latin American rural populations. Hence, a climate study and climate change perception survey were carried out in the Manizales Municipality, in the Andean region of Colombia and one of its major coffee-growing areas. The study spanned three "thermal" levels in the tropical Andes, 1000 m a.s.l. and above, each with distinct environments and livelihoods. Climate analysis yielded significant warming trends in recent decades, particularly in temperature minima for all levels, but no significant local precipitation trends. The perception survey, carried out in a sparsely populated region, mostly with limited accessibility, included 37 households, with structured and semi-structured interviews, adapted to local culture. Interviewees had little or no previous knowledge on climate change. However, almost all had perceived significant changes in both temperature and precipitation, which impacted their livelihoods and environment. Some perceptions could result from a La Niña event prior to the survey, and other environmental destruction processes. Their responses to change were spontaneous adaptation, based on traditional practices and agricultural technical advice from state agencies and coffee grower associations.

Keywords: climate perception; adaptation; rural population; Manizales Colombia

Introduction

Human-driven climate change has been recognized as one of the major human impacts on society and environment (IPCC, 2007a, 2007b, 2013, 2014). Greenhouse gas emissions and widespread regional land-use changes are perturbing the climate system at an unprecedented rate. These external drivers, together with other global transformation, promote such significant changes on social-ecological systems (SES) that the present era is now called the Anthropocene.

Mitigation of climate change drivers and adaptation of SES to ongoing change are necessary to sustain or improve their resilience so that they continue to function under future climate state(s). As numerous studies show (e.g. Adger, 2006 and references therein), the largest impacts of such changes fall upon the most vulnerable SES. Perception of vulnerability at different social levels can strongly influence the overall perspective on risks and challenges such changes pose. Intergovernmental Panel on Climate Change (IPCC) defines vulnerability by the degree at which climate change damages or will damage a given SES. It depends on a system's sensitivity to changes and adaptive capacity. Assessing vulnerability, resilience and adaptive capacity in a given SES requires a correct understanding of present and future climate changes impacting the system, what is the magnitude of these impacts and what are the system's weaknesses and capabilities to face them. Local populations' perception of changes and risks must be thus analysed. Traditional rural societies, with livelihoods strongly linked to climate processes and local ecosystem services, are particularly vulnerable to climate change. Poor societies are the most vulnerable (Huq, Rahman, Konate, Sokona, & Reid, 2003).

Population, public and private sectors and even natural systems may adapt to climate change. Adaptation will be reactive, when inadequate or no understanding on climate

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*Corresponding author. Email: barrucand@at.fcen.uba.ar changes is available, that is, unplanned. Reactive adaptation is limited, resulting in enhanced costs (social, economic and environmental) of reacting *post facto* to risks and impacts. However, knowledge-based planned adaptation which begins before the onset of expected impacts can reduce risks, minimize costs and enhance resilience.

Latin America, spanning tropical to subpolar latitudes, is undergoing a large variety of changes and impacts (IPCC, 2007a, 2007b, 2013, 2014 and references therein). In tropical and subtropical regions, land-use changes with extensive deforestation and biomass burning drive additional changes at regional/local scales (Canziani & Carbajal Benitez, 2012 and references therein). While large changes at high latitudes are not necessarily statistically significant to date, small changes observed at tropical latitudes are statistically significant (Mahlstein, Knutti, Solomon, & Portmann, 2011; Mahlstein, Portmann, Daniel, Solomon, & Knutti, 2012). Tropical climate systems, with well-defined dry and humid seasons, have reduced seasonal temperature variability. Tropical ecosystems evolved within this stable, limited seasonal climate variability and narrow temperature ranges. Tropical biodiversity and societies may thus already suffer even with the comparatively limited but statistically significant changes currently observed.

Colombia, in northern South America, is a tropical country with a complex topography spanning coastal regions, Andean mountain ranges and flatlands, including part of the Amazonian upper basin (Figure 1). Due to its diverse ecosystems including tropical coastal ones to high Andean glacial environments, mountain tropical forest, savannas and mountain agriculture, it is particularly vulnerable to climate change. The First National Communication to the United Nations Framework Convention on Climate Change (IDEAM, 2001) highlighted Colombia's climate change issues and vulnerabilities, for example, risks to the national economy, through impacts on mountain agriculture, in particular coffee, water availability for agriculture and hydroelectric generation, among others.

It is thus necessary to evaluate the current state of rural areas in the mountain regions of Colombia, through the analyses of climate variables and local populations' perception of change. Understanding how local populations perceive climate variability and change is a valuable tool to assess local aspects of climate processes and their impacts. Perception studies are useful to improve social communication of climate change tailored to local needs, evaluate spontaneous adaptation strategies and plan adaptation strategies (O'Connor, Bord, & Fisher, 1999, among others). This study aims to evaluate climate variability and change, and compare it with the local populations' perceptions and the adaptation strategies used to face the challenges in rural areas in one of Colombia's Andean ranges. The study focuses on the Caldas Department, where three altitude ranges with distinct environmental and social characteristics are analysed. The area lies in one of Colombia's main coffee-growing regions, hence important for the national economy. Similar studies have been carried out in different regions of the globe: Leiserowitz (2006), Manandhar, Schmidt Vogt, Perret, and Kazama (2011) and Buys, Miller, and van Megen (2012), among others.

Methodology

Analyses of climate change perception and adaptation strategies in mountain rural populations at three "thermal" levels were carried out for the Municipio de Manizales (Manizales Municipality) and a small area of the Municipio de Villamaría (Villamaría Municipality), both part of the Caldas Department. Climate perceptions and adaptation strategies are compared with meteorological observations made within the study area. This area has a sparse, scattered population. The 2012 population was 27,275 inhabitants in a 38,012 hectares region (de Alcaldía, 2012).

The Mexican National Institute of Statistics and Geography (INEGI) defines "rural population" as people whose life and work are centred in rural areas and activities, with few or limited public services. They dwell in small hamlets or villages, and their main activity and income are derived from agriculture and livestock (López Delgado, 2011). Rural populations in Latin America tend to be sparse and irregularly distributed. The study areas have extended, unpopulated areas, primarily devoted to agriculture and livestock.

Study area

Thermal levels and climatic characteristics

Colombia, due to its topography, spans a variety of climates: hot tropical climate in the flatlands and coastal areas up to glacial areas on the Andes mountain ranges and the Sierra Nevada de Santa Marta. The Andes are split into three basic ranges: Oriental, Central and Occidental, which can be vertically classified into different "thermal" levels, with characteristic climates and ecosystems. The thermal levels considered are all above 1000 m a.s.l.

