## MODELING OF INCREASED $CO_2$ EMISSIONS, CLIMATE SCENARIOS BY THE USE OF SOFTWARE ENERGY AND CLIMATE EC21, CASE STUDY IN LATIN AMERICA COLOMBIA-GUATEMALA


**A.I. Kurbatova, F. Ovalle, M.R. Aruca**

Peoples' Friendship University of Russia
*Podol'skoe shosse, 8/5, Moscow, Russia, 121522*



Latin American and Caribbean countries, including Colombia and Guatemala are in the most vulnerable to climate change. Since much of its population is in the highest parts of the mountains, where water scarcity problems are expected, and instability of soils and on the coasts, where the sea level rise and flooding can affect human settlements and key economic activities. It also has a high recurrence of extreme events, with a large and growing technical impact of climate-related emergency [1]. It's necessary know the historical records of those elements to build mitigation of the negative effects of environmental crisis. However, it has been different advance efforts among stake holders as civil society, academia, government and private sector. As is the case of the Institute of Mining and Geotechnical Glückauf-Verlag of Germany and the British Petroleum Company, which developed the Energy and Climate 21 (EC21) software. The concentrations carbon dioxide in the atmosphere to increase considerably in the last 175 years from 280 ppm (parts per million from 1830 to 380 ppm in 2005) [2]. Under this dynamics, modeling was developed to Colombia with parameters of software with EC21, in order to see the scenario in the medium and long-term $CO_2$ concentrations and temperature increase. And regional plans and visualizing what challenges the country in action lines mitigation and compensation to the effects of climate change.



**Key words:** Environment, Ecosystems, climatic variability, software, concentrations.


The environmental dynamics of the countries of Central America and Latin-American, has been marked by the development factors in each of the regions, which leads make a statement on the realities and ecological, economic and social conditions that provide countless comparative advantages function of the global environmental services to be more competitive in the context of globalization. Its enormous natural, cultural diversity and innovative approaches to regional integration achieved in some sub-regions as Central are relevant examples of this privileged situation. Latin America, with the Amazon jungle, swamps and Andean peaks, houses the richest biodiversity in the world, is home to much of the wildlife world. But given the poor management of land and resources, coupled with economic pressures and pollution are causing an environmental crisis that is affecting the entire continent. Deforestation through logging and burning of forests, mismanagement of wilderness allows burning, poaching and the destruction of habitats and biodiversity. Overfishing, uncontrolled construction and other economic activities threaten the extinction of key species of wild fauna and flora. The combined impact of these local crises, exacerbated by global warming, leading to droughts, floods, heat waves, tidal elevation and melting glaciers. With carrying natural systems to maximum resilience against the socio-economic precessions. Under this order of ideas, Colombia has one of the highest rates of atmospheric pollution in major urban centers and the poor provision of public sanitation and hygiene, particularly natural disasters, floods and landslides and soil degradation are environmental problems that generate the highest economic and social costs in Colombia. The cost of these problems falls in most cases the vulnerable population groups. As well as showed the French Development Agency, about major disasters from floods in the aqueducts, roads and other infrastructure caused by trade in the 2011 floods, which cost the country around $ 5.7 million USD 11.2 billion pesos (two points of GDP) and left 3.4 million homeless, 1,016 missing and 6,000 dead [3]. Central America, meanwhile, is identified as the most vulnerable to climate change from tropical regions of the world "hot spot". The asymmetry of the countries that have contributed least to the problem suffer greater impacts and have less resilience confirm. Historical climatologist indicate that Central America has suffered an average increase of about 0.5 °C over the last 50 years, the most frequent events are floods, storms, landslides and that represent 86% of total events and 9% correspond to drought. In the last three decades the annual growth disasters recorded an estimated 7% from the seventies. Within the Central American group of countries, Guatemala still a mega diverse country; 66 natural ecosystems is at the same time, one of the Central American countries with improved climatic and topographic variability. It is located over three tectonic and on the route of the Atlantic hurricanes and Pacific plates. Under that is highly vulnerable to variability country and climate change, In Guatemala has expressed growing concern about the increase in temperature on the planet that has resulted in recent years due to changes in climate and its variability. This series of events leads to formulate a set of proposals aimed at reducing the cost of environmental degradation while supporting equitable and sustainable development in the context of the search for peace, under government plans internal development and international cooperation, such as ODSs (Sustainable development goals) which were raised between the Colombian and Guatemala governments. Together towards addressing problems of global scope but local impacts from climate change. The governments of Colombia and Guatemala worked together over the last stance Summit on Sustainable Development Rio +20, which is a critical for the international community to reach agreement on a particular approach that generates a mechanism to measure opportunity according to the context and priorities of each country — both progress and bottlenecks in efforts to balance a socio economic growth with sustainable use of natural resources and the conservation of ecosystem services. The ODSs could provide a logical sequence and structure to the process begun almost 20 years ago: in 1992 was agreed upon the guiding principles and the roadmap for sustainable development; in 2002 defined implementation plan; and in 2012 the objectives definite to identify gaps and needs to move in a more structured implementation of the principles and goals set 20 years ago [4].

