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CLIMATE CHANGE

ABYA YALA UNIVERSIDAD POLITÉCNICA SALESIANA

Climate Change according to Ecuadorian academics–Perceptions versus facts

Cambio Climático según los académicos ecuatorianos - Percepciones versus hechos

Theofilos Toulkeridis*[1], Elizabeth Tamayo[1], Débora Simón-Baile[1], María J. Merizalde-Mora[1], Diego F. Reyes-Yunga[1], Mauricio Viera-Torres[1] and Marco Heredia[2]

[1] *Universidad de las Fuerzas Armadas, ESPE. Av. General Rumiñahui s/n y Ambato, Sangolquí, Ecuador.*
[2] *Ciencias Ambientales. Universidad Estatal Amazónica, Km* 2 1/2 *vía Puyo-Tena (Paso Lateral), Puyo, Ecuador.*

*Corresponding author: ttoulkeridis@espe.edu.ec

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Resumen

El cambio climático se ha convertido en uno de los temas principales en las agendas en diferentes países. Los efectos actuales requieren de acciones climáticas efectivas ya establecidas en el Acuerdo de París con el objetivo de reducir las emisiones de gases de efecto invernadero. Sin embargo, los principales cambios para enfrentar y reducir el cambio climático dependen de las decisiones de cada país y no sólo de los acuerdos mundiales, ya que los impactos y magnitudes varían localmente. Uno de los componentes clave para una mejora efectiva es el papel que el comportamiento de la población puede tener sobre la política nacional y las decisiones posteriores. Por esta razón, el nivel de conciencia y conocimiento sobre el cambio climático es vital. El objetivo de la investigación fue comparar la percepción de los académicos ecuatorianos sobre el cambio climático global y nacional con la evidencia científica y los hechos históricos, y cómo su vulnerabilidad puede afectar a los efectos del cambio climático. Los resultados muestran que los académicos ecuatorianos están conscientes de los hechos ocurridos mundialmente sobre el cambio climático, como la existencia, la gravedad y la responsabilidad de los seres humanos. Sin embargo, hay un conocimiento limitado sobre el origen del problema, ya que el 67,2% cree que este es el primer cambio climático en la historia de la humanidad. Los principales efectos del cambio climático en Ecuador presentan percepciones heterogéneas, como sequías más frecuentes (34,36%) y lluvias escasas pero intensas (21,41%) como sus mayores preocupaciones. En cuanto a las regiones más afectadas en Ecuador, las sierra y los valles interandinos representan el 45,6%, mientras que Galápagos sólo alcanza 1,6% a pesar de ser una insignia ecológica con alta vulnerabilidad climática. Parece que los encuestados carecen de conocimiento sobre la situación en otras regiones y creen que su propio entorno se ve más afectado.

Palabras clave: cambio climático, calentamiento global, vulnerabilidad, desastres, ecosistemas, paleoclimatología.

Abstract

Climate change has become one of the main issues in the countries government agendas. The current effects demand effective climate actions which were set out in the Paris Agreement with the global goal of reducing greenhouse gas emissions. However, the main changes to face and mitigate climate change depend on each countrys decisions and not only on global agreements as the impacts and its magnitudes vary locally. One of the key components for an effective adaption and mitigation is the role that the behavior of the population may have over national politics and subsequent decisions. For this reason, the level of awareness and knowledge about climate change is vital. . The objective of the current study was to compare the perception of Ecuadorian academics regarding global and national climate change with the scientific evidence and historical facts, and how it may affect their vulnerability to the climate change effects. The results show that Ecuadorian academics are well aware of globally known facts of climate change such as existence, gravity and responsibility of humans. However, there is limited awareness about the origin, since 67.2% believes that this is the first climate change in human history. The main effects of climate change in Ecuador exhibit heterogeneous perceptions, with the more frequent droughts (34.36%) and rarer but more intense rains (21.41%) as their greater concerns. Regarding the regions more affected in Ecuador, highlands and Inter-Andean valleys sum up 45.6% while Galapagos only reaches 1.6% despite being an ecological flagship with high climate vulnerability. It seems that respondents lack knowledge about the situation in other regions, and believe that their own environment is more impacted.
Keywords: climate change, global warming, vulnerability, disasters, ecosystems, paleoclimatology

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Orcid IDs:
Theofilos Toulkeridis: http://orcid.org/0000-0003-1903-7914
Elizabeth Tamayo: http://orcid.org/0000-0002-7354-9227
Débora Simón-Baile: http://orcid.org/0000-0002-8398-9883
María J. Merizalde-Mora: http://orcid.org/0000-0001-9686-5436
Diego Reyes: http://orcid.org/0000-0002-7792-395X
Mauricio Viera-Torres: http://orcid.org/0000-0001-8888-1866
Marco Heredia: http://orcid.org/0000-0002-6039-3411

1 Introduction

The occurring and potential impacts that climate change has over both nature and societies have converted it into a complex topic to approach if thorough researches and institutional cooperation are not linked (Luterbacher et al., 2004). Although the causes of climate change are globally averaged by the climatic system (UNDP, 2009), they are actually, local, and highly depend on the level of industrialization and habits of consumption of each country. Frequently the data of diverse countries are reported considering the highest emitters of cumulative carbon dioxide. Considering the most recent available data from 2016 (Agency, 2018), the top emitters of total CO_2 are, by far, China with 9056.8 metric megatons (MT), which almost doubles the following being the United States with some 4833.1MT. The USA is followed by India, Russian Federation and Japan. However, if the countries are ranked in terms of the carbon dioxide emissions per capita, instead of the total emissions, the results change dramatically and China, the major emerging economy and most populated country, does not lead the rank any longer. By 2016, the top five countries in the list of CO2 emitters per capita are Saudi Arabia, Australia, USA, Canada and South Korea, with values ranging between 16.3 and 11.6 Metric Tons (T). Hereby, China occupies the 12th place in per capita emissions, with approximately 6.4 T, while India ranks 20, with 1.6 T, ten times less than the average citizen of Saudi Arabia or Australia and, at only 40% of the global average.

These uneven current contributions together with differentiated historical responsibilities for climate change have long been discussed (Rajamani, 2000; Page, 2008; Müller et al., 2009; Baatz, 2013; Friman and Hjerpe, 2015), and are at the core of the challenges the world faces in reaching agreements and achieving commitments in the international climate change negotiations. In a further study it has been discussed the most controversial issue of the Brazilian proposal, which has led to a methodology of calculating shares of responsibility as opposed to the shares in causal contribution considering two conceptions of responsibility being 'strict' or 'limited' (Müller et al., 2009). Other studies focused on specific policy options to compensate those vulnerable to climate change in developing countries, analyzing the applicability of the Beneficiary Pays Principle rather than the Polluter Pays Principle (Baatz, 2013).

In any case, such commitments need to be nationally-tailored, and developing countries should endorse meaningful participation and assume their share while claiming climate justice and compensation for climate change loss and damage (Calliari, 2018; Page and Heyward, 2017). In fact, the developing and poorest countries are facing greater climate change loss and damage because they are at higher risks (Zenghelis, 2006; Mertz et al., 2009; Hedlund et al., 2018). It has been demonstrated that the increase of environmental deterioration through the usage of natural resources is indirectly related to the culture, education, policy decisions, social movements, and economic incomes of each country (Luterbacher et al., 2004). The economic underprivileged people tend to live in areas of even higher risk, re-enforcing the statement that vulnerability is correlated to poverty. For this reason, the socioeconomic inequality and political instability that Latin America faces, added to a multi-hazard geographic location and continuous environmental deterioration in their attempt to reach development, only increases the risks of vulnerability of these regions. Thus, the mitigation of the effects of global and local climate change coincides with the reduction of poverty and social inequalities, the application of sustainable regulation of natural resources, and an in-depth planning that promotes development and reduces risks (Rojas, 2016; Goworek et al., 2018; Furley et al., 2018). Ecuador, in particular, is affected by the regional South American aspects previously mentioned and its specific issues such as socio-economic differences among the Coast, Highlands and Amazon regions, and the way in which energy and soil are being used. Those aspects hence threat the mitigation and adaptation attempts that Ecuador is implementing to face climate change and reduce its impacts (Reuveny, 2007; Buytaert et al., 2010; Luque et al., 2013; Luterbacher et al., 2004).