The lowest level is the temperate or "middle thermal" level (from now on temperate level). It basically spans the 1000–2000 m a.s.l. height range with temperatures between 17°C (minima) and 27°C (maxima). Temperatures are fairly stable year round. Annual precipitations average 2000–2500 mm, with peaks during April–May and October–November. A maximum in sunshine duration (given in total number of hours per month with clear skies and direct sunlight) occurs in January with near 170 h, while, as expected, minima occur during the wet periods with less than 120 h.

The next level is the cold "thermal" level between 2000 and 3000 m a.s.l. (from now on cold level). This is the level

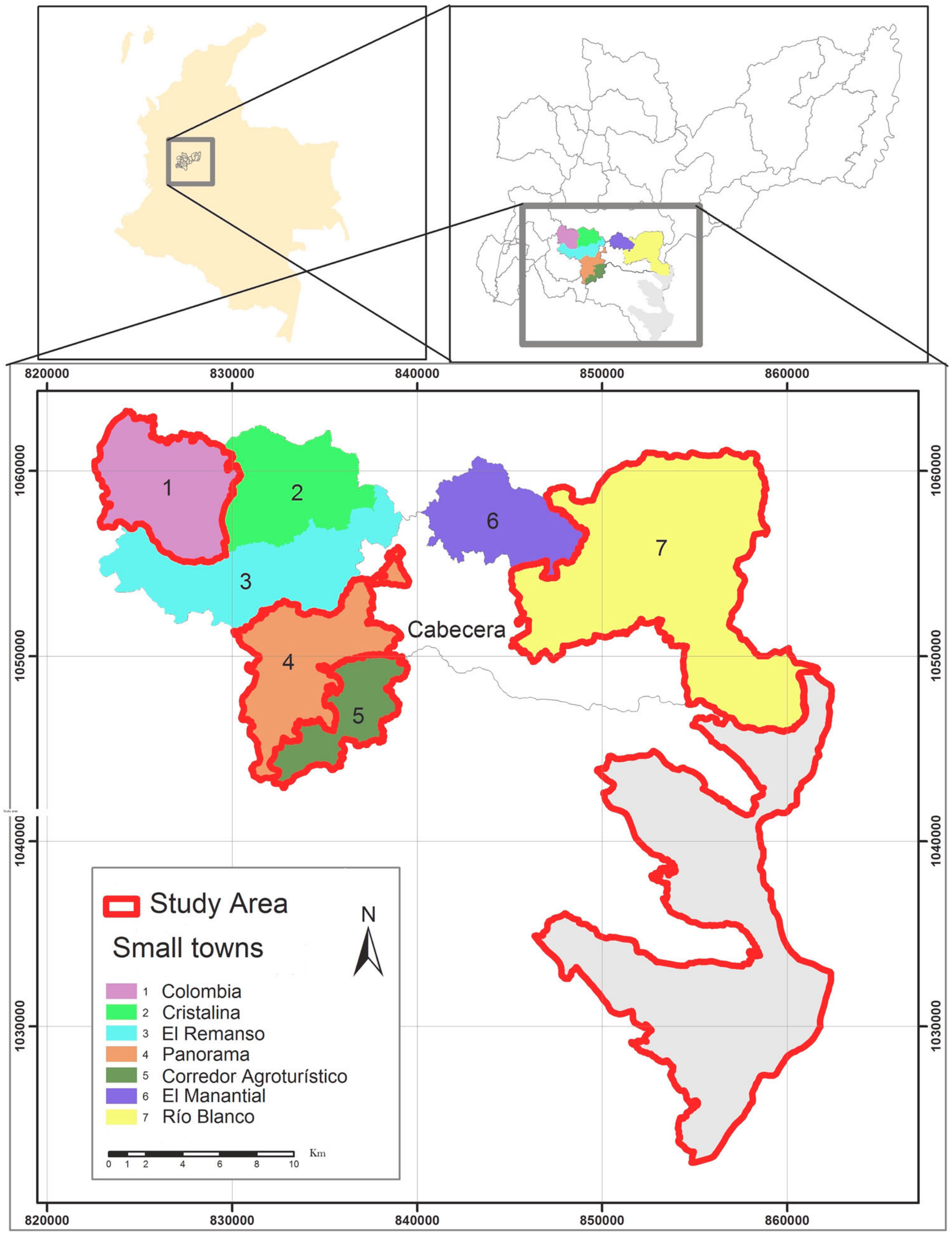

Figure 1. Map of Colombia, the Caldas Department, Manizales Municipality and the corregimientos showing the locations of the latter within the Municipality, Caldas Department and Colombia. Plotted by Diego Arango Arcilla, Instituto Geográfico Agustín Codazzi, Colombia. Author / Instituto geográfico Agustín Codazzi

of Andean or cloud forest. The daily temperature lies between 10°C and 17°C, with very limited annual variability, that is, less than 1°C for the daily minimum and 1.5°C for the daily maximum. Precipitation is similar to the temperate level, that is, about 2000 mm per year with peak during March, April, October and November. Sunlight duration is somewhat smaller with 110 h per month during the wet seasons and 155 h per month during January.

The third "thermal" level is the moorland and glacial zone "thermal" level, 3000 m a.s.l. and above. This level, from now on moorland-glacial level, is characterized by cold winds, scanty rainfall and frequent snowfalls. Minimum temperatures are below 0°C during most months and the highest maxima occur in November (10° C) and May (12°C) approximately. Precipitation, which varies between 69 mm per month and 189 mm per month at these heights, also has maxima in April–May and October–November. Sunshine duration is much reduced, with 42 h per month for April and November and 110 h per month during July and January.