The quantitative models can be useful to determine the burdens and benefits of climate policies, but unfortunately the most vulnerable, regions are also those where it is more difficult to perform a rigorous analysis and modeling due to lack of data, labor competition, institutional capacity, simulation and optimization models. Currently the Intergovernmental Panel on Climate Change (IPCC) working with mathematical models from available information and presenting four scenarios by the end of the century, the most optimistic to the most pessimistic, depending on human intervention. In the most optimistic scenario assumes that the temperature of the Earth is only 0.3° degrees and reheat in the more pessimistic than up to 4.8 [4]. In Colombia, for its economic development conditions, guidelines for incumbent parties not included in Annex I of the convention, "each party shall communicate to the Conference of the Parties, a national inventory of anthropogenic emissions by sources and anthropogenic removals by sinks of all greenhouse gases (GHG) not controlled by the Montreal Protocol, to the extent its capacities permit, subject to the provisions of these guidelines established by the IPPC absorption" [4]. The figures obtained in the second national inventory of greenhouse gas emissions effects are presented in the following table. (GHG) emissions by 2004 (table 1).

*Table 1*

**Domestic Emissions Inventory of greenhouse gases**

| Modules categories of sources and sinks of gases greenhouse effects (2000) | $CO_2$ equivalent (Gg) | % of participation to total emissions |
|---|---|---|
| Total National | 180.008 | 100% |
| 1. Energy | 65.971 | 36.65% |
| 2. Industrial Processes | 9.179 | 5.10% |
| 3. Agriculture | 68.565 | 38.09% |
| 4. Use and change of Earth. | 26.014 | 14.45% |
| 5. Waste treatment | 10.277 | 5.71% |

*Source:* Second National Communication to the Framework Convention of the United Nations on climate change, 2013.

According to this estimate for 2004 inventory, Colombia accounts for 0.37% (0.18 Gt) of total issuance in the world (49 gigatonnes). Based on the results of emissions to greenhouse gases emitted by the Secretariat of the UN Framework Convention on Climate Change (UNFCCC) [5]. You can appreciate the similar annual increase total emissions from the power modules (930 Gg/year); agriculture (938 Gg/year); Land use, change in land use and forestry (996 Gg/year); and to a lesser extent, emissions from waste Module (432 Gg/year) and Process (312 Gg/year). To Guatemala emissions and removals of greenhouse inventory gases (GHG) for 2005 were calculated using the methodology of the Intergovernmental Panel on Climate Change (IPCC) contained in the Revised 1996 Guidelines for National Inventories to Greenhouse Gases (IPCC/OECD, IEA 1997) and the Guide to Good Practice for Change and Land Use, using available national information and default values in the above methodology. Emissions are presented in Giga grams (Gg) equivalent to 1000 tons (table 2) [6].

*Table 2*

**Domestic Emissions Inventory of greenhouse gases**

| Modules categories of sources and sinks of gases greenhouse effects (2000) | $CO_2$ equivalent (Gg) | % of participation to total emissions |
|---|---|---|
| Total National | 229,553 | 100% |
| 1. Energy | 11,012 | 4,9% |
| 2. Industrial Processes | 1,541 | 0,67% |
| 3. Agriculture | 167.513 | 72% |
| 4. Use and change of Earth. | 0 | 0% |
| 5. Waste treatment | 49.5991 | 21% |

*Source:* Second National Communication to the Framework Convention of the United Nations on climate change, 2013.

