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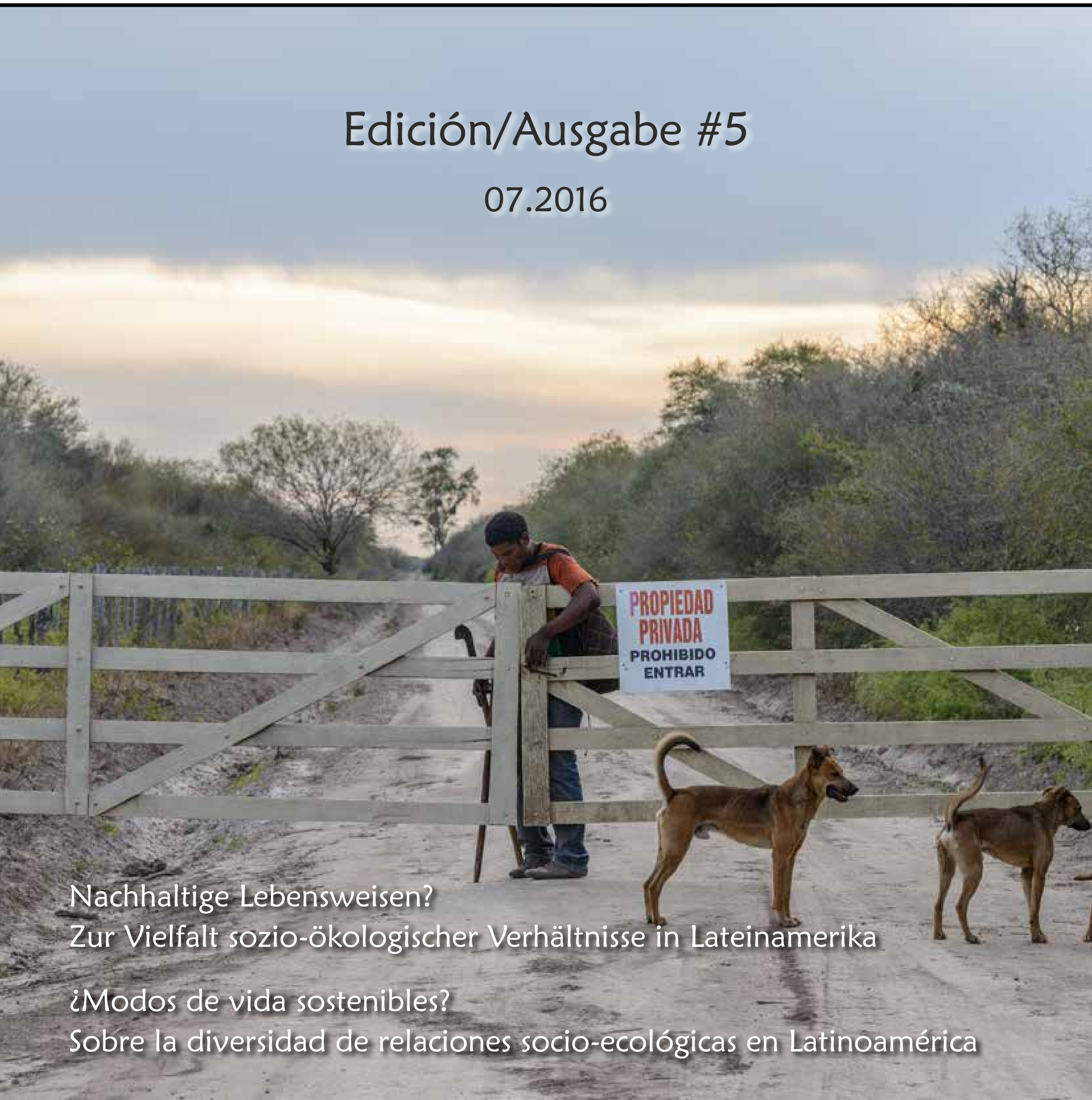

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07.2016

Nachhaltige Lebensweisen?
Zur Vielfalt sozio-ökologischer Verhältnisse in Lateinamerika

¿Modos de vida sostenibles?
Sobre la diversidad de relaciones socio-ecológicas en Latinoamérica

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Lateinamerika

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www.revistarevela.com
revela.viena@gmail.com

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Carolina Rojas

* El contenido de los distintos artículos es responsabilidad de sus autores, y no necesariamente refleja la opinión de la Revista ReveLA

ReveLA
Realidades y visiones sobre Latinoamérica

Editorial

Queridos lectores,

Con la quinta edición de la Revista ReveLA empieza nuestra revista su tercer año. Luego de la publicación de la cuarta edición y la exitosa conformación de la revista como asociación en el invierno pasado, hubo unas merecidas semanas de calma en la editorial, esto debido a que a principio del presente año cinco miembros del equipo editorial finalizaron sus trabajos de investigación y con esto llevaron a término la Maestría en Estudios Interdisciplinarios Latinoamericanos. Sin embargo, la presunta calma no duró mucho tiempo y pronto empezó la Revista ReveLA a dar varios pasos muy productivos.

Así como en los dos años anteriores, una gran parte de los miembros del equipo participaron en el Congreso anual de Invertigación latinoamericana en Austria (LAF) del 29 de abril al 2 de mayo de 2016 en Strobl am Wolfgangsee, en donde se presentaron los progresos de ReveLA del último año. Como asociación y revista, que pretende apoyar el intercambio científico y cultural, esta cita anual resulta especialmente importante.

Un gran avance para ReveLA y la recién fundada asociación, se reflejó en el trabajo conjunto con Claudia Sandoval Romero y la publicación del libro de fotografías "Postcards from Italy" a mediados de Mayo, en el marco de la primera Edición Especial de ReveLA, publicada en abril en nuestro sitio web y de libre acceso para el público.

Con gran satisfacción tenemos el gusto de presentar los nuevos miembros del equipo. En primer lugar Natalia Serrano Àvila, quien ya desde la temporada de invierno se integró al grupo editor con ímpetu y nuevas ideas. Poco antes del cierre de este ciclo, se integraron a nuestra revista los nuevos corresponsales: desde Guatemala, Fatima Antonethe Castaneda y desde Nicaragua, Tania Sosa Jirón. Así mismo Rodrigo Ruiz se convirtió en el primer practicante en la historia de nuestra publicación. Estamos a la expectativa de sus aportes y por este trabajo conjunto, por el que nos alegramos mucho.

También existe la novedad del trabajo en conjunto de nuestro proyecto con la Maestría de Estudios Latinoamericanos en el Posgraduate Center de de la Universidad de Viena. A partir del semestre de invierno 2016/2017 será posible realizar una práctica de seis meses en la Revista ReveLA, esta podrá ser convalidada como curso libre dentro del currículo del programa universitario. Mayor información al respecto se encuentra en la sección Maestría.

En nuestra edición actual nos complace nuevamente presentar una contribución abundante y diversa. En la sección científica aparecen esta vez textos alrededor de la pregunta "¿Modos de vida sostenibles? Sobre la diversidad de relaciones socio-ecológicas en Latinoamérica".

¡Les deseamos una lectura emocionante!

Therese Thaler
Equipo editorial ReveLA

Inhalt
Contenido

*mit Fotos von Gerald Henzinger, Jonas Wagner und Michael Kleinburger

Sección Científica

El tema científico de la quinta edición de nuestra revista aborda las diversas concepciones y prácticas de las relaciones socio-naturales en Latinoamérica. Estas concepciones y prácticas tienen que ver con cuestiones del fundamento epistemológico mismo, que se encuentra, por ejemplo, en términos como "naturaleza", y también generan interrogantes acerca de la relación, concepción y explotación de los ecosistemas naturales en diferentes sociedades latinoamericanas, así como acerca de las consecuencias de los efectos globales ecológicos en tales relaciones socioambientales.

La diversidad de estas concepciones y realidades, sobre las cuales hemos invitado a escribir, no se mueven en planos únicos, neutrales - ni a nivel práctico ni analítico-, sino, que se posiciona en contextos de poder y estructuras de dominación, las cuales llevan al favorecimiento y la implementación de ciertas concepciones sobre la naturaleza y las prácticas socioambientales, así como a la opresión de otras

Un aporte importante, cómo la influencia de la colonialidad existente en el orden del poder y las relaciones de violencia epistémica en las concepciones socio-ambientales en Latinoamérica, es realizado por Juan Pablo Gerez Hade en su análisis sobre la continuidad de relaciones de explotación en las fases consecutivas de neoliberalismo, post-neoliberalismo en los gobiernos "progresistas" de Latinoamérica. Therese Thaler describe en su artículo la relación entre las coyunturas turísticas, las estrategias políticas de protección y la integridad ecológica de los arrecifes de coral en la Isla de Roatán, que pertenece a Honduras. Alexandro Aguilar Zisler se sitúa en las condiciones históricas, así como las consecuencias sociales y ecológicas del programa brasileño de Bioetanol, lo que hace parte de la compleja problemática global de agrocombustibles. Por último, Christoph Eckart, basado en una sinopsis de datos provenientes de las ciencias climáticas y agronómicas, se centra en la cuestión: ¿Qué implicaciones tiene el cambio climático global sobre la producción de alimentos de las diferentes zonas climáticas de América Latina?.

Los últimos tres artículos fueron escritos por estudiantes y egresados del Máster en estudios latinoamericanos en Viena. Juan Pablo Gerez Haded por su parte, desarrolla el programa en Estudios Globales en Graz. Felicitamos el exitoso trabajo de los autores y le deseamos a usted una lectura interesante y esclarecedora.