Figure 2 shows the climatology of maximum and minimum temperatures, precipitation and sunshine of

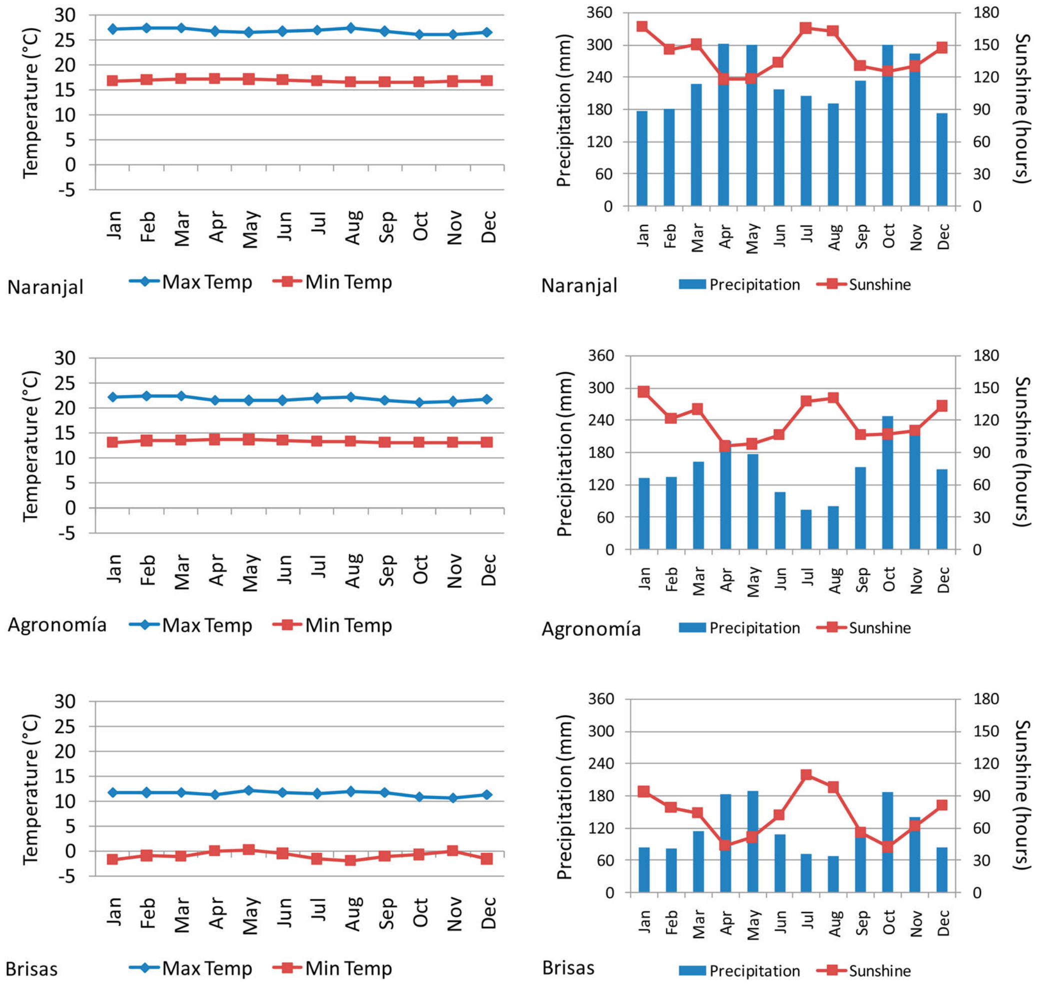

Figure 2. Monthly climatology of the temperate (a–b), cold (c–d) and moorland-glacial (e–f) levels (Naranjal, Agronomia and Brisas stations). Left panel: minimum and maximum temperature (°C). Right panel: precipitation (mm, left axis) and sunshine (hours, right axis).

selected meteorological stations from each level, according to the available data for the period 1982–2006. The data belong to weather stations operated by IDEAM and CENICAFÉ (Centro Nacional de Investigaciones del Café). These stations are Naranjal (1400 m a.s.l.) for the temperate level, Agronomía (2627 m a.s.l.) for the cold level and Brisas (4050 m a.s.l.) for the moorland-glacial level. The regional climate's tropical nature is visible in this figure, with fairly stable maxima and minima temperature throughout the year. There are two rainy seasons: April–May and October–November. A dry season in July–August is present at the moorland-glacial level, while fairly similar precipitation minima occur during solstices at the other two levels.

The main driver of interannual climate variability in Colombia is the equatorial Pacific Ocean El Niño – Southern Oscillation (ENSO) cycle. In the Colombian Andes, El Niño (La Niña) results in drier (wetter) than normal seasonal cycles and longer dry (wet) seasons (Poveda, Alvarez, & Rueda, 2011).

Territorial distribution

The rural areas of the Municipio de Manizales comprise two main territorial entities:

(a) Veredas (sidewalks): These refer to paths or roads along which families settled and built a hamlet which can be either sparse or compact. This is the smallest formal state unit within municipalities, with territorial, social and economic structures.

(b) Corregimiento (small town): These are the intermediate territorial units, between veredas and municipalities. They are divisions within municipal territories with Consejos Municipales (Municipal Councils), whose function is to improve available services and ensure citizens' involvement in local public affairs.

This study includes a number of veredas in the rural areas of selected Manizales corregimientos. Each of the corregimientos has specific characteristics and agricultural aptitudes, depending on topography and climate. The following corregimientos were included:

(i) Corregimiento Panorama: It is located along the south-western border of the Municipality, in the temperate level. Its topography alternates between steep slopes and undulating ground. The main agricultural activities are coffee (covering 71% of the territory), plantain, cane, forestry, pastures and annual cultivars (yucca, beans, tomato and corn) spanning 26% of the territory. The land is subdivided into small holdings, mostly run by the owners. Coffee-growing is the main economic activity. Panorama has basic infrastructure (roads, schools and health centres) which is one of its main assets.

(ii) Corregimiento Corredor Agroturístico: It is located along the southern border of the Municipality, in the temperate level. It has an abrupt terrain with 25–45% slopes. Its main produce is coffee, representing 66% of the land use, and annual cultivars (yucca, beans, corn and tomato), as well as orange and banana, which occupy 6% of the territory. The holdings are usually less than 5 hectares, the largest one not exceeding 50 hectares. This is the smallest corregimiento in Manizales, with the largest population density. Coffee is primarily grown in small holdings. It has reasonable education, health services and a road network which links urban and rural areas.

(iii) Corregimiento El Manantial: It is located to the north of the Municipality, between the temperate and cold levels. It has a steep topography, with slopes greater than 50%, which suffer laminar erosion and are prone to the formation of gullies. The main agricultural activities are coffee, banana, plantain and vegetables. Forestry is an important activity. It also hosts ecological tourism.

(iv) Corregimiento Rio Blanco: On the eastern region of the Municipality, it spans cold and the moorland-glacial levels. It has a steep topography, often with sheer slopes, prone to erosion. Population is small and scattered, with limited accessibility, particularly under bad weather conditions. Land use is primarily distributed between grassland (71%) and forests (23%). Main agricultural activities are potato farming and milk cowherds. Forestry is another important activity. Land uses in this corregimiento are primarily sizeable land holdings and conservation areas. Tourism is also important.

