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Report of Agriculture in Latin America and Ecuador and the Impact of Climate in the Neotropical Ecoregion

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1. Introduction

Agriculture is much more than simply the production of economically important goods. As a source of food for human beings and animals, fiber, materials for construction and for crafts, oil and fuel, agriculture is vital for the cultures and communities that produce them and plays a critical role for the goals of sustainable development and reducing poverty and inequality. Recently special emphasis has also been placed on the role of agriculture in providing environmental services such as mitigation of the effects of climate change, regulation of the water cycle, erosion control, maintenance of habitats for wildlife and preservation of landscapes and places of religious importance. In this sense, agriculture is a multifunctional activity (Chaparro, 2000; Cahill, 2001; Dobbs and Pretty, 2004; Brunstad et al., 2005). This doesn't mean that agriculture can simultaneously satisfy all these functions, since that depends on specific contextual characteristics. Nonetheless, these multiple functions of agriculture should be taken into consideration, especially in the context of development and sustainability goals. In the last 50 years agriculture has contributed only 10 to 12% of GDP; it has been secondary to other productive activities. Nonetheless, agriculture still represents a key sector of the Latin American economy, as it accounts for a large part (30 to 40%) of the economically active population.

In those countries that lack minerals and oil, agriculture represents the main source of exports and foreign exchange. Agriculture is a relatively more important part of the economy in the Central American countries than it is for Latin America generally. While agriculture only contributed 8% of GDP in 1998 in Latin America overall (Dixon et al., 2001), in Central America in 2000 agriculture contributed from a low of 7% of GDP (in Panama) to a high of 36% (in Nicaragua). The importance of agriculture as a generator of foreign exchange is even more significant. In 2000, agricultural exports ranged from a low of 30.8% of total exports of goods in Costa Rica, to a high in Belize of 69.4% of total exports (Harvey et al., 2005). Finally, in most Latin American countries, agriculture represents a subsistence way of life for millions of people, including indigenous communities (IPCC, 1996).

Recent research has shown exhaustively that agricultural activities are diminishing in rural areas from the standpoint of the number of people involved and the income generated, while non-agricultural activities are on the rise, in particular those linked to the provision of services. For these reasons, the families that live in areas defined as rural are increasingly abandoning exclusively agricultural activities to seek out other opportunities (Da Silva, 2004; Dirven, 2004). These phenomena are responsible in part for the migrations from the countryside to the cities, but are not the sole cause. The expansion of the large transgenic monocultures in the countries of the Southern Cone is transforming the agrarian structure, increasing the concentration of land and the migration of peasants (Fearnside, 2001ab; Pengue, 2005). In addition, violence due to territorial interests is causing massive forced displacement, as in Colombia and Ecuador.

Parallel to this difficult context, fishing is also developing; it continues to be one of the key components of certain local economies in many places in Latin America and the Caribbean (LAC), especially the Amazon region, both in terms of the value of production and in terms of employment. Bernal and Agudelo (2006) cite figures from the FAO according to which there are more than 38 million people directly engaged in fishing and fish farming on a full- or part-time basis; and the developing countries now provide 70% of the fish for human consumption. Marine fishing is also an important economic activity in LAC, generating employment and incomes; most of the fish offloaded is accounted for by the Southern Cone countries.

The current status of agriculture in LAC, in terms of production and productivity of goods and services in relation to expectations for attaining the millennium goals, is not uniform across the region. The heterogeneity in levels of agricultural knowledge is due in part to the effect of the structural reforms carried out in the region. In the last 25 years most of the countries of the region began or intensified their processes of adjustment and structural reforms, as a result of which they experienced major changes in their structure of production, productivity, competitiveness and in the profitability of various activities, including agriculture (David et al., 2001).

It should be noted that it is practically impossible to establish typologies of development models by country, as one finds the coexistence of very different and more complex situations than in the rest of the economy, given the major differences between and within the countries. The differentiation of the growth model has occurred within the countries, with repercussions both on the specially located dynamic poles and on the type of activities and actors.