Gregor Seidl

Climate Change & Agriculture in Latin America - Possible Climate Change Impacts on Agro-Ecological Regions of Latin America

*Christoph Eckart**

1. Introduction

On a geological timescale the first eon, called Hadean, started around 4.6 billion years ago, in numerical terms that turns into 4,600,000,000 years ago. First human settlements in the Middle East are dated to have started 10,000 years ago, whereas in the Americas, the Norte Chico civilization is estimated to have started to foster around 4,000 BC in northern central Peru. If human life on the blue planet has come such a long way, it's hard to imagine that humans could alter the earth's atmosphere in just 150 years. Still, this is what climate diagrams tell us, the carbon dioxide content of the earth's atmosphere is estimated to have increased from 200 parts per million to around 400 parts per million since the industrial revolution. Given these differences in time, one can understand if people sometimes face difficulties understanding the issue of a changing climate and treat the subject with neglect and incomprehension. On the other hand though, the distance from my apartment in the 16th district in Vienna to the University of Natural Sciences is 4.3 kilometers, walking that way twice and imagining the travelled distance vertically is approximately the height of Mount Everest, where the air gets so thin that ascenders mostly need equipment to breathe. In this layer from the ocean to the highest peak on earth, also called the troposphere, all the necessary components of air are found, which make survival on earth for fauna, flora and humans possible. Going one step further, we can observe that the population on earth in the beginning of the 19th century was around one billion; in the year 2014 the number is estimated to be greater than 7 billion. Additionally to this number of people, taking into account all the cars on earth, the factories and the animals bred for food consumption, the layer of about 8 kilometers above sea level appears to become increasingly thinner and the probability that the sum of the factors mentioned along with many others have the power to change the planet's atmosphere becomes more likely. This should convince even the hardest opponents of the theory of a human caused change in the climate to think at least about it and get acquainted with the subject. For the reasons above, the question "Does climate change happen?" is not discussed in this paper, but treated as a development of utmost importance.

The idea to write a seminar paper on "Climate Change and Agriculture in Latin America" came from Dr.a Maria Wurzinger and evolved during a seminar course on "Adapted use of natural Resources" in the context of Latin America at the University for Natural Sciences in Vienna. The poster to this paper was presented in June 2014 and a copy can be found in the appendix. The author is very thankful towards Dr.a Wurzinger for the inspiration and the opportunity to write about this topic.

As the question on the existence of climate change was already elaborated on, it remains to be discussed why a change in the climate is important in the first place. In a dramatic fashion one could say, that climate change is about life and death. The changes in the atmosphere can affect the health of every species on earth, including humans, sea levels may rise and drown uninhabited as well as inhabited soil, rain patterns or seasonal patterns may change with regards to timing and intensity, temperatures may rise, melting glaciers and ocean ice, which in turn changes the pH number of the sea, killing corals or other species, which keep life on earth in balance. All these changes and many more with even some that we're probably not aware of yet may result in numerous and unpredictable feedback loops. Theories change why the dinosaurs left the face of the earth or why the Maya civilization broke apart before Columbus' successors colonized and oppressed American societies, but part of the reason could have been a change in the climate. It seems reasonable to have a closer look at the topic.

As there are so many question marks surrounding climate change, this paper will narrow its focus to the possible effects of climate change on agriculture with a regional scope on Latin America. A non-unneglectable part of Latin America's population lives in rural areas and depends on agriculture as a source of nutrition, income and social linkages. This mostly low income population will probably be affected by climate change. It is the group with the fewest possibilities of countermeasures, as it lacks the funding for technology like irrigation or for migrating to other areas – irrespectively, that no one wants to leave home behind anyways. Changes in the climate will hurt the poor rural population in Latin America and place a massive obstacle on an already fragile path of development towards future.

These arguments regarding the importance of climate change lead to the definition of this paper's purpose: To give an overview on how climate change is estimated, which techniques or models are used, to evaluate some outcomes of these models, give an indication which projections on possible developments of climate change on the socio-ecological zones of Latin America are made and finally, to check if there are any mitigation or adaptation efforts. It shall also be mentioned that due to the complexity, depth and broadness of the topic, a study in this context can only serve as a starting point for further research.

Hence, the following questions are subject to discussion in this paper:

• Which climate change estimation models are currently used?

• What are the projected climate changes and their effects on agriculture in Latin America?

• Which countermeasures, to avoid, mitigate or adapt to global warming, are planned or already in place?

In the first paragraph of this introduction the expression "parts per million" carbon dioxide was already mentioned, as there are so many technical definitions in the world of climate change a definitions section will follow the next chapter on the methodology of research applied during the production of this paper. Then, the core sections on climate change estimations for Latin America and their impacts on agriculture are discussed in Section 4 and Section 5 respectively. As discussed during the poster presentation at the end of June 2014 a section on mitigation and adaptation possibilities is included before the closing conclusions and summary.

2. Methodology

To approach the topic and to get an overview, the book "Field Notes from a Catastrophe. Man, Nature, and Climate Change" by Elizabeth Kolbert (Kolbert 2006), Gordon Conway's book "One Billion Hungry: Can we feed the World?" (Conway 2012) and William R. Cline's "Global Warming and Agriculture" (Cline 2007) were read. All three books proved helpful to find interesting studies on the subject. In a next step the online archives of the University of Vienna were researched as well as numerous online publications by the FAO, IAASTD, IFPRI, IPCC and the Stern Review on the economic costs of climate change. Fortunately, exactly during the research period the 5th IPCC Assessment Report was published, on which most of the following sections on climate models will be based, as it "…provides a clear and up to date view of the current state of scientific knowledge relevant to climate change." according to the United Nations Intergovernmental Panel on Climate Change (IPCC 2014).

In order to facilitate the traceability and transparency of the citations, details about chapters and pages were included.

3. Definitions

3.1. Climate Change

"Climate change means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods."[1]

Although this definition is handy and short, the question "What influences our climate?" remains. Figure 1 answer this question of the climate's main drivers in a simplified manner. As shortwave radiation (SWR) from the sun enters the atmosphere about half is absorbed by the Earth's surface, 20% is absorbed by the Earth's atmosphere and 30% is reflected back to space by clouds, aerosols and the Earth's albedo (IPCC 5AR WG1 Chapter 1 2013). Aerosols are solid or liquid particles in the atmosphere and have a cooling effect, or negative feedback, on the atmosphere when small, but if large in size they can also be strong absorbers as they change the consistence of clouds. High aerosol concentrations are often observed after volcanic eruptions and although they can also warm up the atmosphere they're mostly referred to

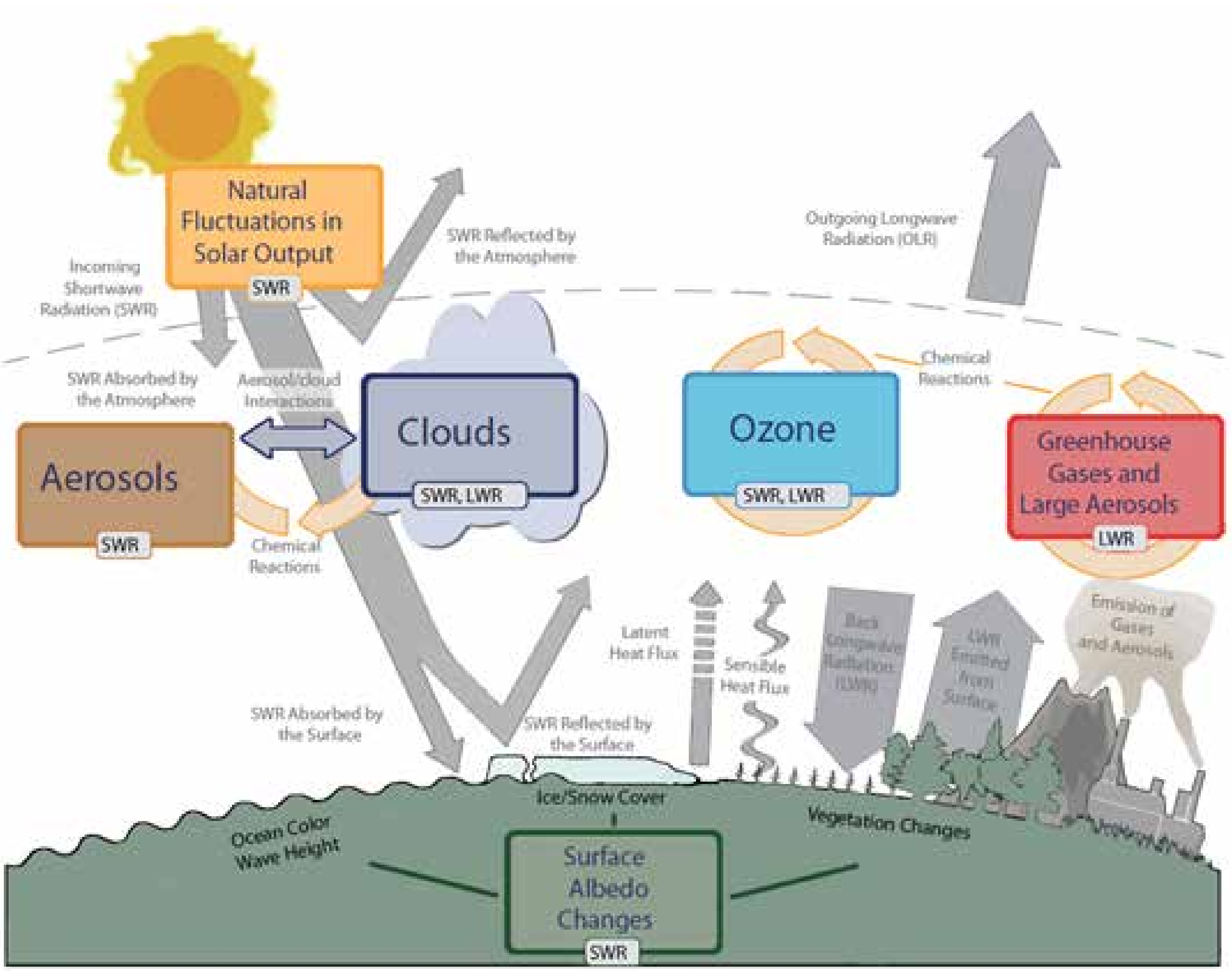

Figure 1: Main Climate Drivers
Source: IPCC 5th Assessment Report, Working Group 1, Chapter 1, Page 126 (IPCC 5AR WG1 Chapter 1 2013).

as 'cooling' in literature. The Earth's albedo can be described as a reflection measure of solar radiation, where an albedo of 1 indicates the highest reflection possible and 0 the lowest possible. Ice or snow cover has an albedo of close to 1, whereas the ocean has a low albedo towards 0. The majority of reflected SWR by the surface turns into longwave radiation (LWR), also called infrared radiation and is largely absorbed by greenhouse gases (GHG), which will be explained in the next section, and clouds. When clouds reflect LWR back to the Earth's surface the outcome is called the Greenhouse Effect. If humans alter the properties of the atmosphere by emitting GHG, or changing the Earth's albedo through vegetation changes such as deforestation or declining ice cover, the Greenhouse Effect increases, the atmosphere gets warmer and thus the climate changes.