The moorland-glacial thermal level was mostly sampled within the limits of Parque Nacional Natural Los Nevados (National Park Los Nevados) within the territory of the Municipalidad de Villamaría.

In most cases, the rural population has limited formal education, being primarily trained for agricultural work. Their economy is a subsistence one. Coffee-growing is mostly in the hands of small landowners, the family being the main labour source. Coffee grown for commercial purposes side by side with subsistence crops is essential for family sustainment. These small units carry out an intensive use of available soils, following traditional practices together with advice provided by agrarian technicians from various state organizations. While these small units represent most of the land usage, there are some larger undertakings, exclusively devoted to commercial coffee production.

Climate data analysis

In order to analyse temporal variability of temperature and precipitation in the region, trend estimates were carried out for the annual time series from selected meteorological stations at each level, using a linear function least-square fit. A 2-tailed T Student test was applied to determine the significance of the resulting correlation coefficient R at the 95% level. In order to assess possible causes of precipitation variability, in particular ENSO effects, a 3-year moving average smoothing was carried out. Then, strong La Niña years were highlighted using both the Oceanic Niño Index (ONI) and the Multivariate ENSO Index (MEI) as reference.

Field survey

The perception survey design for local rural population sampling needs to satisfy three basic objectives: use survey criteria which take into account both the population's educational level and their strong ties to the local environment, sample the local populations at each thermal level so that all those responding to the questionnaire face similar socio-economic conditions and choose the households participating in the survey so that the conclusions obtained are representative of the study area communities. The choice of survey participants must be made such that as many as possible who have lived 10 years or more at the same location are included. In practice most of those interviewed lived 20 years or more in the area.

The corregimientos differ in accessibility conditions, population size and distribution. This constrains the rural population sample size available for the survey. In consequence, the survey was designed as a non-probabilistic judgement or qualitative survey (Pérez-Tejada, 2008). Such a survey is characterized by the choice of sample size and basic sampling criteria by the researcher. Following Cantrell (1996), the choice of sample must be such that the chosen samples are representative for the topic of the survey and credible and that the survey can be carried out in a timely fashion. The basic hypothesis underlying this approach is that while the sample may be of limited size, correct design and procedure will result in a representative set of conclusions. The small and sparsely distributed rural population, particularly in the upper thermal levels, required such a survey. Similar small sample surveys for perception studies on climate and other environmental issues have successfully been carried out in other countries, for example, Australia (Buys et al., 2012), Spain (Oltra, Sola, Sala, Prados, & Gamero, 2009) and México (Sánchez Cortéz & Lazos Chavero, 2011), among others.

The field study applied structured and semi-structured interviews. Popular knowledge was considered a key issue in the questionnaire design. Local residents are aware of changes in biodiversity and their agricultural products which they appear to associate with climate changes. Another issue relevant to survey design is how the inhabitants rely both on popular knowledge for agricultural practices together with technical assistance they obtain from government agencies. Furthermore, the survey evaluated how they have adapted to the perceived climate variability or changes, both in their daily lives and productive activities, and whether such adaptation has been spontaneous or planned. Further details related to the survey can be seen in Giraldo Vieira (2014).

The Manizales Municipal Council for Rural Development provided means of transportation, to access the different veredas. In the field, their technicians well acquainted with the study area and local residents provided invaluable help and direct interactions with residents according to the required segmentation and social characteristics. In the moorland-glacial level, help was provided by the authorities of National Park Los Nevados and Asdeguías, the regional tourist operator. A major difficulty during the survey was the limited accessibility to many of the veredas due to the steep topography and the lack of rural roads. Many visits required 4-wheel drive vehicles in order to get through dirt or grave roads with scant maintenance so as to be able to reach the veredas and specific fincas (farms). Within the National Park Los Nevados, in the area of the Nevado del Ruiz and El Cisne interviews required, after dangerous mountain drives, a further 3 h (on average) walk to the selected fincas.

Questionnaires were completed during interviews during which the language was adapted to the local rural terminology so that interviewees would feel more at ease. During each meeting, not only did the houseowner participate, but also family members and neighbours. Their contributions were considered independent when they provided new independent and valuable insights. Thirty-seven households were thus interviewed between November 2008 and January 2009.

A number of officials and technicians working in the Municipality and regional corporations such as Aguas de Manizales (mixed capital regional water management company) and Corpocaldas (autonomous corporation for natural resources and environmental management of the Caldas Department) also provided insights regarding the technical support provided in the study area.

Results and discussion

Climate variability analysis

Figure 3 shows the temporal evolution of the annual mean for the selected climate variables and their trends. Minimum temperature is the variable which yielded the largest trends, significant at all three stations (Figure 3(a), (c) and (e)). At Naranjal (temperate level, Figure 3(a)) the trend over the whole sample available is 0.25°C/decade (1956–2007), while at Agronomía (cold level, Figure 3 (c)) it is 0.12°C/decade (1956–2005); that is, a larger minimum temperature increase is observed at the temperate level. Mayorga, Hurtado, and Benavides (2011) reported significant changes at Naranjal but not at Agronomía, but do not provide the sample. When the common 1982–2006 period is considered, that is, when all three stations have data, larger trends are obtained: 0.32°C/decade at Naranjal and 0.22°C/decade at Agronomía. At Brisas (the moorland-glacial level, Figure 3(e)), a significant 0.65°C/decade increase in minimum temperature is observed.

Annual mean temperature maxima yield significant trends at Brisas. At Agronomía, a weak 0.15°C/decade significant trend was also observed. Over the common period Brisas yields an impressive 1.1°C/decade; hence, the daily range has increased. Present results agree with previous studies which show that temperature trends in the Andes increase both with height and closeness to the tropics (e.g. Falvey & Garreaud, 2009).