Scientists have been informing the society about the impacts that our activities are having over the planet during the last decades. The monitoring of different substances started around 32 years ago with the signature of the first protocol after the leaders of the main developed countries realized the impact that humanity had on triggering an irrever-

sible climate change. The first global agreement was the Montreal Protocol, signed on 1987, that aimed to protect the ozone layer by reducing and stopping the usage of the main gases that deplete the layer (Ibárcena and Scheelje, 2003). These gases included the chlorofluorocarbon (CFC) and the hydrochlorofluorocarbon (HCFC) (Manzer, 1990; Prather and Spivakovsky, 1990). The second important agreement was the Kyoto Protocol, which was adopted in 1997 but only entered into force in 2005. It targeted the reduction of the Green House Gases (GHG) such as carbon dioxide (CO_2), el metano (CH_4), nitrous oxideo (N_2O), hydrofluorocarbon (HFC), perfluorocarbons (PFC), sulphur hexafluoride (SF_6) (Prather and Spivakovsky, 1990). Lastly, the most recent protocol is the Paris Agreement, sealed in 2015 and with 185 state parties to date. The Paris Agreement looked out for reducing the carbon emissions in order to keep the upcoming increase of global temperature below de 2°C (Ibárcena and Scheelje, 2003; Enkvist et al., 2007; Van Vuuren et al., 2007; Friel et al., 2009; Hoegh-Guldberg et al., 2018).

As the achievement of a global commitment and support requires a trustworthy source of information about the ongoing changes around the world, the UN Environment Agency and the World Meteorological Organization created the Intergovernmental Panel on Climate Change (IPCC) in 1988. The research that the IPCC has been realizing over the past 25 years has confirmed the severity and undeniable effects of the climate change around the globe. Some of these effects include: the temperature increase of 0.85°C between 1880 – 2014, a sea level rise of 19 cm between 1901 and 2010, the decrease of 1,07 106 km^2 every 10 years of the Arctic ice, the absorption of the thermal energy by the oceans, increase of the greenhouse gases (GHG) in the atmosphere, the increase of 40% CO_2 concentration, the acidification of oceans due to their further absorption of CO_2, the loss of ecosystems, and the longer droughts and intense precipitations (Doney, 2006; McNeil and Matear, 2008; Knapp et al., 2008; Frank et al., 2015; Hoegh-Guldberg et al., 2018). The latest special report presented by the IPCC in 2018 confirms that the principal driver of the current climate change is the anthropogenic unsustainable development thus they propose an immediate reduction of CO_2 emissions to keep the global temperature increase below the 1.5°C (Hoegh-Guldberg et al., 2018).

On the other hand, according to the most recent report by the World Biodiversity Council (IPBES), one million species will be threatened with extinction in the coming years and decades if there are no major changes in land use, environmental protection and mitigation of climate change (on Biodiversity and Services, 2019). Hereby, as the most important factor in the extinction of species, the report names the effects of agriculture. The detailed report indicates that a) some 85 percent of wetlands are already destroyed; b) since the late 19th century, around half of all coral reefs have disappeared; c) Nine percent of all livestock breeds are extinct; d) between 1980 and 2000, 100 million hectares of tropical rainforest were cut down and another 32 million hectares between 2010 and 2015 alone; e) 23 percent of the planet's land is considered to be ecologically degraded and can no longer be used; e) the loss of pollinators threatens food production worth 235 to 577 billion a year; and f) destruction of coastal areas such as mangrove forests threatens the livelihoods of up to 300 million people among other facts (on Biodiversity and Services, 2019).

The local effects of the ongoing climate change implies that each country has to face them in different ways compared to others countries. The risk that Ecuador has to tackle is not only due to the hazards linked to its geographic location along the equatorial line, but also due to its economic and cultural vulnerability, its preparation towards upcoming disasters and the importance of climate change for its society (O'Brien and Wolf, 2010). In order to implement effective mitigation and adaption plans against climate change, cooperation and commitment are needed among multiple actors, mainly, the government as law makers and enforcers, industry, corporations, and population as main GHG emitters, and academia as knowledge producers. In the case of Ecuador, its government ratified the Paris Agreement in 2017, and, later in March 2019 presented its First Nationally determined contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC). While the NDCs are not legally binding, they are subject to required normative expectations of progression Rajamani and Brunnée (2017)and to the evaluation of their progress by technical experts to assess achievement toward the NDC. The NDC is the national plan to reduce national emissions and to adapt to

the impacts of climate change.

In particular, Ecuadors NDC has set the target to reduce GHG emissions by 9% in the sectors of energy, industry, waste and agriculture. Furthermore, Ecuador plans to reduce an additional 4% of GHG emissions in change of land uses, that is, deforestation and land degradation. Regarding adaption to climate change, the Ministry of Environment will incorporate actions in seven sectors being natural and water heritage, health, production, human settlements and agriculture (MAE, 2019). The period of implementation of the NDC is 2020-2025, hence, has not yet started. Then, in 2025, an evaluation will be performed to monitor to what extent the targets were reached. The Ecuadorian government considers that, being a developing country with many socio-economic needs, its NDC is an ambitious yet fair plan to tackle climate change. However, the successful implementation of the Ecuadorian NDC requires the generation of strategic alliances and the financial support, especially from the private sector and international cooperation.

Corporation driven lobbied politics of Climate Change should be rejected and overcome in pursuit of ambtious emission policies. Achieving the commitment of the industry in CC plans is arguably one of the main challenges, yet, these policies should incorporate the industry as a key pole of enforcement by identifying the economic opportunities and mobilizing the co-benefits linked to climate actions such as mitigation and adaptation plans, climate change risks, incentive types, and incentivized stakeholders (Huang-Lachmann et al., 2018; Helgenberger and Jänicke, 2017). In facing the current climate crisis, with the active participation of the different actors, there is a need to shift paradigms: from burden-sharing to opportunity-sharing. In all cases, as efficient policies require scientific bases, the different actors need clear and accurate information from the academics.

Therefore, a survey was performed inquiring Ecuadorian academics about their perceptions and knowledge about the climate change processes and its associated vulnerabilities in the Ecuadorian territory with the objective of comparing those with the facts and evidences about the global climate change occurrence in Ecuador. The long term aim or intention is that the results help to determine the degree of preparation about climate change of a well-educated community of academicis, and how this could contribute to the implementation of measures for mitigation and adaptation to climate change whose success would depend on their daily habits. The link between a well-informed community and adequate policies implementation is missing because it's not necessarily true develop argument and state of the art literature on this respect. In countries where there is a limited interrelation between academia and governmental institutions the "well-informed community" indicator may be inadequate.

2 Methodology and data collection

Considering that there is little research in Ecuador about climate change perceptions (Valdivia et al., 2010; Crona et al., 2013) and misconceptions, the first reason for conducting this survey (Appendix) was to collect quantitative baseline data from a relatively homogeneous population. The second reason was to prove or disprove the hypothesis that people with higher education has a more accurate knowledge about climate change, and are more likely to share common perceptions about climate change, as proposed by Crona2013. The third reason was to use the results of this first survey in the future to monitor changes in the perceptions over time. Furthermore, the survey was conducted along the Ecuadorian highlands with the objective of identifying and measuring possible geographical differences, and asses if they are linked to their degree of affectation. Taking into account that this study focuses on perceptions, the possible methodological approaches were a survey, a case study through qualitative interviews with emphasis on openended questions, or a method mixing both.