A warmer climate does not necessarily mean more days at the beach, but an increase in the temperature may have severe impacts on agriculture, the water household of the planet, ecosystems, extreme weather events and can even shift the overall climate system of the planet. Some potential changes to the world as we know it today are summarized in Figure 2, taken from The Stern Review on the Economics of Climate Change (Stern 2006).

In the context of this paper the impacts of climate change on agriculture should be underlined primarily, but as this example shows, the possible effects of climate change are so heavily interconnected, that it is hard to exclude one effect, which would seem irrelevant for agriculture. As the size of this paper is limited, just a few observations are described in the following chapters. With increasing temperatures crop output also known as yields are projected to decrease - with or without 'carbon fertilization', a term to be explained in Section 3.3. The water availability for regions may change, leading to scarcity for one region and to floods for other ones. The Earth's most important ecosystems with their life species are under threat and extreme weather events are expected to increase in frequency and intensity. Overall, developing regions

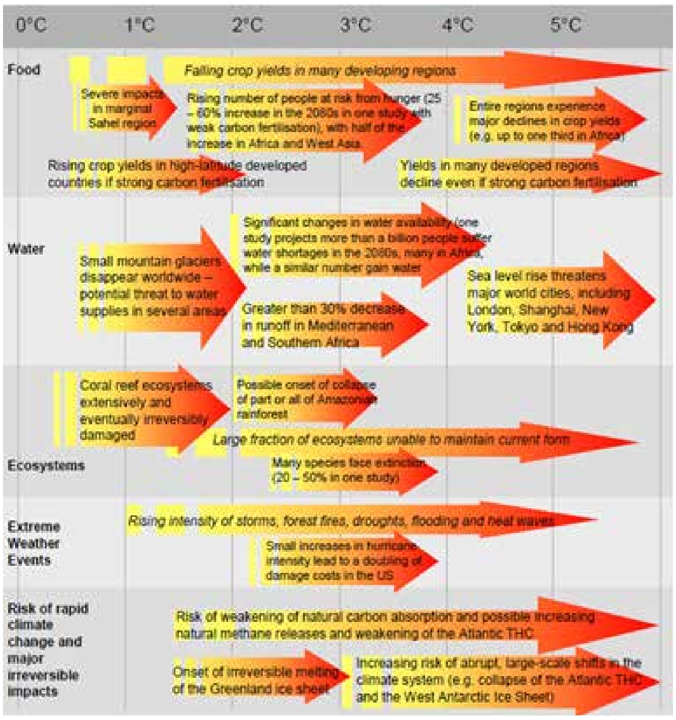

Figure 2: Possible Effects of increased Temperatures according to the Stern Review
Source: Adapted from the Stern Review on the Economics of Climate Change (Stern 2006).

where most of the low income population lives are expected to suffer most. Latin America is one of these developing regions.

3.2. Climate Models

The central components of climate change science are climate models, with the most sophisticated ones being coupled climate models. These coupled climate models are assembled by numerous single climate models, which are often specialized on certain topics e.g. the simulation of ocean warming or with a focus on special regions. A historical overview of climate model development during the last forty years is shown in Figure 3. In the mid-1970s climate models focused on simulating the atmosphere, the land surface, the ocean and sea ice. The most recent models used in the 5th IPCC Climate Assessment Report (AR5) today include simulations and projections for aerosols, the carbon cycle, the vegetation, atmospheric chemistry and land ice like glaciers. The increased complexity and range of the models is depicted by growing cylinders in Figure 3. The analysis in the remainder of this paper will be based on the output of these AR5 models. In the IPCC Climate Assessment Report they are defined under the umbrella term 'Climate Model Intercomparison Project' or CMIP. Because the latest IPCC Report is the 5th one, the models are called CMIP5. As the models try to make projections about future scenarios, assumptions for the development of e.g. future GHG in the atmosphere have to be taken into account. Within the CMIP5 four different scenarios are calculated, with each scenario being characterized by a 'Representative Concentration Pathway' (RCP) for the period starting in the year 2000 until the year 2100. From the year 2100 onwards the scenarios are called 'Extended Concentration Pathways' (ECPs), but this paper only refers to the RCPs. The four RCPs are namely RCP2.6, RCP4.5, RCP6.0 and RCP8.5 and each one of them is characterized by different assumptions regarding GHG, where RCP2.6 is the scenario with the least intensity increase of GHG and RCP8.5 the model with the highest intensity increase of GHG. Alternatively, one could also say that RCP2.6 is the most optimistic scenario and RCP8.5 the most pessimistic scenario. Figure 4 in Section 3.3 depicts the RCPs. RCP4.5 and RCP6.0 represent the middle path. All four RCP models include calculations comprising historical emissions, land use data, reactive gas emissions, aerosol emissions, ozone and GHG. As the details regarding the single attributes of each model are very complex only the assumptions regarding the following GHG for each RCP will be used and elaborated in Section 3.3.: Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFC).

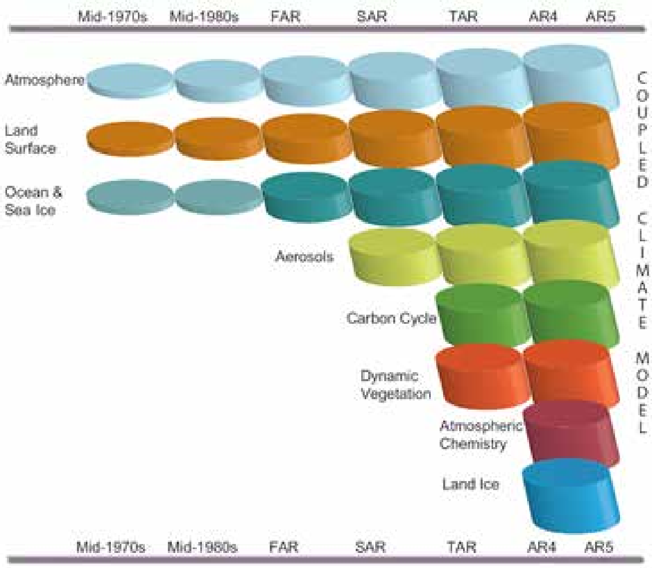

Figure 3: Evolution of Climate Models from the 1970s to date
Source: IPCC 5th Assessment Report, Working Group 1, Chapter 1, Page 144 (IPCC 5AR WG1 Chapter 1 2013).

3.3. Greenhouse Gases (GHG)

In principle there are a number of greenhouse gases, but carbon dioxide, methane, nitrous oxide, ozone, water vapor and chlorofluorocarbons are the primary GHG. Chlorofluorocarbons belong to the family of halocarbons, which are human made or anthropogenic. The Montreal Protocol, signed in 1987, explained the dangers of CFCs for the ozone layer in detail and led the majority of global policy makers to a ban of human activities or products leading to CFC emissions. The primary GHG though are natural as well as anthropogenic and absorb and emit radiation, shortwave (SWR) and longwave (LWR) as described in section 3.1. When natural forces like volcanic eruptions or humans alter the composition of GHG in

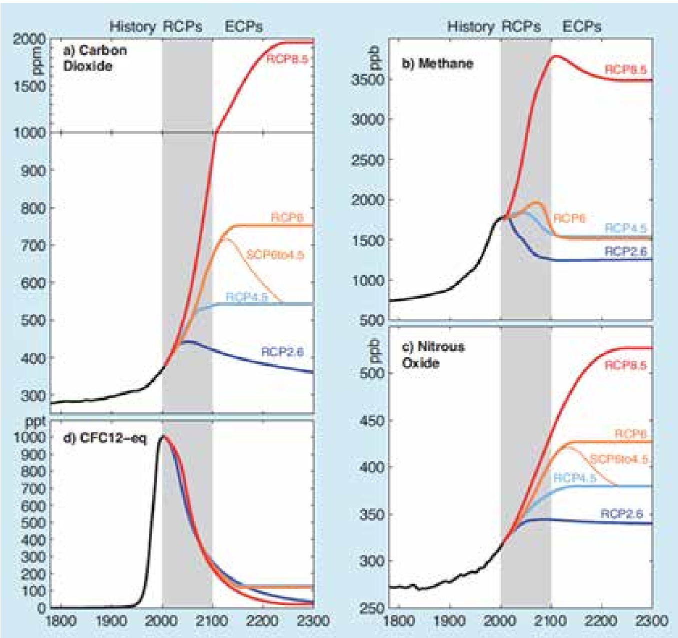

Figure 4: Greenhouse Gas Development Assumptions underlying the IPCC Climate Models
Source: IPCC 5th Assessment Report, Working Group 1, Chapter 1, Page 148 (IPCC 5AR WG1 Chapter 1 2013).

the atmosphere the climate may change. This change can occur abruptly or with a long feedback. Figure 4 depicts the GHG assumptions for a) CO2, b) CH4,c) N2O and d) CFCs for the four RCP scenarios in red, orange, light blue and dark blue. The black lines indicate real observations and increase exponentially since the 20th century. Throughout all four RCPs the CO2 content in the atmosphere is expected to increase until the year 2100. In the beginning of the 21st century the CO2 content stands at approximately 400 parts per million (ppm). According to the Keeling Curve, which tracks the CO2 content at the Mauna Loa Observatory in Hawaii since 1958, the number stood below 320 ppm in the beginning of the 1960s. All four charts can be observed accordingly, but an interesting development can be seen in chart d) on CFCs, which are indicated here as CFC12-eq meaning chlorofluorocarbons equivalents and including also halocarbons. The interesting detail is that these CFC12-eq are human made and increase sharply in the second half of the 20th century, a time of military appliances production during the cold war and when most of the so called developed nations were equipped with refrigerators or air-conditioners. CFCs were an important ingredient for these products.