1.1.Characteristics of the production in Latin America and the Caribbean

1.1.1. Available resources

- ***Natural resources.*** Agriculture produces unprocessed agrifood products using natural resources (land, water, biodiversity) as one of the factors of production and the process may involve "cultivation" (planting, aquaculture, stockraising, forestry) or "gathering" (hunting, fishing, forestry) (Dirven, 2004). The peoples of LAC live in a territory with abundant resources in terms of land, water and biodiversity (OSAL, 2005). The water and soil, key elements in agricultural production, may or may not be considered renewable resources, depending on their degrees of cultural management. In any event, they constitute the main limitations and potential for agriculture at this level (León, 2007).
- ***Land.*** Latin America and the Caribbean is the region with the largest reserves of arable lands in the world. It is estimated that 30% of the territory in LAC has agricultural potential (Gómez and Gallopin, 1995). The region had 160 million ha of land under annual and perennial crops in 1999 and another 600 million ha dedicated to grazing and pasture (Dixon et al., 2001). Nonetheless, due to the mismanagement of the soils and to the use of marginal areas for agriculture, the region has approximately 300 million ha of degraded agricultural area (FAO, 1998), while another 80 million ha of arid lands are

threatened with desertification due to overgrazing, overexploitation of the vegetation for domestic uses, deforestation and the use of inappropriate irrigation methods. This represents more than 50% of the total agricultural area (including grazing areas) affected by degradation. Erosion, acidification, loss of organic matter, compaction, impoverishment of nutrients, salinization and soil contamination are a result of the intensification of agriculture through the intensive use of agrochemicals, fertilizers, and pesticides, as well as the use of inappropriate irrigation technologies and agricultural machinery (UNEP, 2006).

Erosion is the main cause of land degradation in LAC and affects 14% of the territory in South America and 26% in Mesoamerica (UNEP, 1999). This problem is especially serious in steep areas such as the Andean region (central and northern), as well as the maize and bean zone of Mesoamerica. In these areas erosion is causing low levels of production and is affecting the migration of small-scale producers to the cities or the agricultural frontier in forested areas, contributing to soil degradation there (FAO, 1998). This process is also taking place in other steep areas such as the Chiapas highlands in Mexico (Richter, 2000).

Nutrient attrition is another very serious problem that results from the intensification of agriculture and synthetic fertilizers. In South America nutrient attrition affects at least 68 million ha (Scherr and Yadav, 1997). Nutrient attrition may also be a consequence of deforestation in moist tropical zones. The conversion of forest to cropland in these areas has brought about the loss of organic matter and has accelerated erosion and the increase in the sediment load in rivers and lakes (FAO, 1998).

Chemical contamination of the soil and water, which also derives from the technologies of intensive agriculture, has been increasing in the last 30 years. Nitrification of the soil and water is directly related to the use of chemical fertilizers (UNEP, 2006); in LAC the use of fertilizers increased from less than one million tonnes in 1961 to more than 13 million tonnes in 2003 (FAOSTAT, 2005).

- ***Water.*** In terms of water, the region has relatively favorable endowments compared to other areas in the developing world. It has almost half of the world’s total renewable water resources and some 90% of the land area falls in the humid or sub-humid zones. While overall the region is relatively wet, there are several areas where drylands predominate, principally in northern and central Mexico and the coastal and inland valleys of Peru, Chile and Western Argentina, Northeast Brazil and the Yucatan Peninsula and the Gran Chaco area of Paraguay, Bolivia and Argentina. In total, drylands comprise some 15% of the region (FAO, 1998). Natural grasslands or savannahs, many of which are relatively dry, are found in much of Argentina, as well as in central, western and southern Brazil, Uruguay and parts of Colombia, Venezuela and Guyana. Crops occupy around 160 million ha of the region, while another 600 million ha are dedicated to pasture and grazing land (Dixon et al., 2001).

Hydrobiological resources represent another component of South America's biodiversity, with approximately 3,000 fish species. Nonetheless, very little is known of the biological cycle of the fish species dependent on the water cycle and even less of the zooplankton and phytoplankton of the continental and marine waters (Bernal and Agudelo, 2006).