No significant trends for precipitation were obtained over the common period 1982–2006. However, large variability was observed. Mayorga et al. (2011), in a temperature and precipitation study of Colombian climatological data sets, obtained a significant precipitation increase (9 mm/year/decade) for Naranjal station over the period 1970–2010, while Agronomía observations yielded a −11.7 mm/year/decade decrease for the same period. At Brisas, it was reported a −2.8 mm/year/decade trend over the same period. Due to the large interannual precipitation variability, changes in a given choice of trend estimate period can significantly impact these. IPCC (2013) does not show significant changes in the region for the period 1901–2010. It must be noted that the Andean region of Colombia suffered prominent impacts of a La Niña event in 2007–2008, with precipitation enhancements in the study area (IAvH, IDEAM, IIAP, INVEMAR, & SINCHI, 2011). When the social survey was carried out, this was a very recent event. A closer inspection on the occurrence of ENSO events, as given by ONI and MEI shows that La Niña events affect precipitation at all three stations. Strong La Nina events are

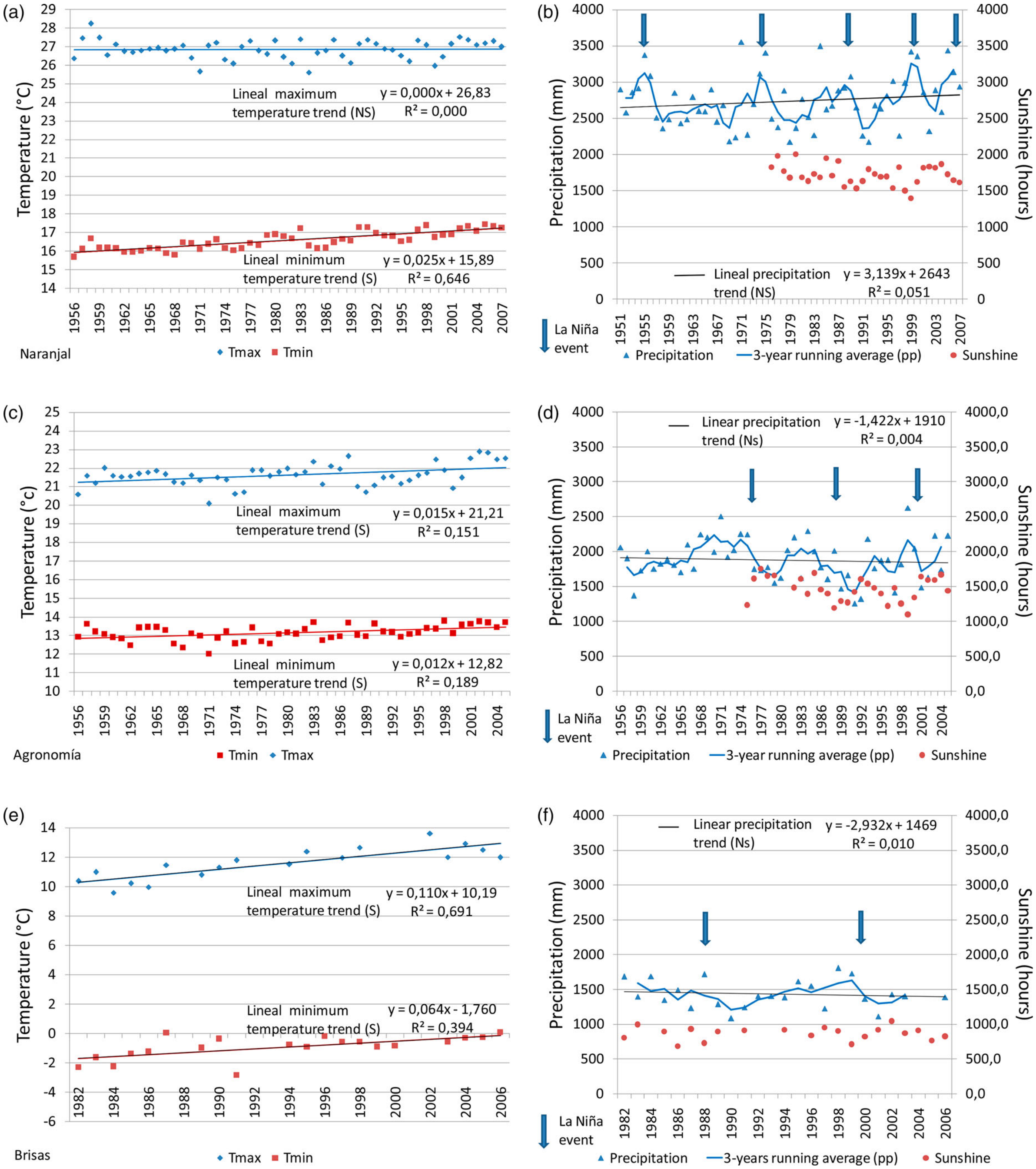

Figure 3. Left panel: temporal evolution of minimum and maximum temperatures (°C). Right panel: precipitation and its 3-year moving average (mm, left axis) and sunshine (hours, right axis) at Naranjal (a–b), Agronomía (c–d) and Brisas (e–f). Lines show trend estimates. Significant trends for minimum temperatures 0.25°C/decade (Naranjal), 0.12°/decade (Agronomía) 0.65°/decade (Brisas) for the total period available at each station. Significant trend for maximum temperature at Brisas 1.1°C/decade. Strong La Niña events are highlighted.

highlighted in Figure 3(b), (d) and (f). The largest La Niña-related enhancements are found at Naranjal.

Finally, sunshine hour trend estimates did not yield conclusive results. Minor non-significant decreases were obtained for Naranjal and Agronomía. that is, a minor cloudiness enhancement. Such results, however, could also be due to large amounts of missing data, particularly at Brisas.

Climate perception

For rural populations, climate variability and change have very specific dimensions, through atmospheric variables that most affect their livelihood and daily activities. How temperature and precipitation evolve is particularly relevant to them. In the steep mountain areas of Manizales, erosion, mudslides, floods and droughts are significant consequences of such changes. Nevertheless, an understanding of abstract concepts of climate change and variability was in most of the survey respondents very limited or non-existent. Their perception in principle is not "tainted" by outside information. Only the rural inhabitants within the limits of the national park, in the moorland-glacial level, have a better understanding of the concept, given that they have strong evidence of glacial retreat and other environmental changes, together with continuous interaction with park officials.

Rural populations have well-established practices and a strong intuitive understanding of their environment and climate, and how they relate to each other, which they use to the best of their ability to produce most if not all they need for livelihood (FAO, 2010). One important cultural perception expression, within this framework, that climate is changing is that many respondents, particularly from the cold level, stated that the "cabañuelas" are no longer respected. The "cabañuelas" (small cabins) is a traditional belief, which originated in Spain and extended to many Latin American countries. It still survives in México, Central America and Colombia. The belief in essence considers that the weather during each of the first 12 days of the year describes the expected characteristic weather during each of the 12 months of that year. Hence a rainy January 3rd implies March will have more rain than usual, while a dry, sunny January 7th implies a sunny drier July. While no scientific evidence whatsoever supports such a belief, rural populations still plan their agricultural activities for the year using this long-term "forecast". During the survey, many argued that this used to work years ago, but now things have changed and that such predictions no longer work. Within limits, this would imply that they perceive a real change in the variability of the local climate system.