United States and Western Europe have contributed similarly to total emissions in recent decades so, the per capita emission rates have historically been higher for the U.S. than for Western Europe. In absolute terms, the five GHG emitters in 2004 were the United States (20.6%), China (14.7%), European Union (14%), Russia (5.7%) and India (5.6%). Followers Japan, Germany, Canada and the UK, which accounted for another 13.3% of global emissions. While Colombia contributed 0.37% of world total and only 0.25% Guatemala.

The vulnerability of a population or against climate change system refers to the exposure of some climate threat and the ability to solve the damage (risks) without affect the adaption mechanisms [8]. In this way the vulnerability is intrinsically related to the threat to which it is exposed, and the sensitivity and adaptability of those exposed. The highly determinant factor in the vulnerability of a population is the economic, poverty tends to do generating other environmental factors, social and physical combine to increase the causation of these weather events such as: rising sea levels, increase in average annual temperature, changes in precipitation patterns. Natural systems (beaches, coast, marshes and mangroves) are highly vulnerable and affected by effects such as coastal erosion and flooding. Thus affecting areas rich in natural resources and areas where the tourism industry and commerce are established. The high vulnerability of these areas, utility infrastructure, roads and dams that significantly influence the processes of erosion.

**Methodology.** The Energy and Climate 21 (EC21) software is designed and developed on the basis of some fundamental concepts generated in Agenda 21. Which simulates global warming generated by increased concentrations of carbon dioxide in the XXI Century. The concentration of carbon dioxide in the atmosphere has increased considerably in the last 175 years from 280 ppm (parts per million in 1830 to 380 ppm in 2005 and 400 ppm record figure of the industrial era in 2013) [9]. Carbon dioxide increased by the burning of tropical forests, but mainly by the energy of humans, such as using fossil fuels, oil and natural gas, being the most important in the production of energy. Burning fuels to 2005 has increased by 25 billion tons on Earth. The software EC21 illustrates concentration curves of carbon dioxide in the atmosphere from 1830 to the present day and calculating it until 2100. EC21 Using these data we simulated global warming in the past and in the future. How much carbon dioxide concentration in the atmosphere could have in the XXI century, depending directly on the amount of fossil fuels used and the energy mix of each country. Which allow us step by step to set the parameters in modeling future scenarios, which in the case of this study will be developed with Colombia and Guatemala given its vulnerabilities and main effects of climate change.

**Basic Parameters.** To anticipate future climate change, we need to project how greenhouse gases will change in the same. A series of emission scenarios have been developed by the Intergovernmental Panel on Climate Change IPCC known as "Special Report on Emissions Scenarios" which reflect a number of ways to the development of future scenarios. In particular, these scenarios are plausible outcome that have been constructed to explain the possible consequences of the influence of human activities on climate in general or specific region. That for the purposes of the study will be held in Colombia. When using EC21 for the first time, it is highly recommended to keep the basic values unchanged for best results, however, advanced users are invited to do some fine tuning for individual purposes.

Step No1.