Qualitative research is often used to explore poorly known or understood topics or to clarify issues of meaning which is not the case of climate change. It was opted for the survey because the goal was to pursue a quantitative research which includes measurement, comparison and hypothesis testing. Good statistical estimates within quantitative research require a big number of samples or surveyed individuals; hence, in order to reach a larger audience, maximize response rate and still be able to analyze a big amount of data, a simple and

short survey was considered the most adequate approach.

The survey consisted on 14 closed-ended questions in a single sheet, that were based on both global and local appearances of climate change and their respective hazards. The inquired universities are located in four sites of the Ecuadorean Highlands (Fig. 1). A total of 7803 inquiries were administered in person to students and lecturers, from which 56% correspond to the capital, Quito. The fourteen questions have been divided into two main groups, the global and the local effects. The group of global climate change questions consists of knowledge background about phenomenon origin, scope and global manifestations. Meanwhile, the second group con-sists of selected Ecuador-related questions about the local vulnerabilities and issues.

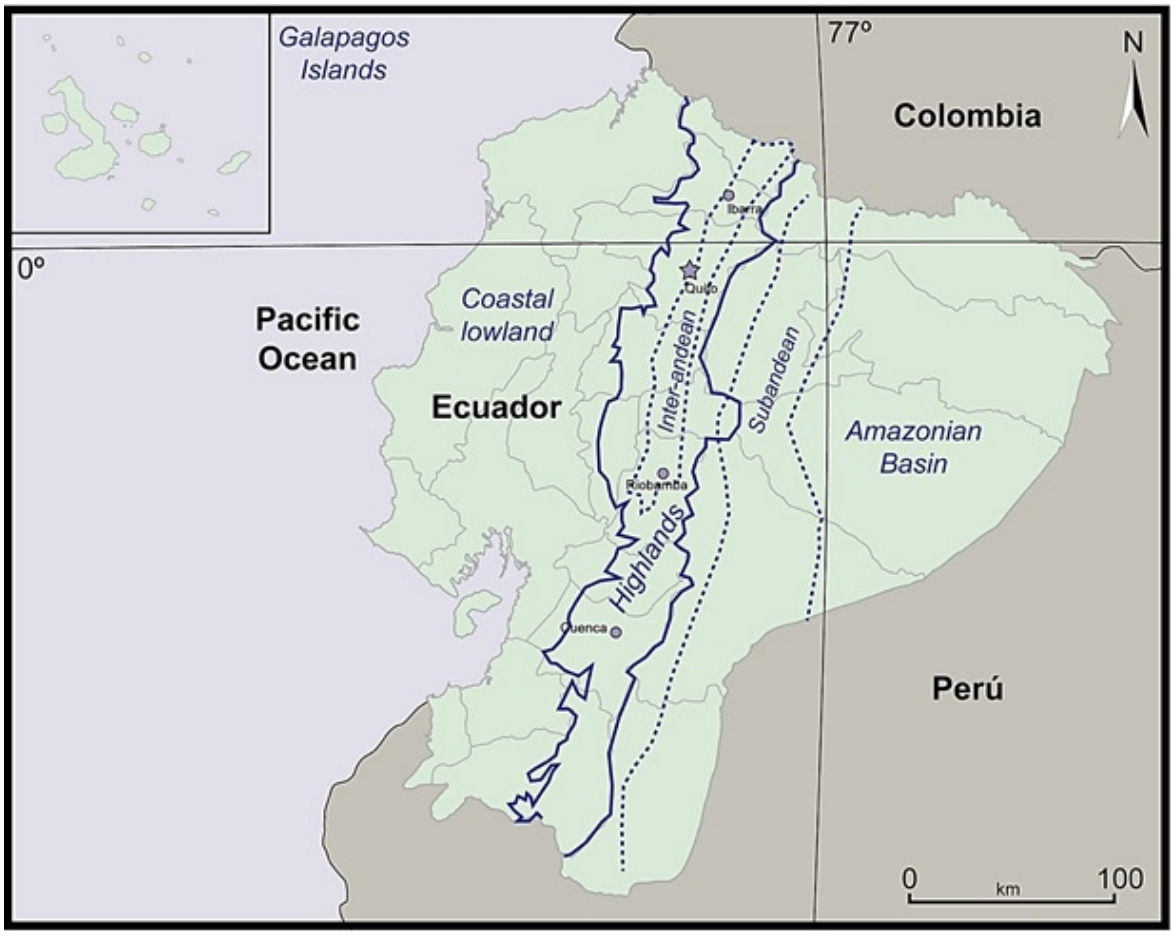

Figure 1. Map of Ecuador with the most important morphological areas and the sites where the survey has been performed.

3 Results and discussion

A) The global perspective. The first three questions of the survey (#1, 2 and 3) focused on global issues by asking about the existence and the seriousness of the climate change, as well as the involvement or not of humans in the rise of this phenomenon. The results to these three questions were affirmative and exposed a major agreement in their responses, as more than the 75% agreed with the given statements regarding the real existence and the gravity of the climate change and the involvement or res-

ponsibility of humans. Those topics are commonly researched worldwide and are regularly presented on the daily news. Therefore, it was assumed that the broad and worldwide inputs infer on the common agreement. According to the PNDU2009, the high importance of climate change is due to the risks that humanity will face at the current trend of CO_2 concentrations. The risks include: (1) reduced agricultural productivity, (2) increased water stress and insecurity, (3) rising sea levels and exposure to climate disasters, (4) collapse of ecosystems, (5) increased health risks, (6) flooding and (7) hunger.

Although there is still a lack of a reliable quantification of the cumulative impacts of climate change on the global-scale agricultural productivity, there is no doubt that there are direct negative effects of an increase of CO_2 on plant physiology and increase resource use efficiencies (Olesen and Bindi, 2002; Battisti and Naylor, 2009; Gornall et al., 2010). Therefore, food insecurity will most likely rise due to the present climate change, especially if societies are unable to cope rapidly with ongoing developments (Lobell et al., 2008; Brown and Funk, 2008). Overall, local biota and human livelihoods are threatened by changing climates and the associated changes in terrestrial ecosystems (Verchot et al., 2007).

Clean water resources are essential for man, society, its life-support system and its industrial develop-ment (Sullivan, 2002; Milly et al., 2005; Falkenmark, 2013). However, increasing temperatures are stressing the existing water resources and the ecosystems which provide this important element. Reduction of glaciers, evaporation of water deposits and high-use of subterranean water resources have led to the overall reduction of water in arid and semi-arid areas (Messerli et al., 2004; Greenwood, 2014; Zografos et al., 2014). An increase of such vulnerability may cause significant social and territorial problems between societies or even among countries (Allouche, 2011; Adano et al., 2012; Gleick, 2014).

An increase of the average worldwide temperature results into rising sea levels (Harley et al., 2006). Such climate-induced changes lead to more damaging flood conditions in coastal areas as well as other vulnerable zones close to the sea level (Watson et al., 1998; Berz et al., 2001; Hoegh-Guldberg et al., 2007). Furthermore, hydrometereological disasters such as hurricanes or cyclones tend towards longer duration and greater intensity being correlated with the rise of tropical sea surface temperatures in the last decades, even in regions which have not been affected in their past (on Climate Change, 2007; Dasgupta et al., 2011; Brecht et al., 2012). Furthermore, the rise of the mean sea-level may also result in the direct collapse of a variety of ecosystems (Worm et al., 2006; MacDougall et al., 2013). Such dramatic effects are especially reported in island regions or states such as those in the Caribbean and southern Pacific areas, where the environmental conditions and coastal communities are alike (Pelling and Uitto, 2001; Dolan and Walker, 2006). A consequence of ocean warming is the enhancement of ocean circulation driven atmosphere-ocean phenomenon such as the ENSO and cyclones. Example of this appears to be the 2015/16 El Niño episode registered as one of the strongest in the history, although it has been also alternatively interpreted (**?**Mato and Toulkeridis, 2017; Brainard et al., 2018). The strong 2015/16 El Niño coincides with the global average temperature in 2015, reaching values of 1 $^{\circ}C$ above preindustrial level for the first time, labeling this year as the warmest so far (P. et al., 2016).