3.4. Carbon Fertilization – C3 and C4 Crops

Carbon fertilization refers to the possibility that an increase of carbon dioxide may have a positive effect on the growth of plants, including crop plants. During photosynthesis plants combine water and carbon dioxide. To absorb carbon dioxide the plant has to open its pores, which goes along with a loss of water. If there's more carbon dioxide in the atmosphere the plant has to respire less to acquire the needed amount of carbon dioxide and loses less water. Some crop plants are supposed to benefit more from carbon fertilization than others, hence they are categorized into two groups: Firstly, C3 crops which include rice, wheat, soybeans, fine grains, legumes and trees. These group C3 plants should benefit from more carbon dioxide in the atmosphere or carbon fertilization. Secondly, C4 crops are corn, millet, sorghum and sugar. Carbon fertilization is perceived to have only limited impact on C4 plants (Cline 2007). According to literature the effect of carbon fertilization is debated and empirical studies have found different results when tested in the laboratory and in the field. William Cline uses a 15% yield increase[2] through carbon fertilization for his study. The results are at the center of Section 5 in this paper.

4. Climate Change Models for Latin America

The following sections will analyze the output or projected climate changes of the CMIP5's RCP4.5 model for Latin America by dividing the region into three sub regions: (1) Mexico, Central America & the Caribbean, (2) the Amazon and Northeastern Brazil and (3) the South American West Coast and Southeastern South America. The RCP4.5 was chosen, because it represents the middle path of the four RCP models. As can be observed in Figure 4 in Section 3.3 above, the RCP6.0 is also located around the middle with regards to assumed GHG, but tends towards the RCP4.5 in the long run. Therefore preference was given to the RCP4.5 over the RCP6.0. For the regional maps the CMIP5 models estimated for the

50% percentile were chosen, which is indicated in the upper right corner of each map. The reason was again to strike a balance among models. Areas with hatched lines in the precipitation maps indicate that the underlying models differ in their estimation. Hence, there is more uncertainty about the possible outcome. The time horizon for the regional projections was chosen from the year 2081 to 2100 to be in line with the results of Cline, who explained his decision to explore the impact of climate change on agriculture for this period by stating "To assess the impact of climate change on agriculture, it is essential to take account of the effects through at least the latter part of this century. A small amount of warming through, say, the next two or three decades might provide aggregate global benefits for agriculture (albeit with inequitable distributional effects among countries). But policy inaction premised on this benign possibility could leave world agriculture on an inexorable trajectory toward a subsequent reversal into serious damage." (Cline 2007).

The season for all projections was selected to be summertime for each region, meaning from June to August for the regions north of the equator and December to February for the regions south of the equator with regards to temperature change and April to September and October to March with regards to precipitation change. This is only mentioned to show that the analysis is consistent throughout all regions and observed during the same season, theoretically wintertime could have been chosen as well.

The analysis includes also a map for each region depicting the suitability for agricultural cereal farming at present times downloaded from the FAO's GAEZ homepage. In that way a preliminary impact of the estimated climate change can be made and the reader can also look up regions of personal interest without being limited to the author's observations.

4.1. Mexico, Central America & The Caribbean

Figure 5 depicts the model estimates for the temperature change and precipitation change in Central America and the Caribbean. The mean temperature change for Central America and the Caribbean is +2 °C and around +1.7 °C respectively. The amount of rainfall or precipitation is expected to decrease slightly for both regions.

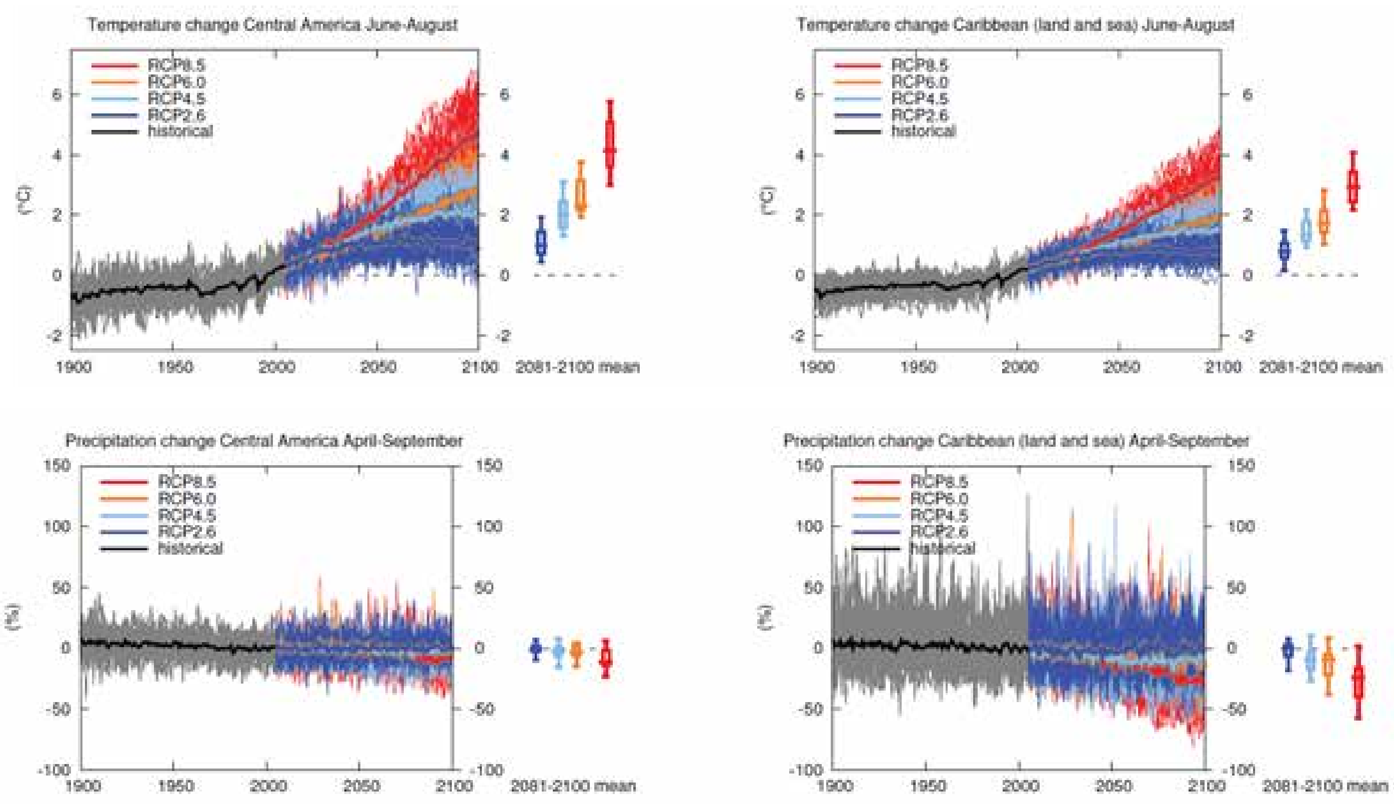

Figure 5: Time Series for the Estimated Temperature and Precipitation Change for Mexico, Central America and the Caribbean
Source: IPCC 5th Assessment Report, Working Group 1, Annex 1, Atlas of Global and Regional Climate Projections, Page 1339 and 1341 (IPCC 5AR WG1 Annex 2013).

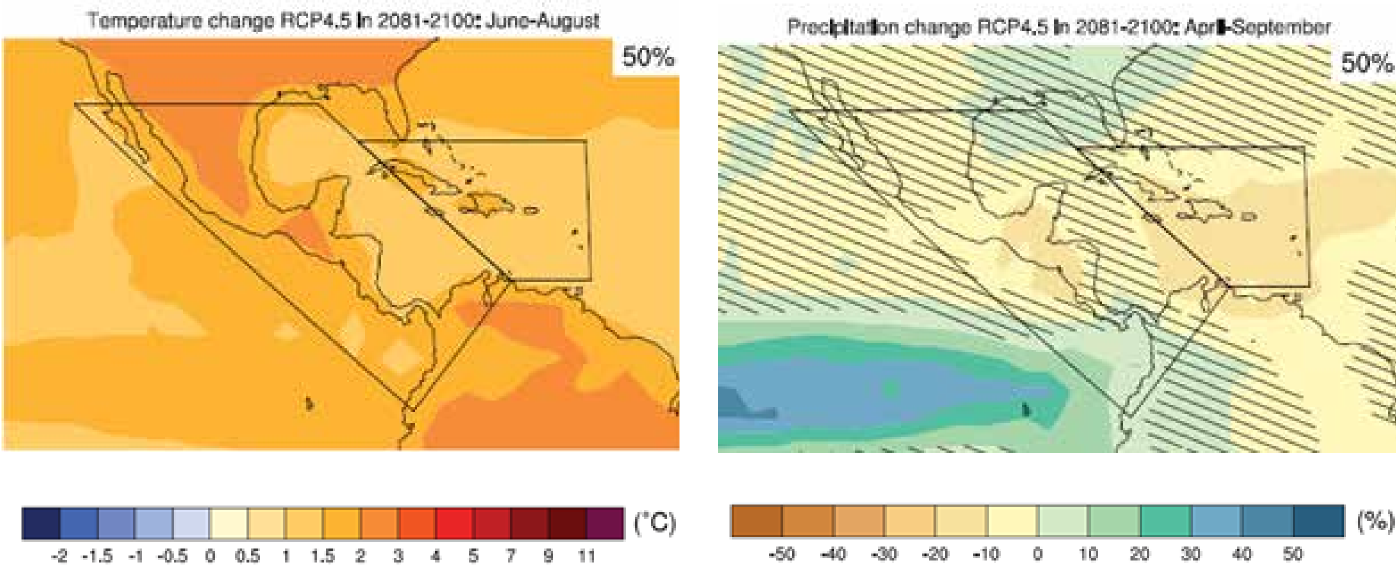

Figure 6: Regional Map for the Estimated Temperature and Precipitation Change for Mexico, Central America and the Caribbean in 2081 to 2100
Source: IPCC 5th Assessment Report, Working Group 1, Annex 1, Atlas of Global and Regional Climate Projections, Page 1339 and 1341 (IPCC 5AR WG1 Annex 2013).