- ***Agrobiodiversity.*** Mesoamerica and the Andes are two major centers of origin of domesticated plants, many of which are now of global importance. Maize and beans are the most prominent of these, but the list also includes potatoes, sweet potatoes, tomatoes, cassava, chili peppers, gourds, squashes, avocado, cotton and peanuts. Wild ancestors have been discovered for some of these crops, such as maize. There is also significant genetic diversity across the region that has been developed since the introduction of non-native crops such as banana and sugar cane. With a few exceptions, the region's agrobiodiversity is not well studied. Maize (*Zea mays*) is one of the most significant crops that originated in the Americas; it is now the most widely grown crop in the world. Due to its ability to grow under highly varied climatic conditions, it is grown in at least 164 countries worldwide (Global Crop Diversity Trust, 2007).

  Mexico is the center of origin and the center of diversity for maize, with more than 60 landraces and numerous local varieties, as well as the wild relatives of maize, the teosintes. Mexico provides one of the earliest examples of deliberate conservation of wild crop relatives *in situ*; the existence of teosinte was the primary reason for the creation of the Sierra de Manantlán Man and the Biosphere Reserve there in 1988 (Iltis, 1994; Meilleur and Hodgkin, 2004). The common bean (*Phaseolus vulgaris*) appears to have been domesticated separately in Mesoamerica and in the Andean region. Wild gene pools are also concentrated in these areas. Mesoamerican cultivars dominate global production; some 60% of beans produced throughout the world are of Mesoamerican origin. Common beans are the world's most important legume food crop and are particularly important for human nutrition because of the high protein content, which is roughly double that of most cereals (Beebe et al., 2000). Potato (*Solanum tuberosum*) was domesticated 7,000 years ago around Lake Titicaca in the Andes (Spooner et al., 2005). Potato is the most important crop for the cultures in the Andes, where over 100 varieties can be found growing within a single valley (Brush, 1992).

  Relatively few animals were domesticated in the new world; only one, the turkey, has spread significantly beyond its native habitats in Mesoamerica and the present-day United States. The llama and alpaca, domesticated in the Andes, still play an important role in Andean society, as does the guinea pig, domesticated for food. The Muscovy duck was also domesticated in South America. Wild relatives of some of these animals, particularly the wild turkey and the vicuña, which is related to llamas and alpacas, are still to be found in the areas where they were domesticated (Heiser, 1990). The agricultural genetic resources of the Latin American region are enormous. As one of only a few places where agriculture was independently invented and the center of origin of many of the world's major food crops, the area retains numerous landraces, local varieties and wild relatives of great importance to the future development of agriculture worldwide.

2. Latin American and Caribbean Agricultural Production Systems

Recognizing the structural heterogeneity and diversity of actors, cultures and knowledge of Latin American agriculture both regionally and subregionally, it was decided to consider three agricultural systems for the purposes of this evaluation:

a) Traditional/indigenous (includes peasant)
b) Conventional/productivist
c) Agroecological

The importance of each of these systems varies not only among subregions, but also within each subregion and even within each country. The performance and impacts of three principal agricultural systems are presented in Table 1.

Table 1: *Main characteristics of agricultural systems considered in the assessment (Ahumada et al., 2009)*

	Indigenous/ traditional	***Indigenous/ traditional***	***Indigenous/ traditional***
Main actors	Indigenous communities, Afro descendants and peasants.	Agribusiness, small, medium and large producers.	Small, medium and large-scale producers, professionals.
Inputs (type and origin)	Low external input, local Technology.	Chemical inputs, technological machinery and tools, externally bought fossil fuel.	Low dependency on external inputs. Biological inputs produced from within the system. High technology integrated to endogenous, natural, physical and energetic processes.
Knowledge and skills	Local/ancestral knowledge. Strongly rooted to the territory.	Academic/ technological Knowledge.	Academic/ technological knowledge and knowhow with emphasis on local/ancestral knowledge. Scientific knowledge strongly based on ecological science.
Diversification of production	Multi-crops; high biological diversity.	Great scale monocultures with spatial and temporal rotations.	Multi-crops, with spatial and temporal integration.
Links to the market	Little or no linking with input/output markets. Production largely oriented to family consumption.	Strong articulation with production chains and links to national and international markets.	Little articulation with production chains, but strong linking with markets of differentiated products.
Labor	Family and communal labor using different forms of labor exchanges.	Dominated by hired labor.	Family and hired labor.