Climate change may affect health through a huge range of forms like more intense and more frequent heat waves as well as changes in the distribution of vector-borne diseases, among many others (Patz et al., 2005; Haines et al., 2006). The effects of global warming have been observed in the temporal increase in temperatures that occur more frequently and by subsequent enhanced hot waves as well as the rise of temperatures in the oceans (Meehl and Tebaldi, 2004). Thus, long-lasting heat waves which occurred in 1995 in Chicago, USA and in 2003 in Paris, France caused 35.000 deaths (Karl and Knight, 1997; Luterbacher et al., 2004; Stott et al., 2004). Further heat waves are expected in a variety of regions all over the planet, based on several modeled scenarios (Lhotka et al., 2018; Frölicher and Laufkötter, 2018; Guo et al., 2018). Additionally, there are many scientific evidences stating that the climate variability of the last decades has given rise to vector-borne diseases, as a result of several droughts and or flooding as well as fires (Martens et al., 1995; Githeko et al., 2000; Amiro et al., 2001; Flannigan et al., 2009; Moritz et al., 2012; El Universo, 2018).

Changes in climate in different regions allows the migration of a high variety of insect and bird

species, who may carry several vector-borne and emerging infectious diseases with them (Patz et al., 1996; Kovats and Hajat, 2008; Tol and Dowlatabadi, 2001; Epstein, 2001; Jones and Mann, 2004; Wu et al., 2016). Based on the compilation by the World Health Organization (WHO), the current global climate change may cause up to 150.000 deaths per year (Cifuentes Lira, 2008).Additionally, as consequences of the current trade of pollution, the global temperature is predicted to rise de 1.5 a 4.5 $^{\circ}C$. This rise will cause the melting of many glaciers, resulting to a sea level rise of about around 50 cm, impacts on the biological systems like the coral reefs, further damage or slower recuperation of the ozone layer, and the spread of tropical diseases such as malaria and paludism (Ibárcena and Scheelje, 2003). The temperature rise and the heavy rainfall are the main causes for the spread of diseases. For example, the malaria distribution model is based on temperatures (Rogers and Randolph, 2000). The effects on people health due to climate change include malnutrition, undernourishment, and infectious diseases (McMichael and Haines, 1997). Examples of this are the health impacts such as the epidemics and diarrhea which occurred after the seasonal variability of the El Niño-Southern Oscillation (ENSO) (Patz et al., 2005).

The responses to question #4, which regard to the level of agreement that scientists have about the occurrence or not of climate change, showed a majority of 60% that believe there is agreement in the scientific community. From the research undertaken in several reports and scientific papers, the response of the survey is supported as most of the scientists agree in the imminent and mostly dangerous effects of climate change and global warming. Both processes have been accelerated by humans and their industrial activity. Moreover, they agree on the effects that pollution and global warming have had and will have over the ecosystem and the atmosphere, which includes ice poles melting, enhanced ENSO, droughts, flooding, coral reef bleaching and the extinction of some species (Timmermann et al., 1999; Clauer et al., 2000; Walther et al., 2002; Thomas et al., 1999; Cazenave, 2006; Brook et al., 2008; Markus et al., 2009; Ibárcena and Scheelje, 2003; Chen et al., 2013; McClanahan et al., 2018; Cai et al., 2019).

Question #5 of the survey focuses on past climate changes during human history, as the idea was to encounter the knowledge background of climate variability by the academics of Ecuador. Based on scientific studies, there have been several climate and temperature changes since the existence of humans, and also significant rapid climate changes during the current Holocene (Mayewski et al., 2004). Such climate fluctuations, even the abrupt ones, seem to have been triggered by changes in earth orbital insolation, volcanic aerosols and associated albedo feedback processes rather than by a significant increase of antrophogenic greenhouse gases (Crowley et al., 1993; Rampino and Self, 1993; Overpeck et al., 1997; Crowley, 2000; Atwell, 2001; Bay et al., 2004; Christensen et al., 2019; Guanochanga et al., 2018; Fuertes et al., 2019).

In a more detailed approach, it should be reminded that since the appearance of hominins over 2,000,000 years ago, the history of human evolution has been intrinsically linked to Earths climate fluctuations, which have helped to shape our species. The origins of bipedalism were in a period of climatic transition, and *Homo erectus* emerged in the time of the colder Pleistocene Epoch and survived various glacial-interglacial cycles (de Menocal, 1995; Rightmire, 2008). *Homo sapiens* domination initiated during the last glacial period and accelerated over the last glacial-interglacial transition (Groucutt et al., 2015; Williams et al., 2016; Asrat et al., 2018; Skillington, 2018). The modern human species has successfully experienced nearly two full glacial-interglacial cycles due to its worldwide geographical distribution, extensive population expansion, and global ecological domination together with superior technology, and more dynamic social relationships (Shea, 2008; Schramski et al., 2015).

Such climate changes have impacted human evolution and dispersal, and are believed to have deter-mined and even stimulated the emergence of agriculture. Animal domestication seems to have initiated in western Asia around 11,000 years ago when goats and sheep were first herded, while plant domestication started some 2000 years later as wheat, lentils, and rye were grown by first time (Diamond, 2002; Terrell et al., 2003). This shift from a nomadic hunter-gatherer lifestyle to agrarian-based settlements took place during a phase of climatic transition after the last glacial period (Richerson et al., 2001). It seems that, although climate change affected nomadic societies by causing dras-

tic decreases in natural resources, it also brought opportunities as new plants and animals spread or appeared. Although certain civilizations may have collapsed due to abrupt and intense climatic changes, humans have adapted and survived climate variations through history. These climate changes range from decadal to centennial and millennial variations, and have been well documented through historical and proxy records, particularly annual growth rings in trees, cave stalagmites, corals, cores of lake and deep-sea sediments and ice cores (McManus et al., 1994; Jones et al., 2009; Esper et al., 2002). Interannual and decadal climate oscillations include El Niño–Southern Oscillation, the North Atlantic Oscillation, the Pacific Decadal Oscillation or the Atlantic Multidecadal Oscillation (Henley et al., 2015; Geng et al., 2017; Kayano et al., 2019). They have also been associated to the collapse of the Maya civilization in Mesoamerica between the 8th and 9th centuries, suggesting that intense droughts may have led to social stresses (Hodell et al., 1995; Haug et al., 2003; Douglas et al., 2015; Beach et al., 2016). As for centennial timescales, the Little Ice Age (LIA) was a period of relative cooling which spanned from early 14th through the mid-19th centuries (Jones and Mann, 2004; Rubino et al., 2016). It is characterized by a mountain glaciers expansion in regions such as the European Alps, New Zealand, and the Patagonian Andes, and a decline of 0.6 °C in the mean annual temperatures across the Northern Hemisphere (Svarva et al., 2018). The effects of LIA include bad harvests and famines over most of Europe due to the increase of rain during summers (Appleby, 1980), as well as the collapse of cod fisheries in the North Atlantic resulting from a pronounced decreased of sea temperatures. The LIA began after the Medieval Warm Period (9̃50–1100 CE) (Cronin et al., 2010), whose warmer winters and summers led to good crop yields over most of Europe, with wheat and vineyard being grown in colder regions than today. In the Northern Hemisphere, the period around ad 1000 to 1100 featured high temperatures-similar to those recorded between 1961 and 1990 while minimum temperatures about 0.7 $^{\circ}C$ below the average of 1961-90 may have occurred around ad 1600 (Moberg et al., 2005). However, neither the Little Ice Age nor the Medieval Warm Period were climatically homogeneous periods nor did they exhibit uniform temperatures everywhere in the Earth. Instead, they featured regionally complex spatial rain patterns and asynchronous warming, most probably as a result of coupled ocean–atmosphere processes (Cronin et al., 2010). For instance, during the LIA, temperatures of areas like eastern China or the Northern Andes did not experience a significant reduction. Nonetheless, past climate changes have been different compared to the recent one, as the climate changes have not been recorded worldwide unlike the current (Neukom et al., 2019a,b; Brönnimann et al., 2019).