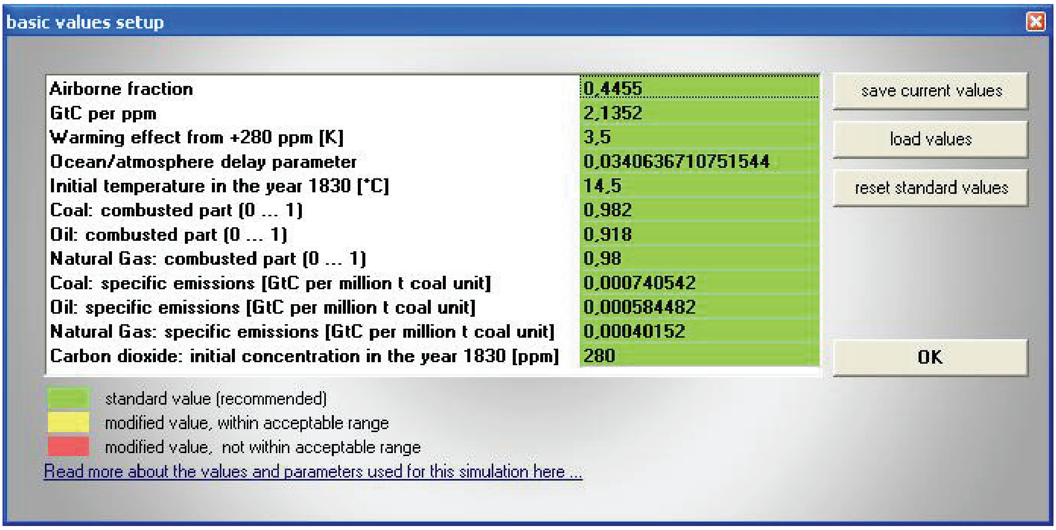


**Fig. 1.** Selection of basic values

About the buttons: "Save current values". This saves your changed values of step 1. When you run EC21 the next time, you may reload them and work with them. On EC21 start, standard values will be loaded by default. To load your own values, load them manually (see next button). "Load values" Load values you have saved in an earlier session. "Reset standard values" All changes of values will be discarded, standard values are loaded. Some short explanation of values: "Airborne fraction" Not all carbon dioxide that has been emitted remains in the atmosphere. More than half of it disappears into carbon dioxide sinks: Some carbon dioxide is absorbed by green plants in photosynthesis, some is physically dissolved in the world's oceans (just to mention the two most important sinks). The standard value is 44.55, which means: 44.55% of the emitted carbon dioxide remains in the atmosphere (this is the airborne fraction), all else disappears into the $CO_2$-sinks. "GtC per ppm" How much $CO_2$ is needed to rise the atmospheric concentration by 1 ppm (part per million): Our answer is: It takes 2.1352 gigatonnes carbon (GtC) in the form of $CO_2$ that remain in the atmosphere, to do this. "Warming effect from +280 ppm [K]" Carbon dioxide heats up the atmosphere. Our simulation standard heat-up is 3.5 degrees Celsius (or Kelvin [K], as scientists say) if the $CO_2$ concentration doubles from pre-industrial 280 ppm to 560 ppm. The effect is linear which means that every rise in carbon dioxide concentration by 280 ppm will lead to an increase of the average temperature on earth by 3.5 Kelvin. “Ocean/atmosphere delay parameter” How quickly does the real warming come true? Carbon dioxide has a radiation effect, the warming of the atmosphere, resulting from the changed radiation balance (less infrared radiation escapes to the space) will take some time: It is also the continents’ surface and especially the oceans with their heat capacity that cause a significant delay. When you click on the value-button you may adjust the temperature adaptation speed in % per year. The standard value is an adaptation speed of 50% in 20 years or approx. 3.4% per year. Please note that a higher delay is equal to a lower adaptation speed.

Step No2.

Initial temperature in the year 1830. In the second step of the EC 21 simulation you may adjust the second major source of atmospheric $CO_2$ increase: Fire clearances, burning forests, especially in tropical rainforests. We recommend you use “standard configuration” when going your first steps with EC21. However, you may create your own forest burning scenario by clicking on “individual configuration”. The following forest burning parameters are available:

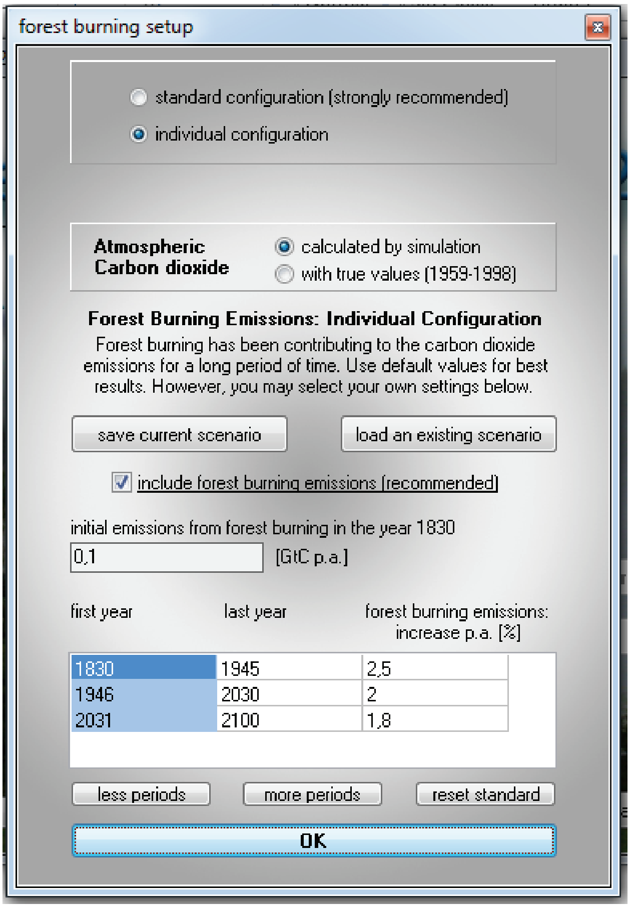


**Fig. 2.** Picking standard forest burning

"Atmospheric carbon dioxide": Click this option to let EC21 calculate the global warming using true atmospheric concentration data in the period from 1959 to 2005 instead of calculating the $CO_2$ concentration from emissions. 1959 is the starting year because this was the first year to have precise measurements of atmospheric carbon dioxide. "Include forest burning emissions (recommended)": This allows you to include or exclude forest burning into the EC21 global warming calculations. By default they are included since forest burning causes a highly considerable amount of $CO_2$ emissions every year. However, to just find out about the effect of fossil energy consumption, it might be interesting to exclude forest burning and see what happens. "Initial emissions from forest burning in the year 1830"Set the initial value for forest burning emissions here. Our simulation starts in the year 1830. By default the value is set to 0.1 gigatonnes in the year 1830.

Step No 3 This window offers you three regional options for your simulation.

"Worldwide View": Click this option when working with EC21 as a beginner. You may enter the development of future emissions on a global scale, as world average data. "One Region View": This gives you the opportunity to take a special look at one region of your choice. Settings for future emissions can be made for one out of six world regions and for the rest of the world (all other regions). See how big the influence of one world region is. "One Country View":

Take a look at the influence of one country here. Make special future emissions settings for this country as well as special settings for the rest of the world. Due to database restrictions not all 190+ countries of the world are available in the list, in many cases countries are only available as country groups (F.3.)


**Fig. 3.** Selecting region, countries or globally

Step No. 4: First time periods are defined. Within the first time the scenarios are defined, starting from 2005 and should finish 2100. The values are taken from the web portal for trading economics Colombia, on the percentage of energy and fossil fuels on the report of projected electricity demand in Colombia, 2013 [9].