A further cultural aspect present in the perception of the moorland-glacial level inhabitants is that they have to abandon their traditional dress. One particular item, the *ruana*, a thick woollen cloak which protects from strong, cold mountain winds and rain, is used less and less, they point out as a result of weaker winds and warmer temperatures. Thus, these two direct perceptions based on impacts on traditional culture show that overall the rural population in the study area is aware that something is happening with climate that is impacting their lives.

Figure 4(a) shows the perception of change in three climate variables: temperature, precipitation and wind. In the temperate level, more than 80% replied that temperatures had increased, while in the cold level one-third said so, but two-thirds considered temperatures had decreased. In the moorland-glacial level, all agreed temperatures had increased, in agreement with comments on the clothing changes. When asked about rainfall, at the temperate and cold levels there was 100% agreement that precipitation has increased. At the upper level, approximately two-thirds of the interviewees considered that precipitation had increased, while the remaining third considered that it had decreased. Finally, when asked about wind changes, responses were more varied. In the temperate level two-thirds considered they were stronger, while the rest either considered they had decreased or remained the same. At the cold level, only 20% thought the winds were stronger, while the rest were equally split between no changes and weaker winds. In the moorland-glacial level, 80% agreed that the winds were not as cold or as strong as they used to be.

Figure 4(b) shows the perception of change in local/regional processes which could be associated with climate variability or change. These are soil erosion, river flows and drought. Soil erosion, due to enhanced rainfall in areas with steep topography resulting in minor or major landslides, is an important feature of the Tropical Andes, linked to the distinct seasonal tropical precipitation cycle. Such landslides can have enormous costs in lives, assets and the surrounding agricultural lands. River flows and excessive runoff can also deteriorate lands along riverbanks or develop deep gullies that affect the value of agricultural soils. These impacts related with climate represent important issues for local inhabitants.

The perception that erosion has increased is overwhelming, being 100% in the first two levels, and almost all the respondents in the moorland-glacial level considered erosion was increasing. Regarding river flows, 80% of the temperate level interviewees perceived enhancements, while 50% of the cold level inhabitants perceived increases and the rest considered that either the flow had decreased or was the same. In the upper level, 80% considered that river flows were decreasing and only 20% said the opposite.

In the temperate level, about half considered droughts were increasing, while about 30% said they were decreasing and the remainder that they were the same. In the cold level, approximately 50% perceived a decrease in drought occurrence, 25% an increase and 25% no changes. In the moorland-glacial level, 70% considered that droughts were more frequent and 30% that they were less frequent.

Comparison between climate perception and climate analyses

The climate analyses and the inhabitants' answers on climate variability show that the perception of the temperate and moorland-glacial inhabitants agrees well with the observed increase in annual mean temperatures, both maxima and minima. In the cold level, however, the local population actually perceived a cooling, while the increases in minima and maxima remain stable. This level underwent smallest changes, with limited impact on daily range compared to the other two levels. At the moorland-glacial level, temperature changes resulted in a warmer climate and an increased diurnal temperature range, which agrees well

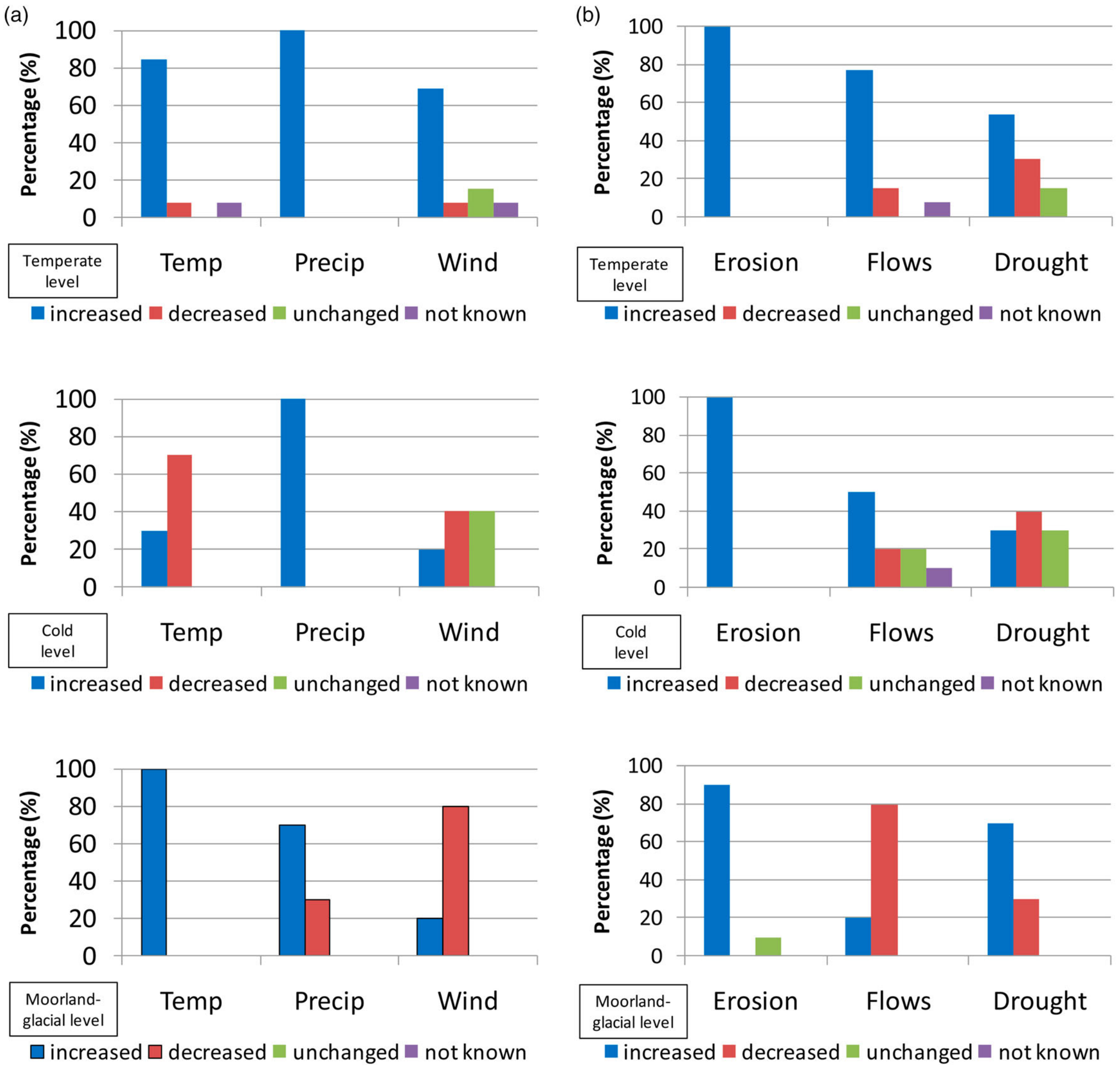

Figure 4. Results of climate perception survey at each thermal level (in percentage of interviewees), a) perception of change in climate variables b) perception of change in climate impacts. Upper panel: temperate level. Middle panel: cold level. Low panel: moorland-glacial level.