In this respect, and based on the aforementioned studies, the perceptions recorded in the survey does not match with the facts, since most of the inquired academics (6̃7.2 %) believe that the current climate change is the first climate change humans are experiencing. Hence, there has been no clear recognition of earlier climate changes since humans appeared on the earths surface (Fig. 2). The options of totally and mostly agree reach an average of 39.77 % of the results, while the options of totally and mostly disagree sum up only 32 % on average; furthermore, 27.42 % of the answers correspond to the option probably. However, among the four cities surveyed, Ibarra and Riobamba are the ones with a higher percentage (38 %) of totally and mostly disagree answers, hence, with a better knowledge of the facts, while Quito is the city with the lowest percentage (20,5 %) in these options, showing a worse correspondence with the reality. Independent of the city, the diverse results clearly indicate that there is lack of agreement in the perception of this issue, most likely linked to a lack of knowledge or less to no access on facts about paleoclimatology.

B) The Ecuadorian perspective

The second part of the survey aims to evaluate the knowledge and perceptions of the Ecuadorian academics about many visible or perceived changes in the climate of their own country. Therefore, the first question of the second part (#6) has been if the inquired people think that Ecuador experiences a climate change. The answers agreed with about 60 % to 80 %, having a concurrent perception in all four sites of the survey. From past events, it is commonly known that the geographic location of

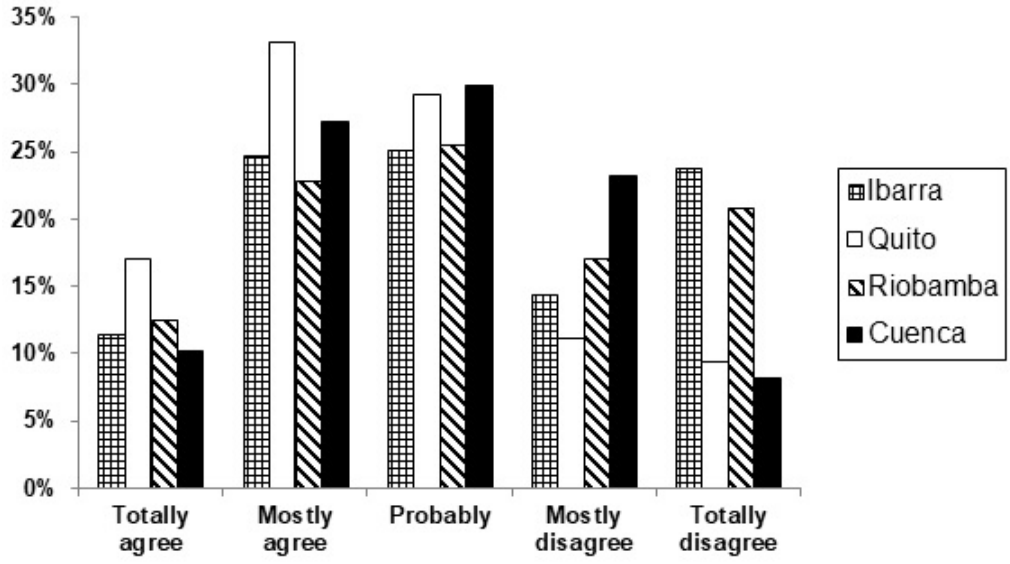

Figure 2. Answers with a histogram to the question #5 of the survey with the question-affirmation that since the existence of human history (humanity) it is the first time that there is a climate change impacting the planet.

Ecuador makes it a vulnerable country to climate change due to the effects that the ENSO has over the Latin-American coasts but also more inland, in the Highland and even the Amazonian Lowland, although with opposite effects since thousands of years (Rodbell et al., 1999; Riedinger et al., 2002; Terneus and Gioda, 2006). These effects, together with corroborating observations of an increasing trend in temperature, and increases in intra and inter-annual variations, may be some of the main reasons to agree that a climate change is occurring in Ecuador.

In Ecuador, the impacts of climate change are highlighted in a variety of observations. There is first the intensification of extreme climatic events, such as those that occurred as a result of the ENSO phenomenon; specifically, the El Niño extreme events of 1982-83 and 1997-98, and in later years, causing significant damage to livelihoods, agriculture and infrastructure (Rossel and Cadier, 2009; Aceituno et al., 2009; Bendix et al., 2011). Secondly, a certain rise in sea level has been determined during the aforementioned climatic variations (Cucalon, 1987; Rodbell et al., 1999). The increase of the sea level threats to coastal flooding of near-coast towns and further towns as the effect of the ENSO was also enhanced. Third, the retreat of the glaciers which is most visible particularly in summer, with tremendous retreat ranges (Francou et al., 2000; Jordan et al., 2005; Francou et al., 2005). Fourth, a determined decrease in annual runoff, as indicated in a variety of studies (Yates, 1997; Poulenard et al., 2001; Laraque et al., 2007; Zubieta et al., 2015). Furthermore, in Ecuador there has been an increase in the distribution range of dengue, malaria and other tropical diseases (Gueri et al., 1986; Ruiz and Roeger, 1994; Kovats et al., 2001; Gabastou et al., 2002; Stewart-Ibarra and Lowe, 2013; Stewart-Ibarra et al., 2014; Padilla et al., 2017), as a consequence of temperature and humidity rise, which create greater areas suitable for the expansion of tropical diseases (Reguero et al., 2015; Ibárcena and Scheelje, 2003). Additionally, the expansion of populations of invasive species in Galapagos and other sensitive ecosystems of continental Ecuador (Schofield, 1989; Mauchamp, 1997; Roque Albelo and Causton, 1999; Wikelski et al., 2004; Chaves, 2018; Rueda et al., 2019; Urquía et al., 2019) and finally even the extinction of several species (Haase, 1997; Bataille et al., 2009; Moret et al., 2016).

Regarding the question #7, about global climate change, a few aspects must be mentioned about this issue. The geographic location of Ecuador at the equator allows higher solar radiation, which added to a rise of the global temperature may also represent a threat for the human health of this region

such as skin cancer (Farmer et al., 1996; Duro Mota et al., 2003; Torre et al., 2015; Echegaray-Aveiga et al., 2018). Global warming, besides affecting the crops and vegetation, also contributes to the sea level rise due to thermal expansion in the ocean and the glaciers melt (Solomon et al., 2009). The elevation of the glaciers in Ecuador is higher than in other countries, for this reason, a change in the Equilibrium Line Altitude (ELA) may have critical impacts in glacier regression and even its disappearance. Many provinces in Ecuador, such as Pichincha and Cotopaxi obtained part of their water from the glaciers; hence, its reduction will cause serious social issues (Rojas, 2016). Some of the problems that Ecuador would have to face with an ongoing climate change and increase of the average temperatures would be the scarcity of water in some cities, such as Quito, fact similar to Lima in Peru, where their water supply derives predominantly from glaciers (Buytaert et al., 2017; Beeman and Hernández, 2018; Johansen et al., 2018). The glacier in Latin America, like almost all glaciers worldwide, are in constant reduction (La Frenierre and Mark, 2017; Milner et al., 2017). Several studies have concluded that particularly the tropical glaciers below an altitude of 5500 meters above sea level will be vanished in less than a decade (Chadwell et al., 2016; Veettil et al., 2017; Wu et al., 2019). Several glaciers have been already reduced dramatically or disappeared completely such as those in Bolivia and the one-third of the Quelccaya ice cap in Peru (Miranzo, 2015; Veettil et al., 2016; Yarleque et al., 2018). In Ecuador its effects are also seen in the drought of the Andes Cordillera and flood of the coastal area (MAE, 2017). Furthermore, the nature impacts or issues in Ecuador include expansion of the invasive species in Galapagos islands and other protected areas, a decrease of ecosystems and extinction of species (Diaz, 2012).