As can be seen in Figure 6, the temperature increase is highest in the interior of the country with less temperature increase in coastal areas. Southern Mexico, the state Chiapas, parts of Guatemala and El Salvador are also estimated to experience a temperature increase of more than +2 °C. This area is also expected to receive around -20% less rainfall in the observation period. Parts of Cuba and Hispaniola see similar results, higher temperatures and less precipitation.

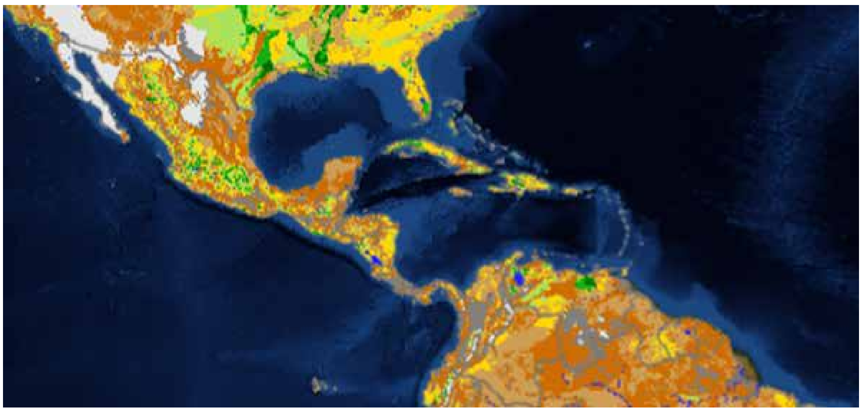

Figure 7: FAO Cereal Farming Suitability Map for Mexico, Central America and the Caribbean
Source: FAO Global Agro-Ecological Zones (FAO GAEZ 2014).

The FAO's map, labeled Figure 7, for suitability of a region for cereal farming shows, that some of the regions impacted by higher temperatures and less rainfall are partially regions with moderate to very high cereal farming suitability these days e.g. Northern Mexico, the valley of Mexico, parts of Guatemala, Cuba and Hispaniola with Haiti in particular.

4.2. The Amazon and Northeastern Brazil

Moving on to the regions mostly south of the equator in the Amazon and Northeastern Brazil, the estimated mean temperature increases for the period 2081 to 2100 are +2 °C for the observed RCP4.5 model. Precipitation seems unchanged for both regions, but as can be seen from the hatched areas in the precipitation map of Figure 9 the models differ in their estimation for a large part of the region.

The temperature increase for the whole region levels around +1.5 °C and +3 °C. Precipitation is expected to decrease by -20% in Venezuela and parts of Guyana.

The FAO map indicates the region around the Venezuelan cities of Barcelona and Cumaná as an area of high to very high suitability for cereal farming. According to the climate observations above, this agricultural region will experience a temperature increase of +2 °C with a precipitation decrease approximately -20%. Farmers in Brazil's north eastern states of Bahia, Ceará, Rio Grande do Norte, Paraíba and Pernambuco will also have to adapt to higher temperatures and lower precipitation.

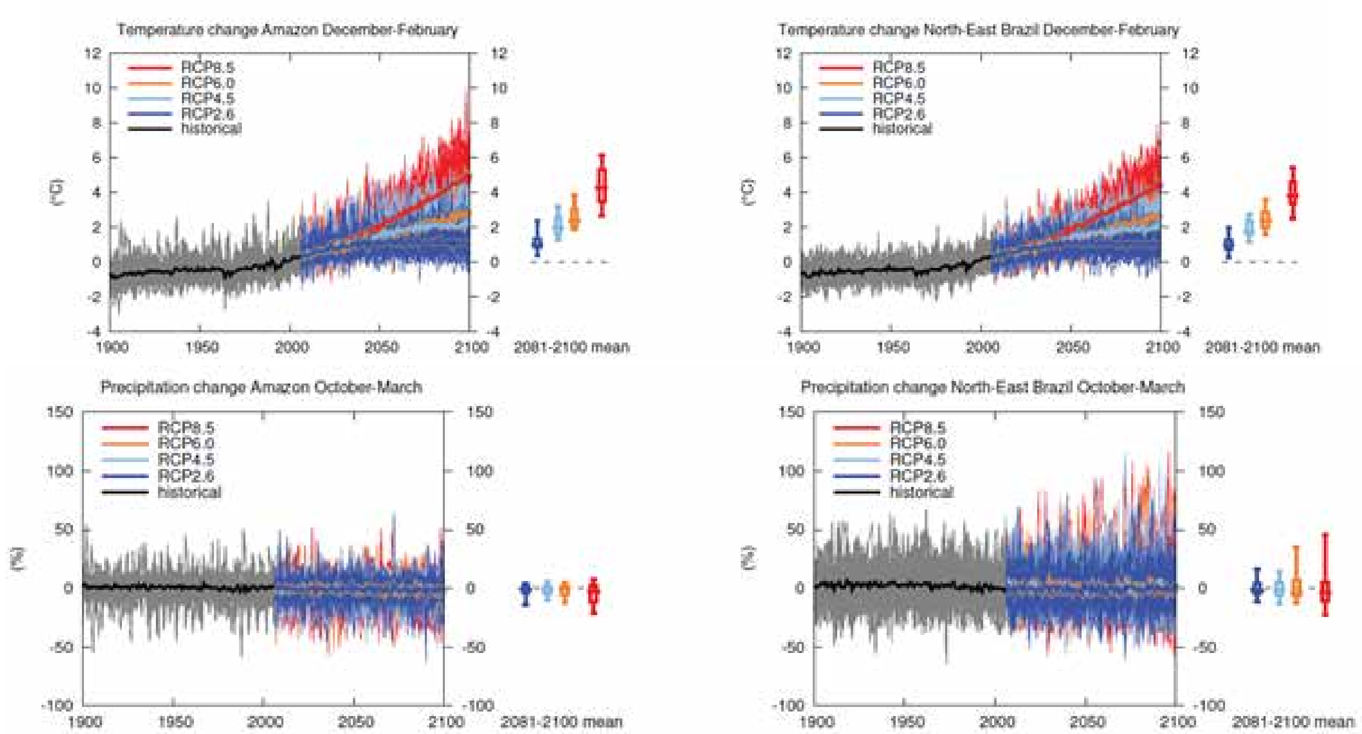

Figure 8: Time Series for the Estimated Temperature and Precipitation Change for the Amazon and Northeastern Brazil
Source: IPCC 5th Assessment Report, Working Group 1, Annex 1, Atlas of Global and Regional Climate Projections, Page 1342 and 1344 (IPCC 5AR WG1 Annex 2013).

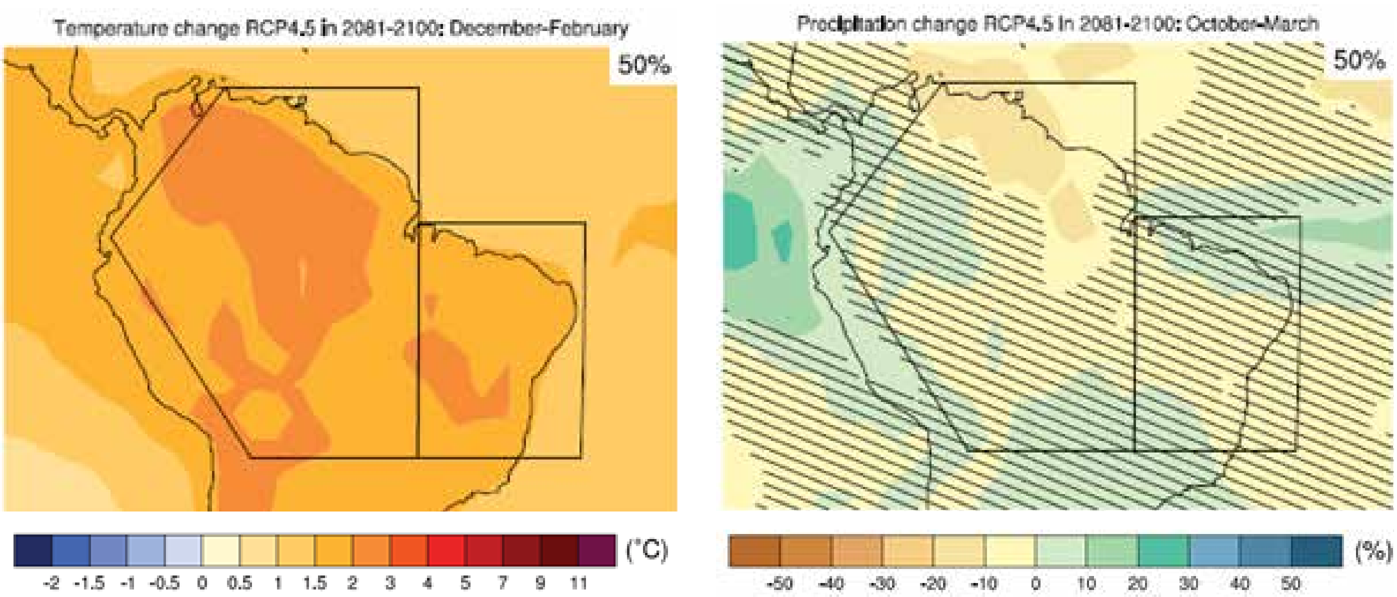

Figure 9: Regional Map for the Estimated Temperature and Precipitation Change for the Amazon and Northeastern Brazil in 2081 to 2100
Source: IPCC 5th Assessment Report, Working Group 1, Annex 1, Atlas of Global and Regional Climate Projections, Page 1342 and 1344 (IPCC 5AR WG1 Annex 2013).

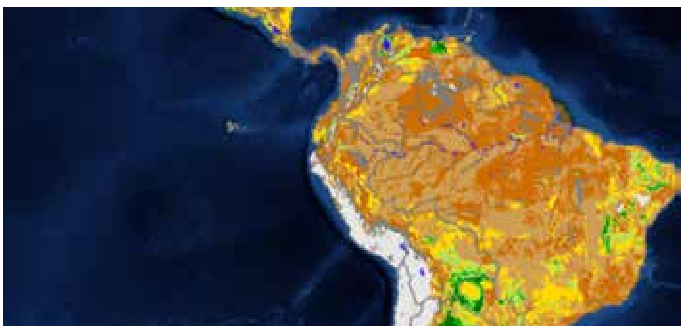

Figure 10: FAO Cereal Farming Suitability Map for the Amazon and Northeastern Brazil
Source: FAO Global Agro-Ecological Zones (FAO GAEZ 2014).