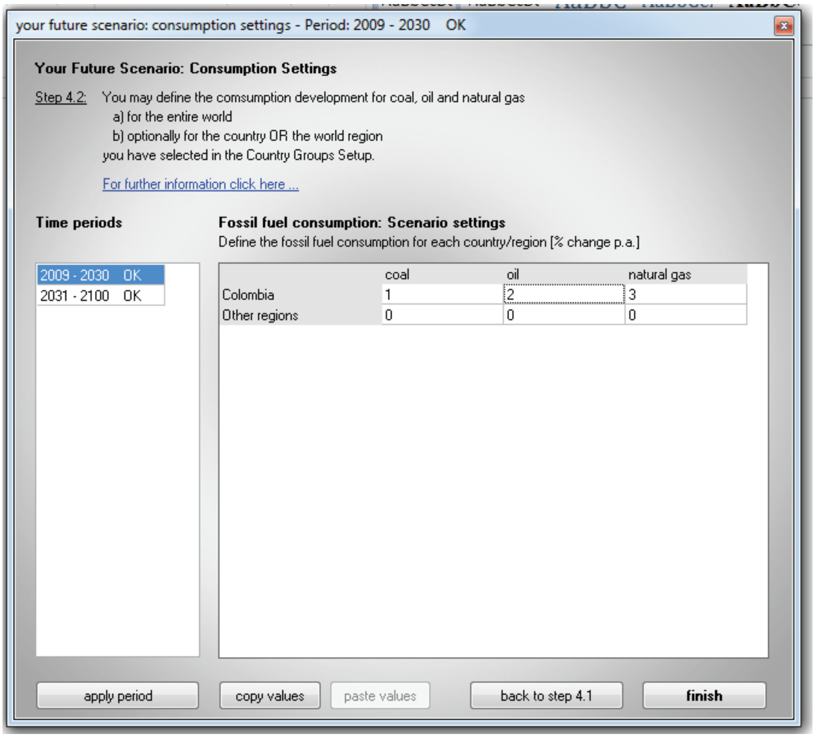


**Fig. 4.** Percentages of increase in fossil fuel consumption during 2009—2030

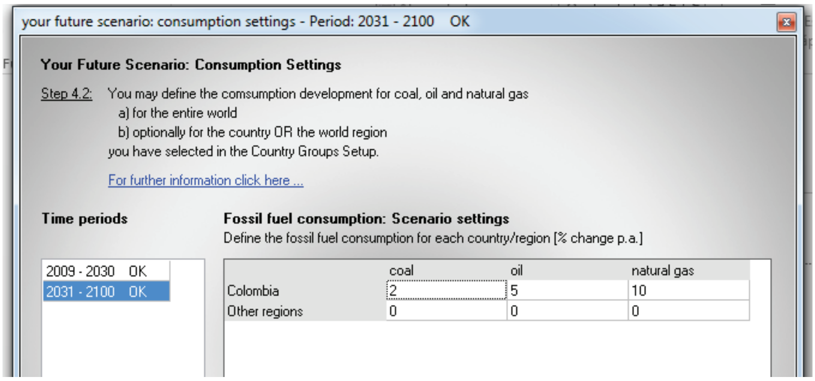


**Fig. 5.** Percentages of increase in fossil fuel consumption during 2031—2100 Period

### Modeling $CO_2$ concentration (PPM)

In the following figures we can see increase in $CO_2$ concentration (ppm), exceeding the current 380 ppm. Which under the future scenario in the medium and short term with the percentage increase in consumption of fossil fuels in Colombia. The exponential of $CO_2$ growth to 2030 year a concentration of 425 ppm and to 2100 more than 560 ppm (fig. 6).

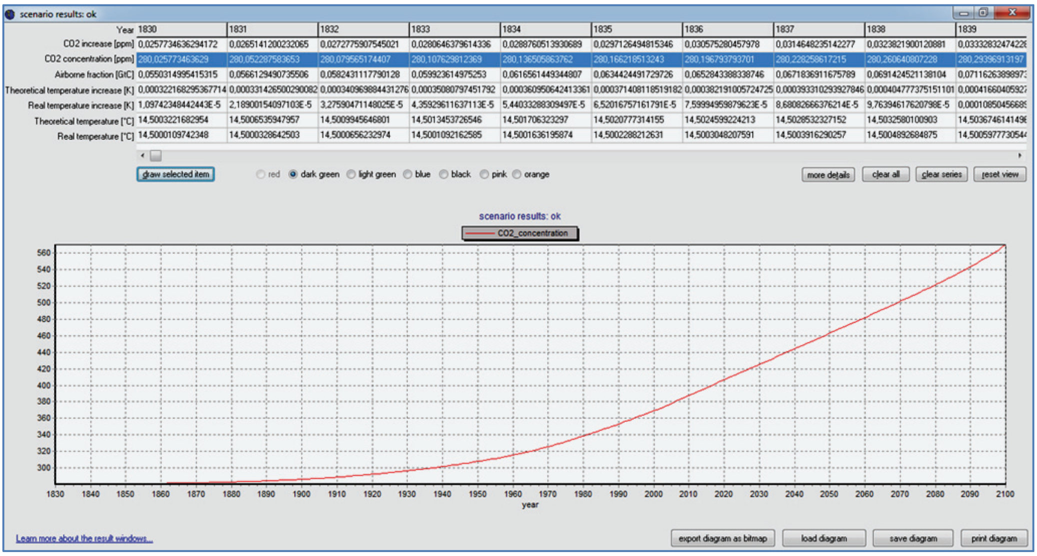


**Fig. 6.** Modeling of increased $CO_2$ emissions

Modeling increase in theoretical vs real temperature. Estimating the main factor in the concentration of $CO_2$ is increasing the temperature, which for these scenarios the two trends of increasing the real temperature (RT) and theoretical (TT) are compared.