On the other side, also beneficial issues may arise by the appearing climate change conditions worldwide as well as in Ecuador (Bonan, 2008; Wassmann et al., 2009). There are areas where precipitation have been very low and the surrounding population struggle in their agronomic outcome for decades may benefit from higher precipitations and up to the potential use of dry and or unfertile areas for future exploitation for agricultural purposes (Cassman, 1999; Barrow, 2012; Junk, 2013). This would also allow a variety of plants and also animals to thrive in these new evolved warmer ecological niches. Farmers will be able to plant crops earlier in the year, having the opportunity to obtain potentially more harvest than before (Grau and Aide, 2008; Sissoko et al., 2011). Trees may be able to be planted at higher altitudes due to the now given warmer conditions, which simultaneously may allow farmers to use higher altitudes for pasture and livestock (Grace et al., 2002; Hemery, 2008; Hemery et al., 2010; Mathisen et al., 2014). Based on higher temperatures worldwide, there is a less need of cutting trees or even entire forests for firewood, which will subsequently lead to a decelerated evolution of global warming with less wood burning (Herrero et al., 2013; Rahn et al., 2014). Warmer conditions lead to a less use of fossil fuels, in order to warm up homes (Edwards et al., 2004; Sathre and Gustavsson, 2011). Additionally, warmer environments are more conductive to human health against health related sicknesses of cold climates (Kalkstein and Greene, 1997; Khasnis and Nettleman, 2005; Epstein, 2000; Kovats and Hajat, 2008; Séguin et al., 2008; Wilke et al., 2019).

By comparing the scientific facts and the perceptions registered in the survey about question #7 ″ the climate change only generates disasters for Ecuador″, a fairly good correlation was identified be-tween facts and perceptions, since a majority of the surveyed academics (55 %) chose the options of mostly agree and probably. Therefore, there is a general belief that climate change mostly brings disasters or negative effects to Ecuador, although, at the same time, they also recognized that climate change may have some few positive effects in their country, which coincide with the facts exposed above (Fig. 3). The results are distributed among all categories, with each option reaching more than 10% of the responses. The options of totally and mostly agree reach an average of 44.08% of the results, while the options of totally and mostly disagree sum up only 27.35% on average; furthermore, 26.66 % of the answers correspond to the option probably. An analysis of the responses of the four locations surveyed shows that three out of the four cities, Ibarra, Quito and Riobamba, has its highest percentage in the option of mostly agree, in particular, 32.3% of academics from Quito chose this option, demonstrating a better knowledge of the facts. On the other hand, Ibarra and Cuenca exhibit divergent patterns: Ibarra is the city with highest percentage of both to-

tally agree and totally disagree, revealing more extremist perceptions, whereas Cuenca is the city with lowest percentage of both totally agree and totally disagree, and highest percentage of probably, indicating a conservative approach regarding the issue of effects of climate change in Ecuador. Overall, the diverse results indicate a lack of consensus in the perception of this issue, hence, a need of more detailed knowledge on facts about both negative and positive effects of climate change in their country.

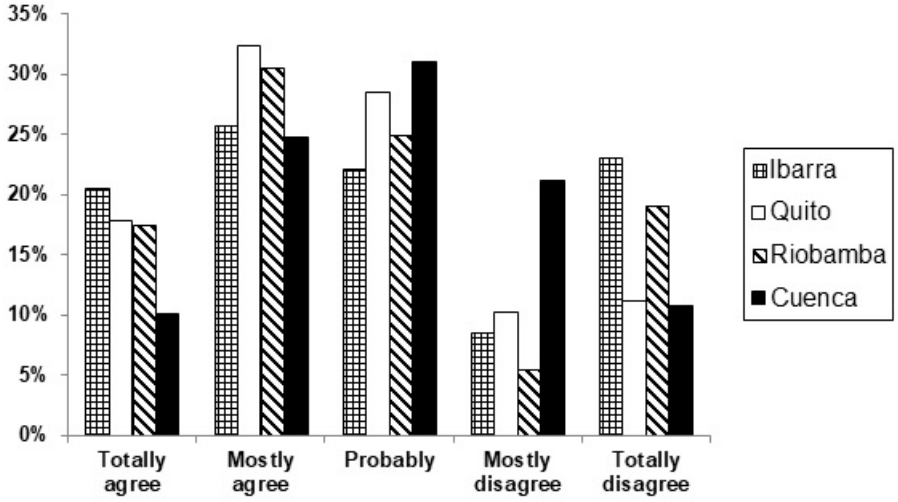

Figure 3. Histogram with the results based on question #7 of the survey with the question-affirmation if global climate change only generates disasters for Ecuador.

The question #8 of the survey pointed out about the features which may demonstrate the most the global warming and the climate change in Ecuador. The NOAA in 2015 determined that a new record in greenhouse gas emissions and global increase in temperatures was reached. As results, impacts on water and terrestrial ecosystems have been evident in all regions of the world. Ecuador has suffered several changes over time due to climate change, and it has been evident on the increasingly intense flooding, beach erosion, decreased biodiversity in the Andean paramos, retreat of glaciers, reduction of agricultural productivity and freshwater supplies. The city of Quito has undergone an increase of 1.1 $^{\circ}C$ from 1880 to 2017. The collateral effects of this increase have produced intense winter seasons that have increased in the last 30 years (García-Garizábal et al., 2017).

As for perceptions (Fig. 4), the academics believe that the feature which mostly shows climate change in Ecuador is more frequent droughts reaching 34.36% of the responses, the four cities coincided in choosing this option as the first. The second feature is the rarer but more intense rainfall with the 21.41% on average. These two options are indeed the extreme ends of the spectrum, and may seem opposite; however, as Martin2018 explains, when it gets warmer, water vapor will build up in the atmosphere, so when it does rain it rains a lot, but there will be longer periods between rain events so droughts will become worse, and more frequent.

Contrary to expectations, only 18% of the surveyed academics chose the option of increase in temperature, which indicates that Ecuadorians do not perceive the temperature as the most affected variable; on the contrary, they believe that rainfall is the main feature. However, this option exhibits divergent results among cities, Ibarra and Riobamba show high values around 26-27% while Quito and Cuenca report very low values of 9.6 and 8.4% , respectively. Some 9.98% on average opted for the

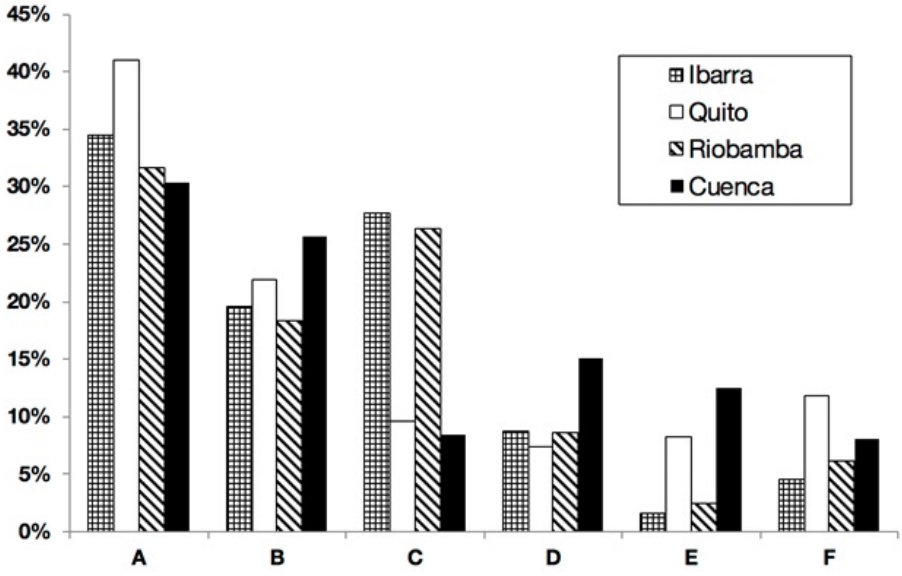

Figure 4. Histogram with the results based on question #8 of the survey with the multiple choice answers about which may are the main effects of climate change in Ecuador. A = more frequent droughts; B = rarer but more intense rains; C = increase in temperature; D = glacier retreat; E = sea level rise; F = lack of water.

feature of glacier retreat, but with marked differences between 7.4% in Quito, and Cuenca which doubles the percentage of Quito (15 %). Although the reduction of ice caps is a visible reality in Ecuador; it seems that the role of glaciers is not considered so relevant, especially in Ibarra, Quito and Riobamba. These results are more surprising considering that Quito and Riobamba are two cities which obtain part of its water from glaciers while Cuenca does not depend on glacier water.