2.1. Traditional/indigenous

The traditional/indigenous system is a family agricultural system, primarily involving family consumption, under which one can distinguish the ethnic systems constituted by indigenous and Afro-descendant communities linked to the territory and the peasant systems. It is based on local/ ancestral knowledge and is not very well articulated to the market for inputs and products, though today many peasants market part of their production. In general, this system is high in agrobiodiversity, outside inputs are used to a limited extent, if at all and labor is drawn from the family (Altieri, 1999; Toledo, 2005). The cosmovision of indigenous communities assumes a relationship with natural resources that goes beyond an economic-extractive activity: it implies an ecological-cultural-spiritual vision linked to the territory. (For the example of the Andean world view, see Figure 1.) (Ahumada et al. 2009).

This system stands out for sustainability with respect to the environment and energetic balance, with variable levels of production (Barrera-Bassols and Toledo, 2005). In several regions traditional/indigenous agriculture is displaced to marginal lands and much of the knowledge that undergirds it is being lost (David et al., 2001; Deere, 2005). In these conditions one finds low yields. In most countries of the region, governmental and/or institutional support has not fostered the strengthening of this system.

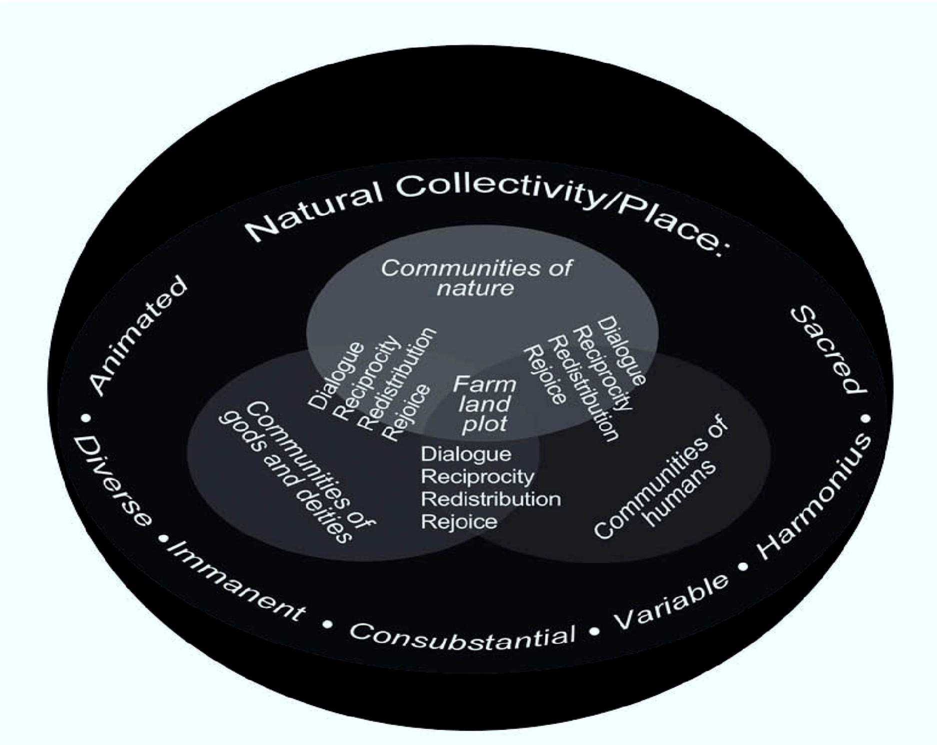
2.2. Conventional and/or productivist

At the other end of the spectrum one finds the conventional and/or productivist system, also called the "industrial system." This system is characterized by a high degree of mechanization, monocultures and the use of external inputs, such as synthetic fertilizers and pesticides, as well as contract labor. It is based on technological knowledge and is highly articulated to the market and integrated to productive chains. This system has been supported by development models and it has benefited from support systems such as credit and technological capital. Its prominence in the national and international markets makes the conventional and/or productivist system stands out for high levels of productivity and competitiveness. Nonetheless, it gives rise to significant negative externalities in terms of environmental, social and cultural costs (Ahumada et al., 2009).