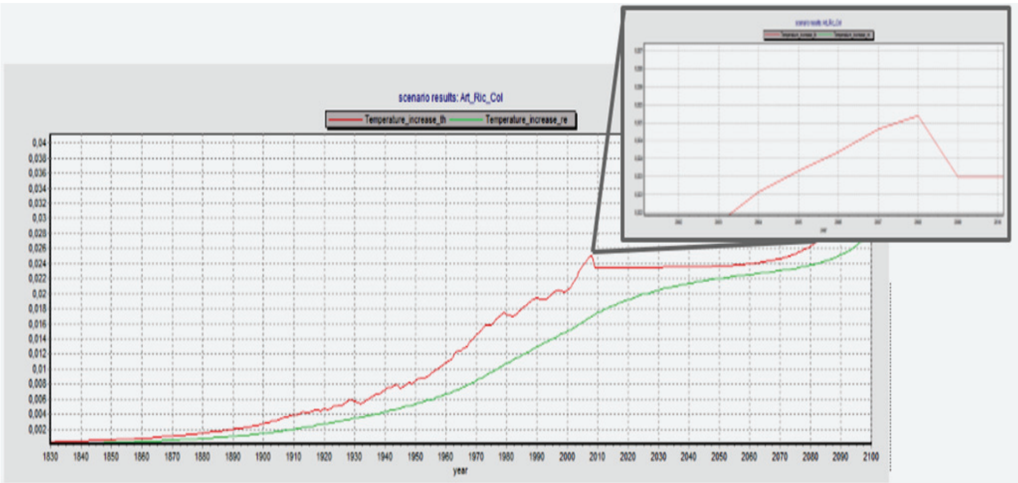


**Fig. 7.** Modeling increase in theoretical vs actual temperature

**Analysis.** Reviewing the main stages of the modeling results with the EC21 software and documents generated some nationwide Colombia on global warming. Hurricanes, droughts and floods and economic losses in agricultural sectors: the increase in climate-related disasters is anticipated. Since the change of land use, grazing animals, has affected the ecosystem as bioclimatic zones of high mountains, valleys and dry Caribbean region, initially by water stress and high water demand crops such as; rice, tomato, wheat and potatoes. The temperature increase in Colombia extends between 2 to 3 degrees Celsius, thermal levels in each region. In the model on increasing the temperature, we observe a peak followed by a prolonged desizing valley, mainly because the impact of "La Niña" during the years 2009/2010 on the main regions. Leaving significant economic losses in urban and rural areas by large floods and average temperature regulation, despite its intrinsic condition similarly moderate, the more negative effects than positive dynamics reveal a growing global warming announcing further adaptation climate change. With respect to the behavior of the snowy glaciers or Colombian, has accelerated a loss of area from the late Age of Glacier Small (1850). The data rate of glacier area in Colombia indicate a rapid glacier melting as illustrated in Figure (4), especially in the last three decades, with losses of 3—5% per year glacier coverage and glacier melting retreated in front of 20 to 25 m per year. Thus, for the period 2002—2003, the total area of glaciers was 55.4 km2, while for the period 2006 to 2007 the area was reduced to 47.1 km2 [2]. As a permanent laboratory from this loss on the water and glacial snowy, which it is estimated that between 2030 and 2040 glaciers disappear in Colombia. Given the progress that Colombia has on policy and environmental and industry regulations, the proposed adaptation actions are aimed largely at strengthening measures already taken but need to consider the weather variables in their planning and execution as strengthening management research and knowledge transfer in the academic sector. However one of the main routes of adaptation to climate change is the use of natural resources and land use planning, Colombia has been making progress in the inclusion of all development plans of the environmental component that allows to reduce environmental impacts, social and economic. The Government of Guatemala in recent years has sought to reverse this trend of the past particularly through the Ministry of Environment that defined the issue of climate change as a priority of his administration. Since early 2008, the process of developing national climate change policy seeking the identification and implementation of principles began.