The sea level rise was the option with lowest average percentage (6.22%) since it is minor and difficult to observe in Ecuador. Still, the results show a wide range, with higher val-ues for Cuenca (12.45 %) and Quito (8.3 %), and very low values for Riobamba (2.5 %) and Ibarra (1.63%), despite being all of them highland cities with similar distances from the coast. Regarding the lack of water, Quito shows the highest percentage with 11.78%, probably because it has a higher population. Therefore, the diversity in the inquiries demonstrated a coincidence with the heterogeneity of the real circumstances. Overall, the rainfall, due to its changing frequency and intensity trends, seems to be the feature that concerns the academics the most.

In early 2015, the Ecuadorean Ministry of Environment, conducted technical visits to demonstrate the effects of climate change in the Cuyabeno Lagoon and the retreat of the Chimborazo glacier. During these visits, the direct relationship between the low flow of this lagoon and the glacier was confirmed. It was determined in this study that one of the causes of this phenomenon is the deforestation, which alters the hydrological cycle, influencing the flow of nearby water sources. It was concluded that climate change directly affects the ecological flow in a decrease of 10% along with the reduction of biodiversity in these sites. Additionally, it was verified that the Chimborazo glacier has decreased by 58.9% between 1962 and 2010, with unusual landslide records of ice and stone material attributed to the increase in temperature in that area (Telégrafo, 2016).

In the southern region of the country, studies have been carried out about the vulnerability to climate change and potential impacts on ecosystems, biomass production, and water production. It was evident that Ecuador has a high vulnerability index to environmental changes related to global climate change due to anthropogenic and climatic factors as it has a diversity of ecosystems. The area studied has 41 ecosystems, all of these are strongly threatened by the exploitation of resources and changes

worldwide (Aguirre et al., 2015). Similarly, the effect in El Oro includes higher levels of precipitation while in Zamora Chinchipe it includes an increase in temperature. These patterns of temperature increase and precipitation in the study area could affect the physiology, phenology, dynamics, structure, the productivity of communities and the functioning of ecosystems. This evolution demonstrated the sensibility of the area to the anthropogenic activity and its negative effect (Aguirre et al., 2015).

A recent study carried out in the province of Santa Elena determined predictions of temperature increase in the coastal area of 2.7% by the end of the 21st century. The results were based on theoretical models and historical climate data. An increase of 8.2% could possibly lead to a reduction in the degree of aridity of the region, passing from arid semi-desert to a Mediterranean semi-arid, and from Mediterranean semi-arid to sub-humid (García-Garizábal et al., 2017).

The final question #9 focused more in detail about which area in Ecuador shows the most of the effects of global warming and climate change. Hereby, a relatively high percentage has indicated the coastal lowland (29%) with similar values, close followed by the Inter-Andean Valley with the 17.26 %, that are apparently the regions where the strongest effects of global warming may have occurred and still occur (Fig. 5). While inquiries of Cuenca opted also highly for the Subandean region (23 %), such site with 12.37 % as well as the Amazon basin with 10.07% on average have been less a target of global warming according to the majority of the opinions. The Galapagos Islands obtain only the 1.6% on average, demonstrating that academics in highlands do not consider them a target probably due to its distance, despite being a biodiversity hotspot with high climate vulnerability.

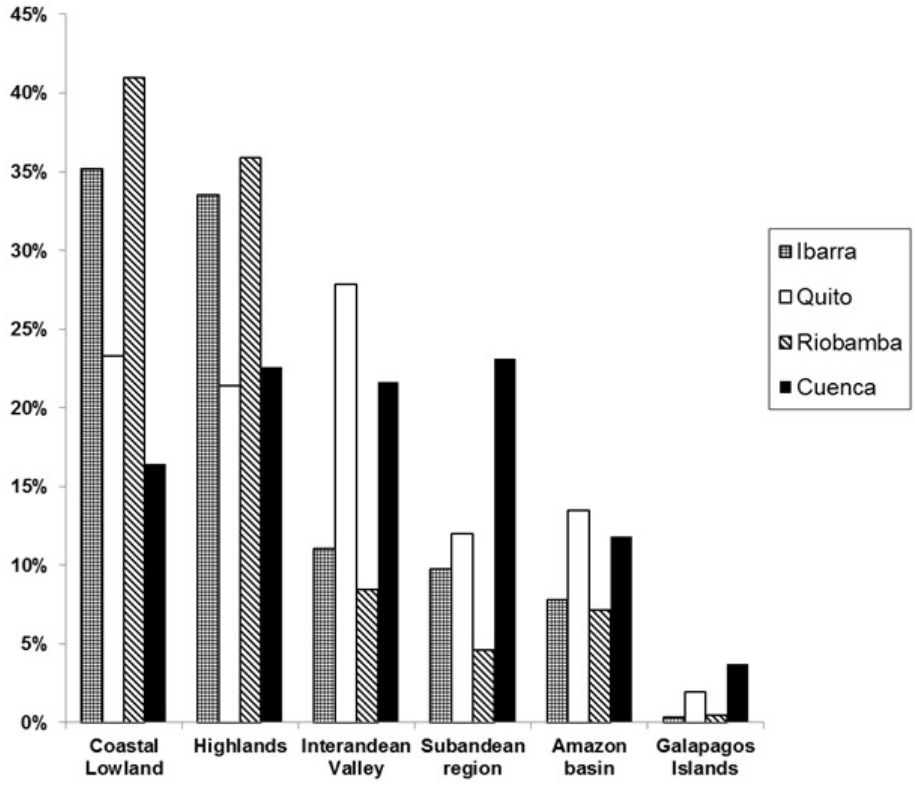

Figure 5. Histogram with the results based on question #9 of the survey with the question-affirmation about which regions of Ecuador are more affected by climate change.

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The results have indicated that people apparently tend to see that their own environment is having some severe effects as also previously demonstrated with #8 of the survey (Fig. 4). This allows to potentially interpret that people most likely do not know well or less frequent visit other regions in order to be able to have a better view and more aspects for a better evaluation of potential effects of global warming and also other atmospheric effects based on climate change. However, the coastal lowlands, with the highest percentage, especially in Ibarra and Riobamba (35.2 y 41 %), was an exception since it was generally perceived as highly impacted by climate change for the inhabitants of the highlands, who often watch on TV and newspapers the effects of El Niño and the recurrent floods in the Ecuadorian coast.

Finally, an overall view based on the survey shows that the two main patterns have been the tendency to choose options 'b= Mostly Agree' and 'c=Probably' which are ambiguous, but only in specific questions like 1 and 10 the options 'a= Totally agree' or 'e= Totally disagree' that are specific, were chosen. These two questions are highly spoken about in the media and institutes; hence, it is a clear choice. However, this 'certainty' is dependent on information that is broad and vague where no reference to scientific papers or primary source is given. The omission of the source in the publications of some newspapers in Ecuador was verified in 18 news about climate change. It was noticed that the answers of the academic population agreed with the scientific investigation performed around the world, however most of this knowledge lack of deepness. In addition, about the other 50 % indicates doubt. This is most likely related to the lack of information and poor research and data information about climate change worldwide in general and particularly about Ecuador.