4.3. West Coast South America and SOUTHEASTERN South America

The Southern Cone regions of west coast South America and southeastern South America are also expected to have a temperature increase of around +2 °C. An interesting observation for both regions is, that the mean precipitation will probably increase, which is contrary to the other regions discussed before.

This result can also be seen in the regional maps: The temperature might increase by +3 °C and there will be an increase of rainfall for almost all regions of up to +10%.

The impact of these developments may be favorable for already high yielding agricultural regions in Argentina, Chile, Uruguay, Paraguay, Bolivia and Brazil, especially the area stretching from the Argentinean Pampa to Bolivia's El Gran Chaco.

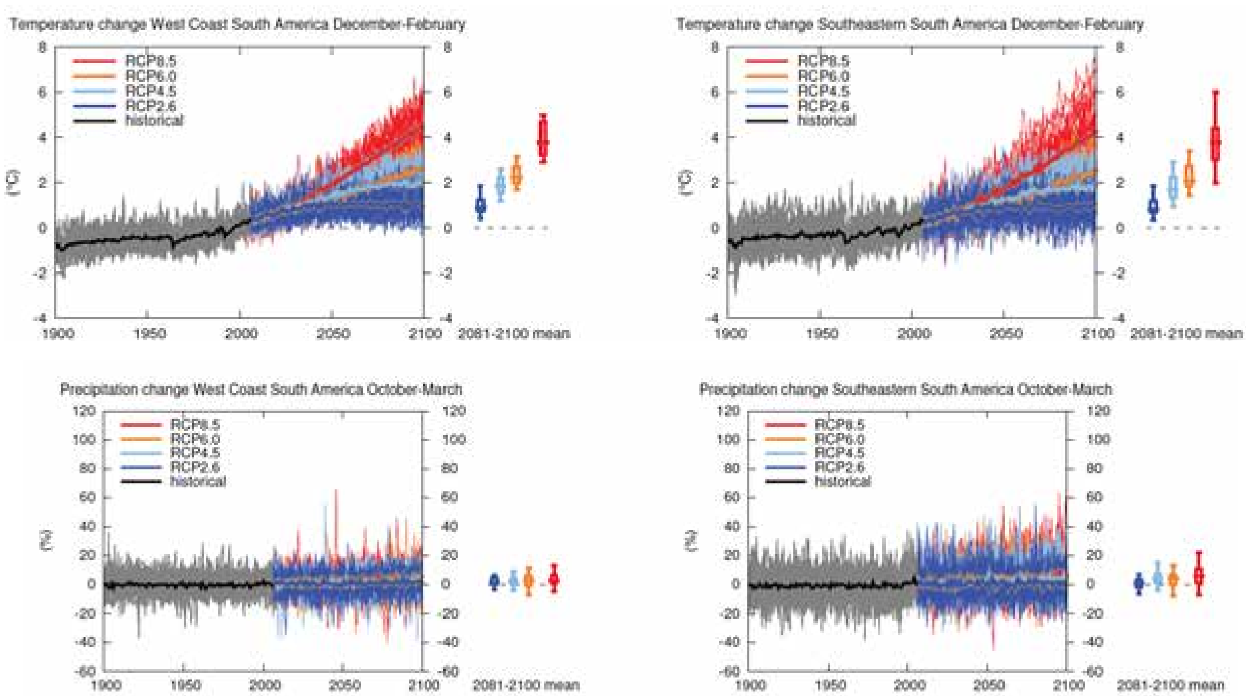

Figure 11: Time Series for the Estimated Temperature and Precipitation Change for West Coast South America and Southeastern South America
Source: IPCC 5th Assessment Report, Working Group 1, Annex 1, Atlas of Global and Regional Climate Projections, Page 1346 and 1348 (IPCC 5AR WG1 Annex 2013).

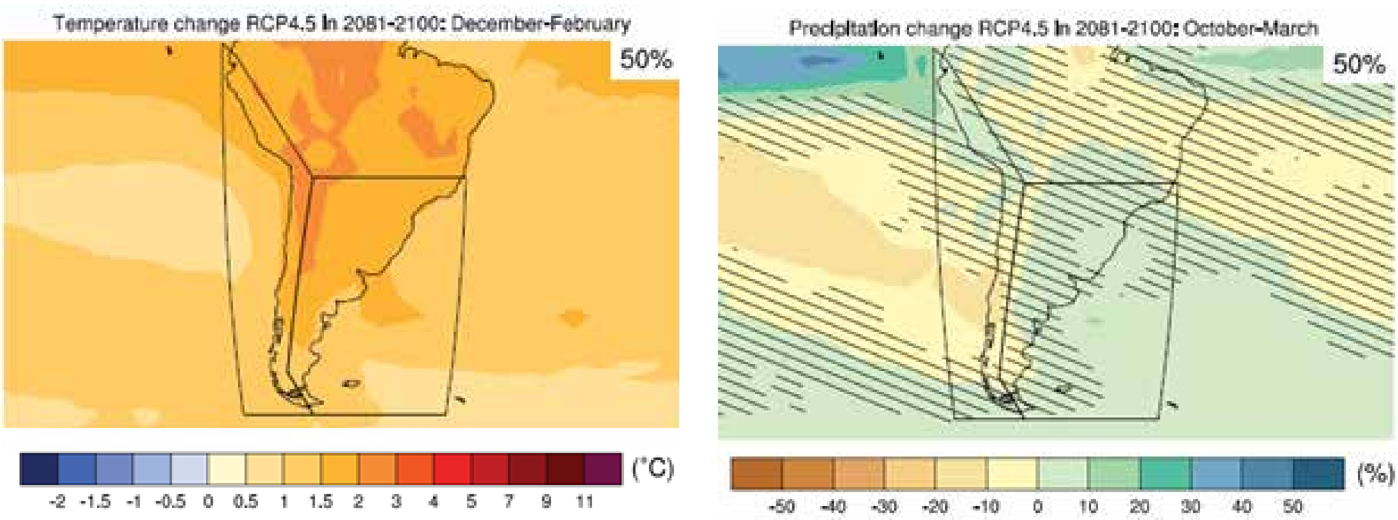

Figure 12: Regional Map for the Estimated Temperature and Precipitation Change for West Coast South America and Southeastern South America in 2081 to 2100
Source: IPCC 5th Assessment Report, Working Group 1, Annex 1, Atlas of Global and Regional Climate Projections, Page 1346 and 1348 (IPCC 5AR WG1 Annex 2013).

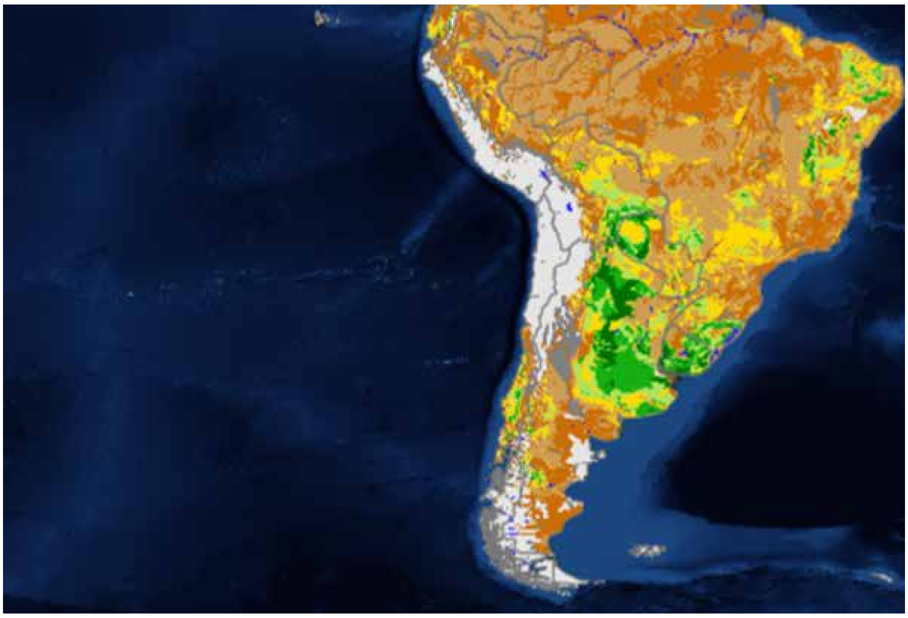

Figure 13: FAO Cereal Farming Suitability Map for West Coast South America and Southeastern South America
Source: FAO Global Agro-Ecological Zones (FAO GAEZ 2014).

decline of -11% without carbon fertilization and experience even an increase of 2% if carbon fertilization is accounted for. Brazil's farmers are projected to be moderately impacted by global warming, with farmers in the north being more hit by negative output changes than farmers in the south.