2.3. Agroecological.

As the environmental and human costs of conventional production have increased, the agroecological system is becoming more important. It is based on the knowledge of agroecology stemming from the interaction between scientific and traditional knowledge and aimed at reducing the negative impacts of the conventional systems through productive diversification and the use of ecologically-friendly technologies. This system is characterized by the search for sustainability in social, economic, cultural and environmental terms; scant articulation in productive chains; and a strong link to the market for differentiated products, especially organic products. The systems described are expressed in the subregions with differentiated nuances and through mixed forms or particular combinations (Ahumada et al., 2009).

Figure 1: *Andean cosmovision (Gonzales, 1999; Gonzales et al., 1999)*

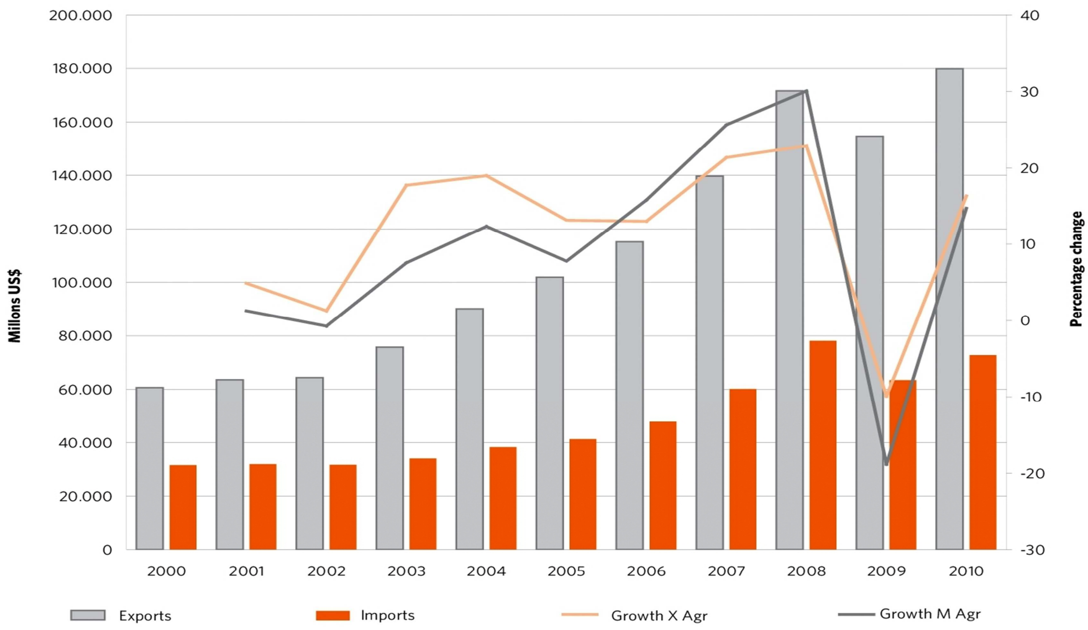


3. Agriculture and Future Climate in Latin America and the Caribbean

Agriculture plays a key role in the economy and the social fabric of Latin America and the Caribbean (LAC). The sector contributed 5% of the region’s gross domestic product (GDP) in 2012. It also accounted for 19% of male and 9% of female employment during 2008-2011 (World Bank 2013). In addition, exports from Latin America represent a growing contribution to global agriculture trade from 8% in the mid-1990s to about 13% in 2011 (World Bank 2012) and now account for about 23% of the region’s exports. Therefore, the region’s ability to produce and export agricultural commodities is expected to play an increasingly important role in global food security. At the same time, an estimated 49 million people are under-nourished in LAC (OECD-FAO 2012) and the agricultural share of total household income is more than 50% among poor rural households in some Latin American countries (Vergara et al., 2014).