with clothing changes the inhabitants stated. Given that sunshine hours relate to an inverse change in cloudiness, increases in sunshine hours would help understand such differences in perception. Indeed, limited temperature changes with enhanced cloudiness could be locally perceived as cooling, while sunshine enhancements may be perceived as a warmer climate. Nevertheless, available sunshine hours data sets do not provide conclusive results.

Precipitation perception suggests that perception may be biased by recent important episodes such as the enhanced precipitation during the 2007–2008 La Niña event, since no distinct trends were obtained in the common period, while other studies with longer samples do yield trends of different signs. Even these values represent comparatively small changes, considering the local climatologies, embedded in precipitation series modulated by ENSO. Long-term ENSO variability may only be perceived by few long-term residents, since La Niña events were mostly weak and few between 1976 and 1998. The monthly mean data used in this study do not allow the analysis of a further aspect, which are changes in the way precipitation occurs, that is, changes in precipitation intensity which can also influence local perception even though the mean monthly values will not yield significant trends or only weak ones. Hansen, Sato, and Ruedy (2012) similarly noted the impact of recent severe events on climate change perception in the USA using results of a perception survey (Borick & Rabe, 2012).

Perception of impacts on biodiversity and agriculture

The rural population at all three levels is aware of the rich biodiversity surrounding them. For example, temperate level population recognized 24 different indigenous bird species, cold level interviewees 34, while moorland-glacial level ones 18. They also noticed population reductions or disappearance of wild bean and tomato varieties. Almost half of those interviewed recognized the appearance of new species in all biodiversity categories as well as population decreases or disappearance of some species for all visible life forms. In the moorland-glacial level, the recent appearance of butterflies, common to the cold level, was mentioned by many. Due to the limited climate variability of the tropics, changes in temperatures as those observed here can significantly impact tropical ecosystems (Mahlstein et al., 2011, 2012). Some of these changes, for example, butterfly migration into the moorland-glacial level, could result from the observed temperature increases, but many biodiversity changes perceived in the different levels may not necessarily occur in direct response to climate change. A detailed analysis regarding biodiversity changes perceived at each level is currently beyond the scope of this study, in particular since some of these perceptions could result from environmental processes not necessarily linked to climate processes, for example, land-use changes, pollution and soil degradation.

There is overall agreement that changes are affecting their agricultural activities. They noted changes in colour and size of some traditional crops and surrounding vegetation as well as a reduction in yields, both coffee and staples. Oranges and avocados appear to yield smaller fruits. In all three levels, the respondents recognized between 20 and 40 different pest varieties affecting their crops. The largest number of new or enhanced pests corresponds to the cold level. Farmers from the cold and moorland-glacial levels highlighted their concern about pests and diseases increasingly impacting their cultivars. Among the staples affected by different pests, beans are perceived to be particularly at risk by all interviewees. Crop loss and reduced quality are affecting the farmers both in their staple diet and economy, through lower yields and lower quality, unmarketable produce. In most cases, producers stated concerns about the costs of facing this growing challenge to their livelihoods. Changes in the quality of produce, adapted to the limited regional climate variability, could indeed suffer from temperature changes. Such changes can not only impact growth and quality, but also alter pest impacts. While no significant precipitation trends were detected, the impact of severe events as those associated with La Niña event previously mentioned may have influenced pests and disease impacts, and hence appears prominently in local perception. Impacts from other environmental changes occurring in the region, however, need to be considered for a full assessment.

Adaptation strategies

The changes rural populations note, despite some differences in climate variability and change perception, are of such entity that they stated they had to adapt to them, be it trends or recent severe weather. Clothing changes in the moorland-glacial level exemplifies spontaneous adaptation to a long-term temperature trend. The ways in which the population responds to change at each thermal level are different.

Erosion and flooding

The temperate level inhabitants are the most concerned about strategies to mitigate erosion, land slides and flooding. Such problems may be the result of a combination of factors and not just climate change, that is, recent severe weather, bad land-use practices which destabilized topsoils, etc. Frequent strategies comprise forestation/reforestation, improved soil cover with indigenous and foreign species. A traditional approach is to reduce the speed of running water with rocks, particularly in gullies, and the construction/clearing/improvement of drainage ditches to channel the water, protecting topsoil and river basins. In the moorland-glacial level, the main strategy is soil coverage improvement using native plants and recovery of natural underbrush. However, cold level inhabitants did not consider the need to implement strategies for these impacts.

Biodiversity changes

Temperate level inhabitants are the only ones who mentioned asking for technical assistance to manage vegetation changes and diseases/pests affecting them. Technical assistance request at this level can be considered as their primary approach to adaptation. Some follow the recommendations on agrochemical use made by the Comité de Cafeteros (Coffee Growers' Committee). Some interviewees stated that they try to use less agrochemicals and more natural approaches, such as composting and biological controls. Insects, in particular borers, impacting coffee plantations are controlled by hand clearing the parcels, thus removing weeds which are their habitat. Others nevertheless note that they have increased insecticides, fungicides and herbicides applications to protect their fields. They also manufacture traditional insecticides; for example, for ants, mixing ashes, onion and rotten oranges. They are improving/building greenhouses and promoting the development of community orchards and vegetable gardens for their food crops. These community activities are jointly coordinated by all participants in an attempt to improve crop quality as well as to enhance income through their produce. They fertilize with pig manure and agricultural residue. Some try to access improved seeds, better adapted to the current growing conditions, and use vegetation to protect the plantations. Another option is to anticipate harvests as soon as the produce is ready, to limit the loss by new or enlarged populations of species that eat their crops, such as squirrels and parrots.