4 Conclusions

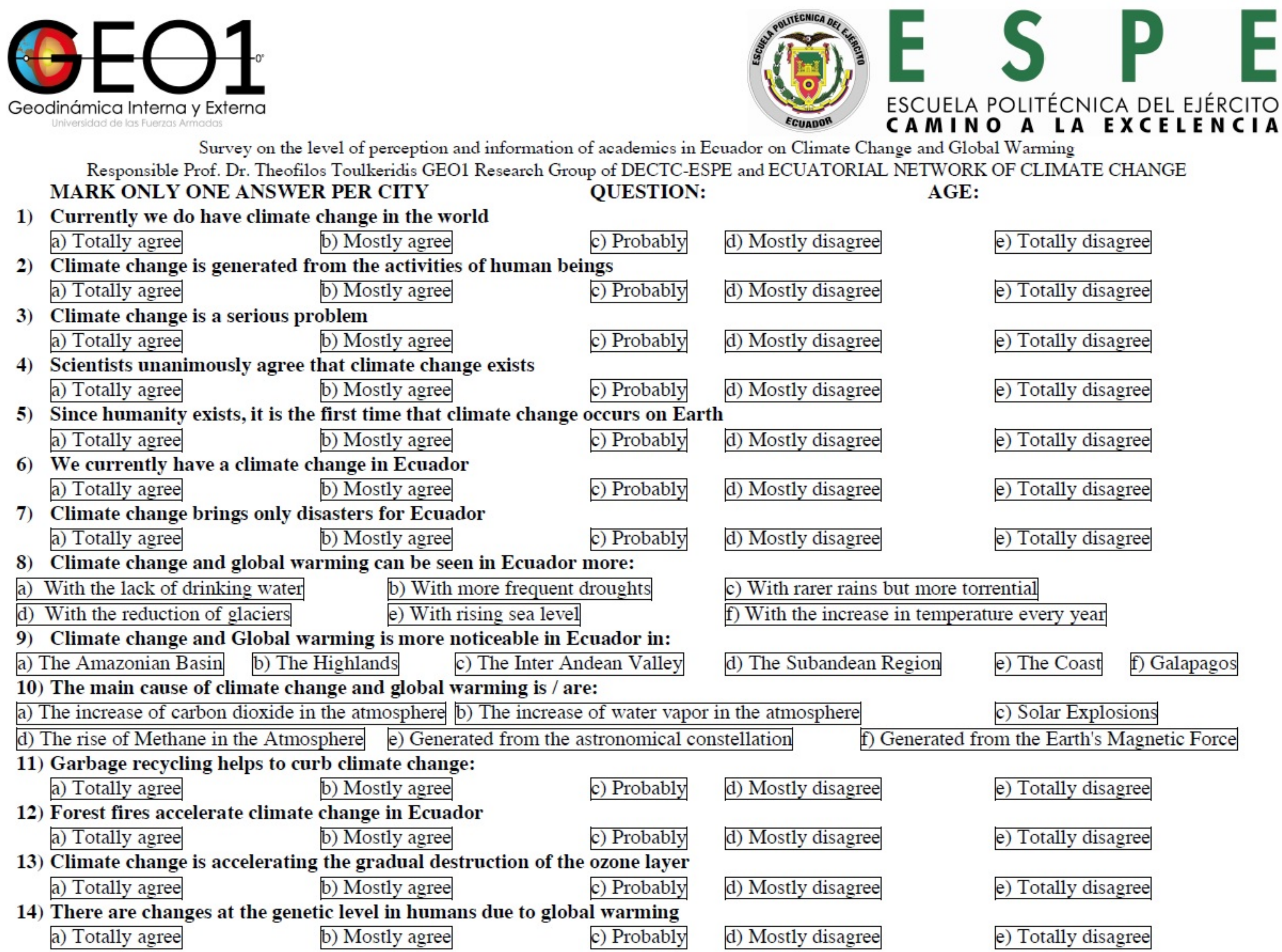
There is lack of a wider perspective, discussion of the role of the government, corporations, academics and community in emission, mitigation and adaptation policies implementation.

The Ecuadorean academic community of the highlands is aware of many globally known facts of global warming and climate change. This includes the potential damages and disasters for a variety of environments. However, there is a clear lack of deepness of the origin and reach of such climate issues. There is also an obvious reduced awareness of adaptation issues as well as mitigation and personal preparation against eventual disasters as result of climate change.

Such conditions increase the vulnerability of Ecuador to the Climate change effects, as only few reflected knowledge about the real impacts and how they will affect the future of the country. There is a lack of think ahead planning, as demonstrated in the given results of the survey. However, the effects of the climate change in Ecuador are undeniable, and it is perceived mainly in the more frequent and intense flooding and droughts, and the retreat of the glaciers in the highlands.

Appendix

Figure 1A shows the questions corresponding to the survey conducted to generate the collection of information developed in Section 2.



GEO1 Geodinámica Interna y Externa
Universidad de las Fuerzas Armadas

ESPE ESCUELA POLITÉCNICA DEL EJÉRCITO
CAMINO A LA EXCELENCIA

Survey on the level of perception and information of academics in Ecuador on Climate Change and Global Warming
Responsible Prof. Dr. Theofilos Toulkeridis GEO1 Research Group of DECTC-ESPE and ECUATORIAL NETWORK OF CLIMATE CHANGE

MARK ONLY ONE ANSWER PER CITY **QUESTION:** **AGE:**

1) Currently we do have climate change in the world
a) Totally agree | b) Mostly agree | c) Probably | d) Mostly disagree | e) Totally disagree

2) Climate change is generated from the activities of human beings
a) Totally agree | b) Mostly agree | c) Probably | d) Mostly disagree | e) Totally disagree

3) Climate change is a serious problem
a) Totally agree | b) Mostly agree | c) Probably | d) Mostly disagree | e) Totally disagree

4) Scientists unanimously agree that climate change exists
a) Totally agree | b) Mostly agree | c) Probably | d) Mostly disagree | e) Totally disagree

5) Since humanity exists, it is the first time that climate change occurs on Earth
a) Totally agree | b) Mostly agree | c) Probably | d) Mostly disagree | e) Totally disagree

6) We currently have a climate change in Ecuador
a) Totally agree | b) Mostly agree | c) Probably | d) Mostly disagree | e) Totally disagree

7) Climate change brings only disasters for Ecuador
a) Totally agree | b) Mostly agree | c) Probably | d) Mostly disagree | e) Totally disagree

8) Climate change and global warming can be seen in Ecuador more:
a) With the lack of drinking water | b) With more frequent droughts | c) With rarer rains but more torrential
d) With the reduction of glaciers | e) With rising sea level | f) With the increase in temperature every year

9) Climate change and Global warming is more noticeable in Ecuador in:
a) The Amazonian Basin | b) The Highlands | c) The Inter Andean Valley | d) The Subandean Region | e) The Coast | f) Galapagos

10) The main cause of climate change and global warming is / are:
a) The increase of carbon dioxide in the atmosphere | b) The increase of water vapor in the atmosphere | c) Solar Explosions
d) The rise of Methane in the Atmosphere | e) Generated from the astronomical constellation | f) Generated from the Earth's Magnetic Force

11) Garbage recycling helps to curb climate change:
a) Totally agree | b) Mostly agree | c) Probably | d) Mostly disagree | e) Totally disagree

12) Forest fires accelerate climate change in Ecuador
a) Totally agree | b) Mostly agree | c) Probably | d) Mostly disagree | e) Totally disagree

13) Climate change is accelerating the gradual destruction of the ozone layer
a) Totally agree | b) Mostly agree | c) Probably | d) Mostly disagree | e) Totally disagree

14) There are changes at the genetic level in humans due to global warming
a) Totally agree | b) Mostly agree | c) Probably | d) Mostly disagree | e) Totally disagree

Figure 1. A. Survey about perception of climate change in Ecuador.

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