Overall, the Brazilian agricultural sector will lose most, if the effects of carbon fertilization won't materialize: The difference between scenarios with or without carbon fertilization is 13% or around 4 billion US-Dollar[3]. The results for the Central American region in table one comprise Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama and account for only 8mil hectares of farm area, which may lose as much as 24% due to the impact of global warming. Mexico, with a substantial farm area of 184mil hectares may see its agricultural output decrease by more than a third without carbon fertilization. As the cultural crop of Mexico and Central America is often corn, which as explained in Section 3 is a C4 crop, carbon fertilization will not have a substantial effect on the plants and the cultural damage from global warming will perhaps even exceed the material loss. The most hit region in the prevailing study is 'Other South America', under which Cline aggregated Paraguay and

5. Impact Estimatesfor the Agro-Ecological Regions

The results obtained from William Cline's work on the impact of global warming on agriculture correspond to the regional observations made in Section 4 of this paper. Table 1 depicts the farm area, output and the impact or change in output for the available regions in Latin America based on Cline's results and is ranked from the lowest impacted region according to 'Without Carbon Fertilization' to the most impacted. Unfortunately there are no results for Uruguay, Guyana, French Guyana, Suriname, Belize and all Caribbean States except Cuba. The existing results show, that Argentina's agriculture will suffer a modest

				Impact of Global Warming on Agriculture for the Period 2080 to 2100		Change in Output in mil. USD	
Country	Farm Area in mil. Hectares	Output per Hectare in USD	Output in bil. USD	Without Carbon Fertilization (%)	With Carbon Fertilization (%)	Without Carbon Fertilization	With Carbon Fertilization
Argentina	172	83	14	-11	2	-1.581	320
Brazil South	217	109	24	-16	-3	-3.767	-770
Brazil	354	84	30	-17	-4	-4.976	-1.292
Brazil Northeast	95	48	5	-19	-7	-886	-332
Colombia	51	186	9	-23	-12	-2.188	-1.100
Central America	8	1429	11	-24	-12	-2.586	-1.340
Chile	27	246	7	-24	-13	-1.590	-851
Brazil Amazon	42	29	1	-27	-16	-323	-190
Ecuador	12	176	2	-29	-18	-627	-394
Peru	35	171	6	-30	-20	-1.852	-1.221
Venezuela	30	114	3	-32	-22	-1.091	-742
Mexico	184	136	25	-35	-26	-8.856	-6.428
Cuba	4	285	1	-39	-30	-423	-325
Other South America	24	118	3	-43	-34	-1.207	-967

Table 1: Overview of the estimated relative and absolute Impact of Climate Change on Agriculture in Latin America
Source: Adapted from William R. Cline "Global Warming and Agriculture. Impact Estimates by Country" (Cline 2007).

Bolivia, and which agricultural sector may face loses of about 43% without carbon fertilization.

The regional maps of Figure 16 in Section 7 summarize the results above and show the difference between 'with carbon fertilization' and 'without carbon fertilization' visually.

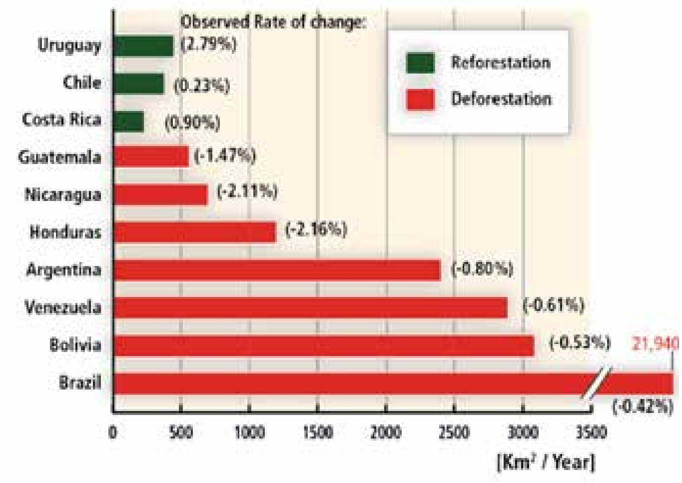

Figure 14: Average De- and Reforestation Rates between 2005 and 2010 for 10 Latin American Countries Source: IPCC 5th Assessment Report, Working Group 2, Chapter 27, Page 99 (IPCC 5AR WG2 Chapter 27 2014).

6. Mitigation and adaptation

The possibilities for mitigation or a reduction of a person's individual carbon footprint are numerous and range from less meat consumption over more sustainable means of transportation to carbon trading mechanisms intended to make 'polluting' more expensive and hence to count on the general economic logic to avoid what's expensive. It would be very interesting to research which means of mitigation exist at present and how efficient they are, but in the context of this paper the discussion would become too extensive. One mitigation possibility shall still be mentioned here, because it is most likely the most efficient one: Less or even better 'no' deforestation. Deforestation exacerbates climate change in two ways, first when the forest is burned or cleared CO2 is released into the atmosphere and secondly the chopped trees and vegetation cannot absorb additional CO2 anymore. Besides these two primary effects deforestation is a disaster for biodiversity as animals as well as plants lose their habitat and increased water run-off may lead to quick desertification. Figure 14 shows the annual deforestation rate for ten Latin American countries from 2005 to 2010. Although deforestation rates in the early 21st century are mostly

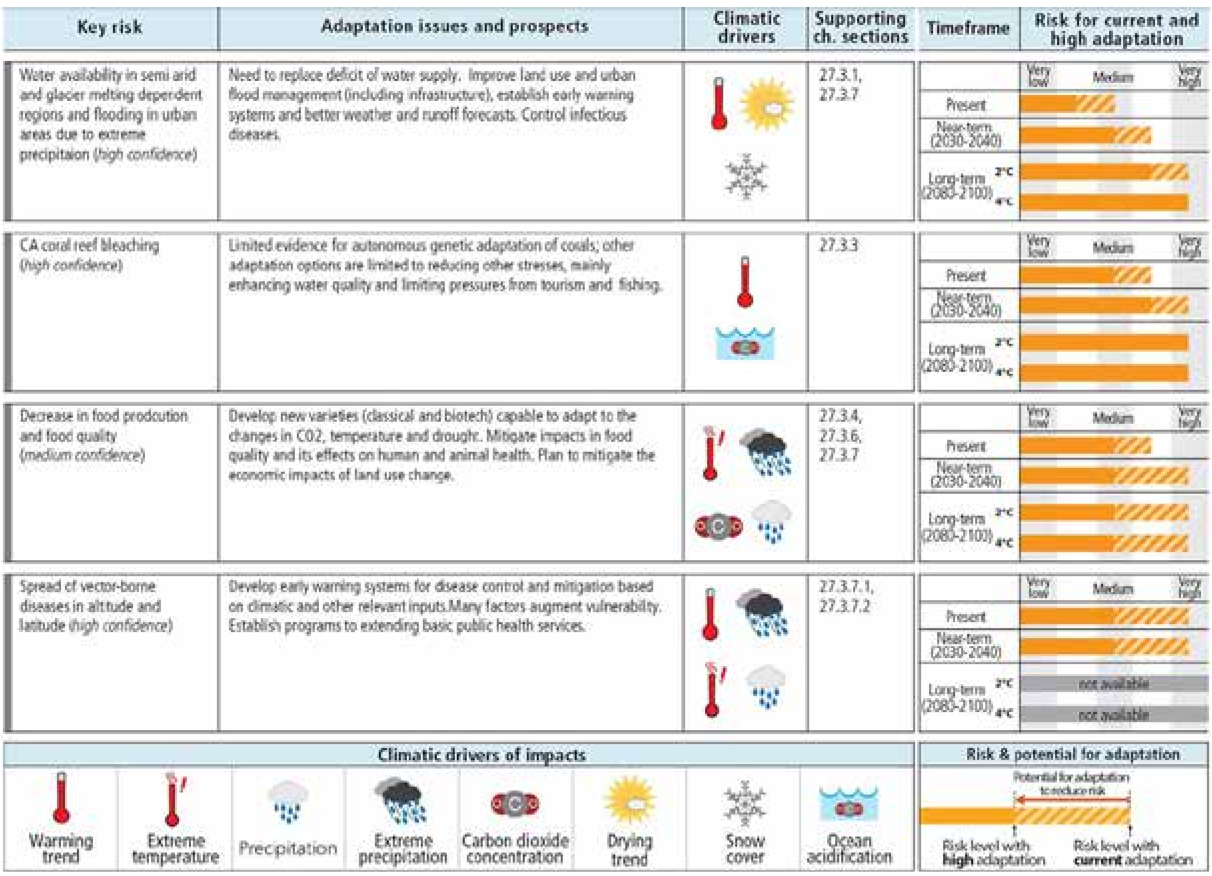

Figure 15: Key Risks of Climate Change for Latin America and Adaptation Possibilities Source: IPCC 5th Assessment Report, Working Group 2, Chapter 27, Page 96 (IPCC 5AR WG2 Chapter 27 2014).

declining in comparison to the rates observed at the end of the 20th century, there are still deforestation rates higher than 2% e.g. in Nicaragua and Honduras. A positive sign are reforestation rates in Chile, Costa Rica and Uruguay.

Mitigation of climate change would clearly be the best solution, but as some climate change processes seem to have already begun, adaptation to the new circumstances is an alternative. Figure 15 was taken from the current IPCC Assessment Report 5 and indicates some key risks and potentials for adaptation. An increased warming and drying trend will alter the water availability and increase glacier melting, resulting in extreme events like flooding or long dry periods. Adaptation possibilities could be a better water supply through e.g. irrigation, flood management and early warning systems. According to the illustration by the IPCC the risks could be decreased to a 'medium' level in case these adaptation measures were implemented. If the temperature increases by +4 °C in the long-term view towards the end of the 21st century, these risks will still be very high and the adaption effect negligible.

Another interesting point mentioned in Figure 15 and in the context of this paper is concerning the key risk of a 'Decrease in food production and food quality' resulting mostly from extreme temperatures and precipitation. The main adaption possibility mentioned is the development of new varieties, supposedly crop varieties, capable of producing a satisfying harvest. With this adaption strategy the risks of a decrease in food production and food quality may be reduced to 'medium'. In the context of the last point it should be mentioned, that the discussion on new crop varieties, especially when genetically modified varieties are included, is very intense and continuous research is needed.