In the cold level, most inhabitants stated that they had to use more chemicals to protect their fields, that is, an enhanced use of chemical fertilizers and manure. The intensive use of agrochemicals nevertheless impacted the rural economy, in particular of small farmers. Many are now resorting to traditional pest controllers such as mashed nettles and other local plants, together with soap diluted in water. To improve soil quality, they are introducing the Californian worm. They have increased reforestation in different parts of the study area. Nevertheless, the overall perception of those interviewed is that not much can be done to limit insects and other pests impacting their crops.

Moorland-glacial producers describe themselves as more concerned about conservation, given that much of their land lies within the boundaries of a national park. Hence, they try to avoid cutting native plants and promote reforestation. They use greenhouses to facilitate the growth of native specimens which are then reintroduced in natural areas, as well as non-native trees for reforestation elsewhere. Regarding agricultural activities, they stated that they are considering the use of seeds better adapted to new climate and soil conditions. Some have requested technical assistance to analyse the soil in their fields. Potato producers are particularly affected by an increase in pests affecting this crop. At this level, despite considering the need for environment-friendly practices within or near the national park, they stated that they use chemicals to reduce the impacts of insects, fungi and other pests. Nevertheless, they added that they are concerned about this. In this level as well as the cold level, many farmers have decided to abandon their traditional crops in favour of livestock, which is easier to manage under variable conditions, or work for companies dedicated to reforestation.

In order to protect the native fauna, in particular birds, some temperate level inhabitants have installed bird feeders around their homes. Others try to prevent hunters from coming into their veredas or corregimientos. Cold level population showed limited concern regarding the fate of native fauna, nor much concern for the appearance of new species. Their main concern is that such changes did not impact their rural activities. The moorland-glacial level population is much more concerned about the changes in the local fauna and many are active in educating the local population and tourists visiting the area on regional biodiversity and conservation practices. While they actively interact with the park authorities and conservation NGOs, 50% of those interviewed argue that they are not getting the technical support they request to carry out such activities.

Thus, in most cases the way in which rural populations of the three thermals are facing climate and environmental change challenges is basically spontaneous adaptation. They recognize having received some form of technical assistance or environmental advice, in the temperate and moorland-glacial levels, but not in the cold level.

Education on climate change and productive processes

In order to develop adaptation beyond spontaneous adaptation, it is important to promote education on the main aspects of climate change as well as relevant potential regional and local impacts. This is particularly relevant for rural populations. Specific questions about climate change education were included in the survey. In agreement with replies regarding adaptation strategies, cold level interviewees stated that they had received no education about climate change. Even in the temperate and moorland-glacial levels, a limited number of inhabitants acknowledged that they received some kind of information. In the first level, information was provided by coffee grower societies, while in the upper level information came from park officials.

Regarding soil erosion and flooding (Figure 5), less than 20% of those interviewed in the temperate and cold

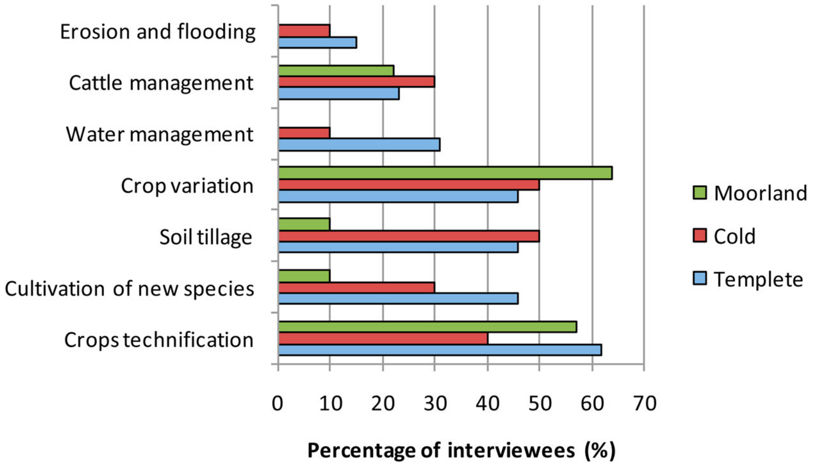

Figure 5. Technical support received to face the various challenges and needs declared during the interviews (in percentage of interviewees).

levels, none in the upper level, acknowledged receiving education about managing these issues. A related issue, water management education, linked to agriculture appears to be better catered, with 30% of temperate level interviewees having received information on this issue. All other issues, soil management, new crop introduction and crop management and crop technologies, appear to be far better off, since they are all linked to the local livelihoods and economies. As can be observed in Figure 5, for most of these topics positive responses are between 30% and 60% in the temperate and cold levels, with a wider range in the moorland-glacial level. This is primarily due to the information activities and technical support provided by the Comité de Cafeteros and UMATA (Municipal Farming Technical Assistance Unit).

The inhabitants of the first two thermal levels nevertheless considered that the information on erosion, water and livestock managements was scant at best, and they basically had to "fend for themselves" to handle such problems. The moorland-glacial population considered themselves self-sufficient on these issues.

Concluding remarks

The present study shows that in the vicinity of Manizales, Colombia, rural populations spanning three thermal levels, with different ecosystems and productive activities, are aware that environmental and climate conditions are changing, albeit with some differences between levels. The cold thermal level population showed the least concern about environmental change. Except in the upper moorland-glacial level, awareness and response to changes seem predominantly spontaneous, based on traditional customs and abilities, with limited knowledge or access to knowledge on the main environmental issues and techniques to face new challenges. Some technologies to protect or improve agriculture, such as the use of chemical fertilizers and pest controls, are being introduced, apparently with some technical support, in particular in the coffee production sector, but the costs may be too high for the rural producers to support their use over time.

A basic climatological analysis shows that significant changes to the climate system are found with temperature increases, particularly at minimum temperatures. As expected, changes are largest in the upper thermal level. However, changes in precipitation are not significant. Perceptions related with precipitation, at all levels, appear to be influenced by recent ENSO variability processes, in particular a 2007–2008 La Niña event that took place shortly before the survey.

Some of the perceived impacts on lifestyle, agriculture and the surrounding environment reported during the survey could be due to significant temperature increases. Other changes may not be directly linked to climate change processes, occurring in response to other environmental change drivers such as land-use changes, deforestation and bad agricultural practices.

While public and private organizations appear to be active in educating rural populations, either on climate/environmental processes or production improvements, the population's overall perception is that they are not receiving information and support necessary to face the challenges from changes they perceive in their surroundings and livelihoods. This could imply that the services provided by these organizations are either insufficient or require to be better planned and delivered to satisfy the needs of the rural population.

Disclosure statement

No potential conflict of interest was reported by the authors.

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