**Conclusions.** Population accelerated growth and pressure on the environment, makes a urgent call to action and decision making about the resilience of ecosystems, maximization the scope in environmental policy and economic and social benefits, also respecting the planetary ecological limits. While developing countries have presented a greater vulnerability to climate change, without being the main sources of $CO_2$ emission, it is a challenge for states, because not only is affecting its main economic activity, as is the agriculture and the provision of ecosystem services, there is a large gap in the inclusion of adaptation and mitigation plans that lead to increased vulnerability in climate disasters. All government institutions must include in its management the issue of climate change to reduce risk and prevent large economic and social impacts generated. For countries like Colombia and Guatemala, which highlights its high environmental management standards, has a large deficit in the quality and management of natural resources, however for purposes of analysis, show the main consequences of climate change on fragile ecosystems as coastal areas due to sea level rise, increasing the average temperature mainly affects high mountain ecosystems such as paramos and glaciers. Thus, one strategy must be aimed at in the Reduction of $CO_2$ emissions energy, agriculture and transport sector. But because of its position in countries vulnerable to climate change is of great importance to strengthening mitigation and adaptation plans in each state strategies and programs focused on the population has been affected in recent weather events. Finally, the challenge presented to the Latin American governments and society in resolving environmental conflicts and negotiation of sustainability goals, which ensure the existence of a transparent, informed and participatory debate and decision-making towards sustainability, articulating clear decentralization processes that promote greater involvement of the most vulnerable local communities, as well as an active participation of the private sector and civil society.

## REFERENCIES


[1] *Marjolaine C.* El Cambio Climático en Colombia y en el Sistema de las Naciones Unidas, revision de riesgos y oportunidades asociadas al cambio climático //. — 1987. — Vol. 1. — P. 3—4. Colombia.

[2] *Lozano P.* República de Colombia segunda comunicación nacional ante la convención marco de las naciones unidas sobre cambio climático //. — 2010. — P. 16—20. Colombia.

[3] *Garcia M.* Colombia el tercer país del mundo más vulnerable al cambio climático //. — 2012. — P. 1.

[4] Propuesta Rio+20. Objetivos de Desarrollo Sostenible (ODS's) Propuesta de los Gobiernos de Colombia y Guatemala // Ministerio de Relaciones exteriores de Colombia. — P. 11—20.

[5] *Oswaldo B.* Información técnica sobre gases de efecto invernadero y el cambio climático // Ministerio de ambiente. — 2008. — P. 36—50.

[6] Ministerio de Ambiente y recursos Naturales Guatemala // Inventario de Gases de efecto Invernadora. — 2005. — P. 6—10. Guatemala.

[7] Australia Government // Climate Change, Risk and Vulnerability promoting and efficient adaptation response in Australia. — 2012. — P. 14.

[8] Mauna Loa Observatory // Trends in Atmospheric Carbon Dioxide (Scripps/NOAA/ESRL). — URL: http://www.esrl.noaa.gov/gmd/ccgg/trends. — 2014.

[9] Trading economics Colombia // Economic indicators. — URL: http://www.tradingeconomics.com/colombia/indicators. — 2014.


# МОДЕЛИРОВАНИЕ СЦЕНАРИЕВ ИЗМЕНЕНИЯ КЛИМАТА И ВЫБРОСОВ $CO_2$ В СТРАНАХ ЛАТИНОАМЕРИКАНСКОГО РЕГИОНА НА ПРИМЕРЕ КОЛУМБИИ И ГВАТЕМАЛЫ С ИСПОЛЬЗОВАНИЕМ ПРОГРАММНОГО ОБЕСПЕЧЕНИЯ “ENERGY AND CLIMATE EC21”


**А.И. Курбатова, Рикардо Фонсека Овале, Мариделин Рамос Арука**

Экологический факультет
Российский университет дружбы народов
*Подольское шоссе, 8/5, Москва, Россия, 121552*



Латиноамериканские и страны Карибского бассейна, включая Колумбию и Гватемалу, очень уязвимы к последствиям изменения климата, так как регион характеризуется неустойчивостью агроэкосистем, находящихся на побережьях и большая часть населения испытывает дефицит пресной воды, что оказывает ключевое воздействие на экономику. Для оценки и прогноза возможных изменений климата в регионе авторами было использовано программное обеспечение «Climate 21 (EC21) и энергия». Прогнозирование было применено на основе данных для Колумбии. Для моделирования были заданы различные параметры, влияющие на выброс углекислого газа, что позволило оценить колебания температуры как в краткосрочном, так и долгосрочном периоде.



**Ключевые слова:** окружающая среда экосистемы, последствия изменения климата, программное обеспечение, концентрации углекислого газа.