7. Conclusion and Summary

The conclusion to be drawn from the prevailing paper on possible impacts of climate change on agriculture is quite straight forward: Agriculture in Latin America is going to be even more challenging in the future compared to today and the odds are high that harvest output will become more volatile with a strong bias to a decrease in yields. Almost all regions will suffer from global warming and for those regions where a positive effect on yields is estimated the results depend on optimistic assumptions like an increase in yield through carbon fertilization. Anyways, even if higher output was to materialize in some regions, it will not be able to make up for the losses of the whole region. Having a look at the world map by William Cline depicting the impact of climate change on agricultural productivity one observation is increasingly striking:

The regions and countries around the equator, which are mostly developing countries, are to suffer the most. Just to mention one example, the agricultural output for Bolivia is estimated to decrease by more than 25% of current levels regardless of carbon fertilization. Although this paper focusses on Latin America, a glance to the African continent underlines the possible magnitude of the damage. These regions are the ones where most of the Earth's poor and low income population already lives today. The living conditions of these people will deteriorate further and their lack of savings and other financial means will make them even more vulnerable, because adaptation is usually expensive. This concern was already expressed in the introductory part and further evidence was generated through the accomplished research. The most economic and efficient way to stop climate change would naturally be to avoid further pollution of the climate. This may sound utopian at first, but if policy makers and researchers foster further awareness among the public a big step in the right direction would already be made. A positive historical milestone was set at the Montreal Conference in 1987 regarding the ban on substances that deplete the ozone layer, which is expected to reduce the amount of CFCs in the atmosphere significantly during the next decades as can be seen in Figure 4 of Section 3.3. If humans were able to apply the emergency brake already once, there's still hope that we'll be able to apply it again and that climate change and its impact can be at least mitigated.

To close, this paper tried to give a broad introduction to the topic on the possible impacts of climate change on agriculture by introducing some basic definitions and elaborating on the latest available climate models as well as their estimates for Latin America. The results of the climate models were put in relation to agricultural suitability maps to see if climate changes may affect important farming regions. The visual observations were cross checked with the results of a quantitative study. Briefly, mitigation and adaptation strategies were discussed before the final conclusions. An academic observation on existing mitigation as well as adaptation possibilities and their effectiveness would be a very interesting task for further research.

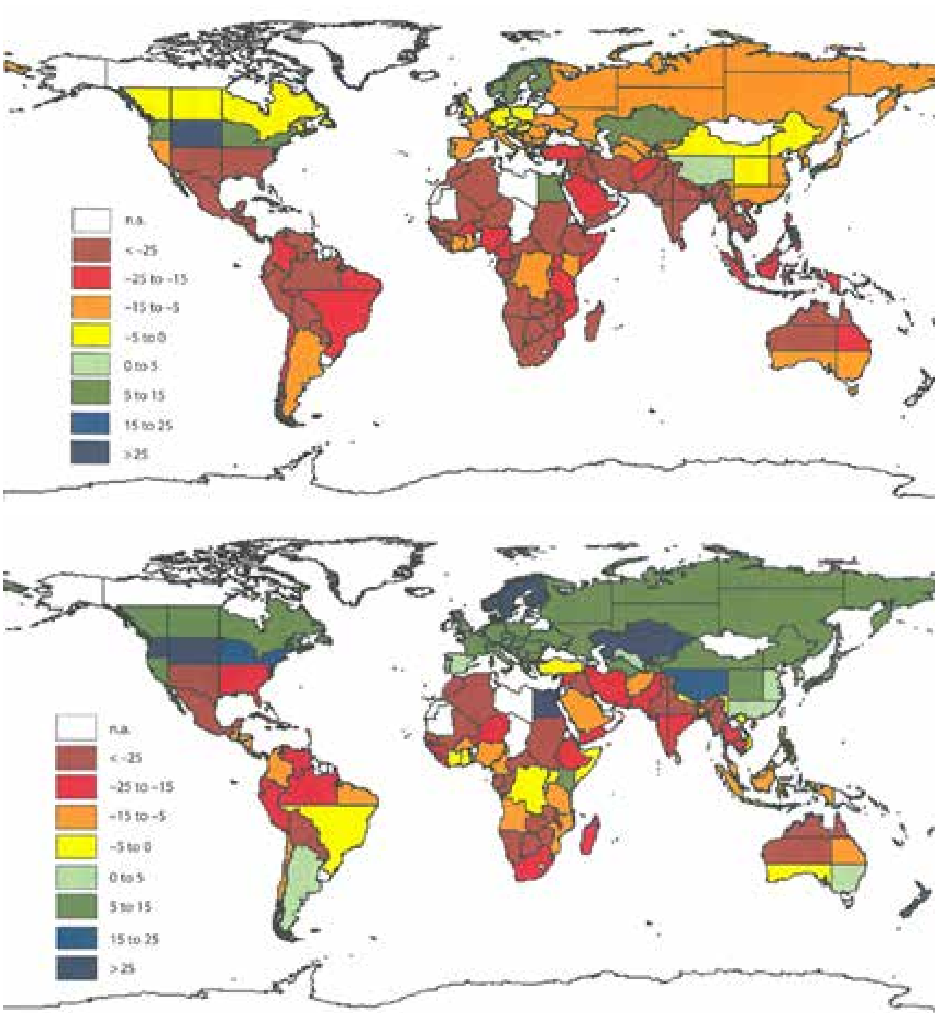

Figure 16: The Impact of Climate Change on Agriculture in Percent of Output Change according to William R. Cline without the Effect of Carbon Fertilization in the Panel above and with the Effect of Carbon Fertilization in the Panel below. Source: William R. Cline "Global Warming and Agriculture. Impact Estimates by Country" (Cline 2007).

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Appendix A: Abbriviations

AR: Assessment Report (AR5 relates to the 5th Assessment Report by the IPCC)

CFC: Chlorofluorocarbons

CH4: Methane

CMIP: Climate Model Intercomparison Project

CO2: Carbon Dioxide

FAO: Food and Agricultural Organization

FAO GAEZ: Food and Agricultural Organization Global Agro-Ecological Zones

GHG: Greenhouse Gases

IAASTD: International Assessment of Agricultural Knowledge, Science and Technology for Development

IFPRI: International Food Policy Research Institute

IPCC: Intergovernmental Panel on Climate Change

LWR: Longwave Radiation

N2O: Nitrous Oxide

SWR: Shortwave Radiation

RCP: Representative Concentration Pathway

WG: Working Group (WG1 or WG2 refers to the IPCC's Working Groups – overall there are three Working Groups: WG1, WG2 and WG3)

UNFCCC: United Nations Framework Convention on Climate Change

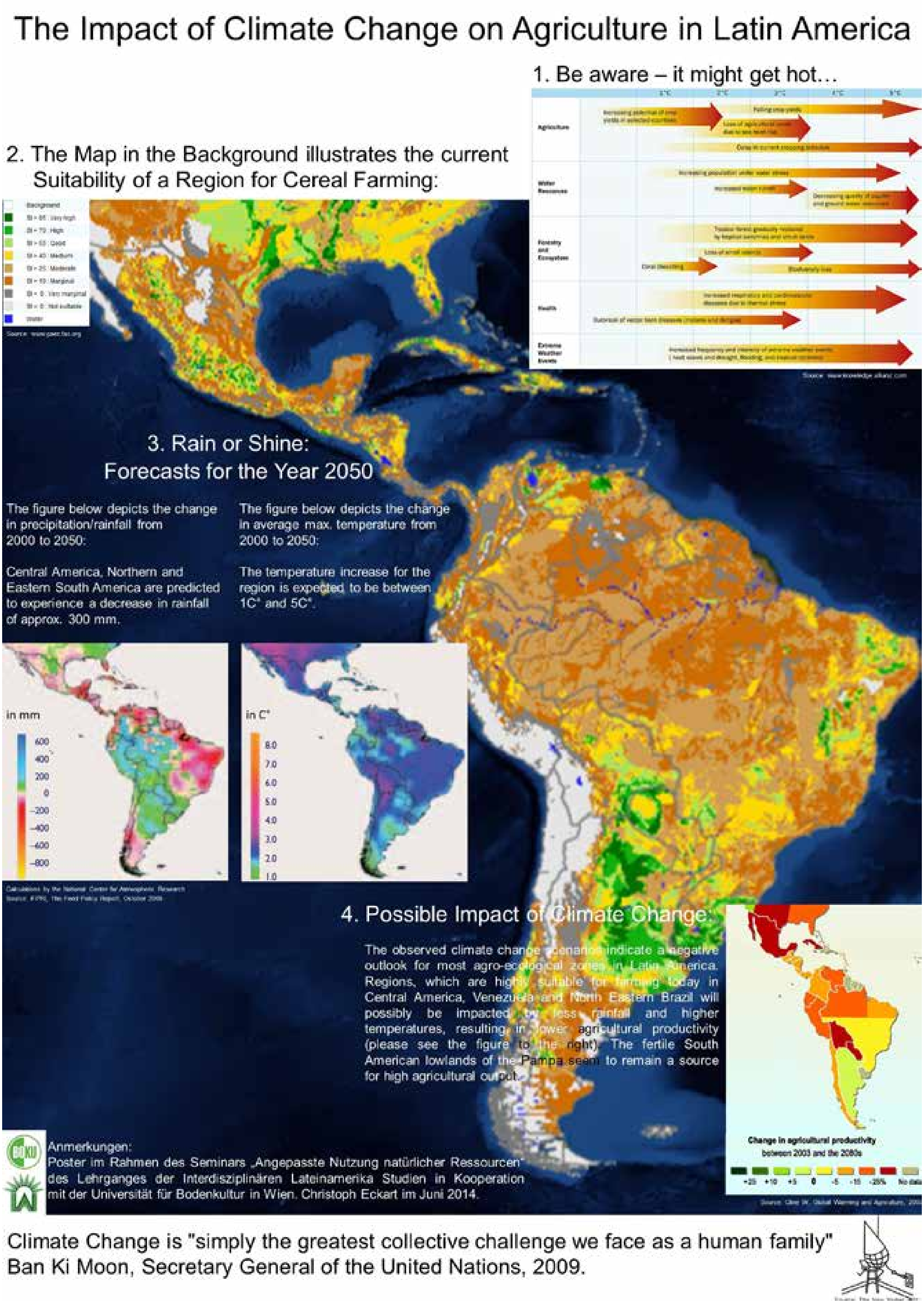
Notes

1. Article 1, Paragraph 2 of the United Nations Framework Convention on Climate Change (UNFCCC 2014).

2. With the base being the yield at the beginning of the 21st century.

3. 3.684.000.000 USD to be more precise.

Appendix B: The Poster for the Seminar Paper presented in June 2014



**Mag. Christoph Eckart, Bakk. arbeitet seit 7 Jahren mit Inclusive Finance Projekten unter anderem im Kaukasus, Zentralasien, Südasien, Osteuropa, Nordamerika, Zentralamerika und Südamerika.*