Agrifood trade in Latin America and the Caribbean was hit hard by the global financial crisis in 2009, when it suffered a significant contraction and a reversal of its decade-long growth trend. Indeed, during 2009 the region saw a sharp decline in agricultural exports and imports, which fell by more than 9% and 19%, respectively, but subsequently recovered in 2010, achieving growth rates of 16% and 15%, respectively (see Figure 2).

Figure 2: *Annual variation in agricultural trade of LAC (2000-2010) (FAO, 2013)*



The agricultural sector's share of total exports has remained relatively stable during the last decade accounting for 20% of total exports in 2010. Imports of agricultural commodities represented 8% of total imported goods. This reflects a positive trade balance, which reached a figure of approximately us $107.1 billion (FAO, 2013).

Within this context, climate changes anticipated during this century may exert additional pressure on environmental conditions under which agriculture activity has developed, and if not properly addressed may ultimately result in significant economic and social impacts. Physical changes anticipated by commonly used future climate scenarios, of relevance for agricultural activity, include: increases in air and soil temperatures, changes in CO_2 concentrations in the atmosphere, sea level rise, changes in the hydrological cycle and in water quality and availability, intensification and increase in frequency of extreme weather events, including droughts and floods, changes in the altitudinal level of dew points, and others. Some of these changes are gradual and unidirectional, that is, they will show over time at a rate still uncertain but with a known direction. That is the case of increased temperatures, levels of CO_2 in the atmosphere and sea level rise. This document focuses on the implications for agriculture of those changes; other changes are more uncertain and variable (e.g. weather and rainfall patterns) and more research is still required to ascertain −with a higher degree of accuracy− their systemic implications on agriculture. The objective of this report is to highlight the need to better understand future climate implications for, and to plan for climate change adaptation actions in, the LAC agricultural sector. For this purpose, an overview of the sector's climate challenge is presented, including the consequences of projected impacts and possible responses (Vergara et al., 2014).

3.1. Latin America and the Caribbean's agriculture sector

While, as of lately, there has been a great deal of sector diversification in the region, agriculture production remains a back bone of economic activity. The sector accounted for 5% of LAC's GDP in 2012, but contributed to more than 10% of total GDP in several countries (World Bank, 2013). LAC's aggregate output of agriculture is estimated to have surpassed US$300 billion in 2012, driven in large part by increases in the value of agricultural commodities (see figure 3 and 4), but also gains in productivity and area under production. The region is also the main source of sugar, soybeans and coffee, supplying over 50% of worldwide exports for these commodities (FAO, 2014).

Figure 3: *Index of Agricultural Commodity Prices for Key Exports from Latin America (OECD-FAO 2012)*

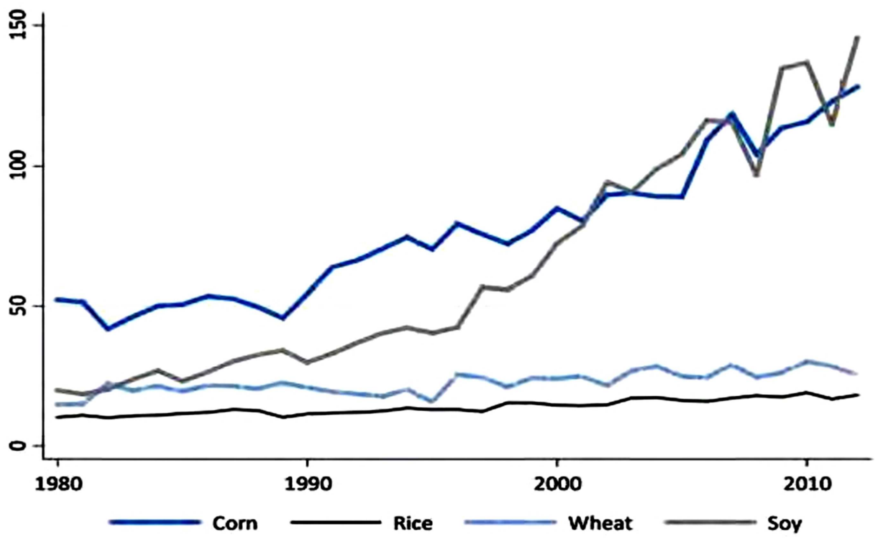
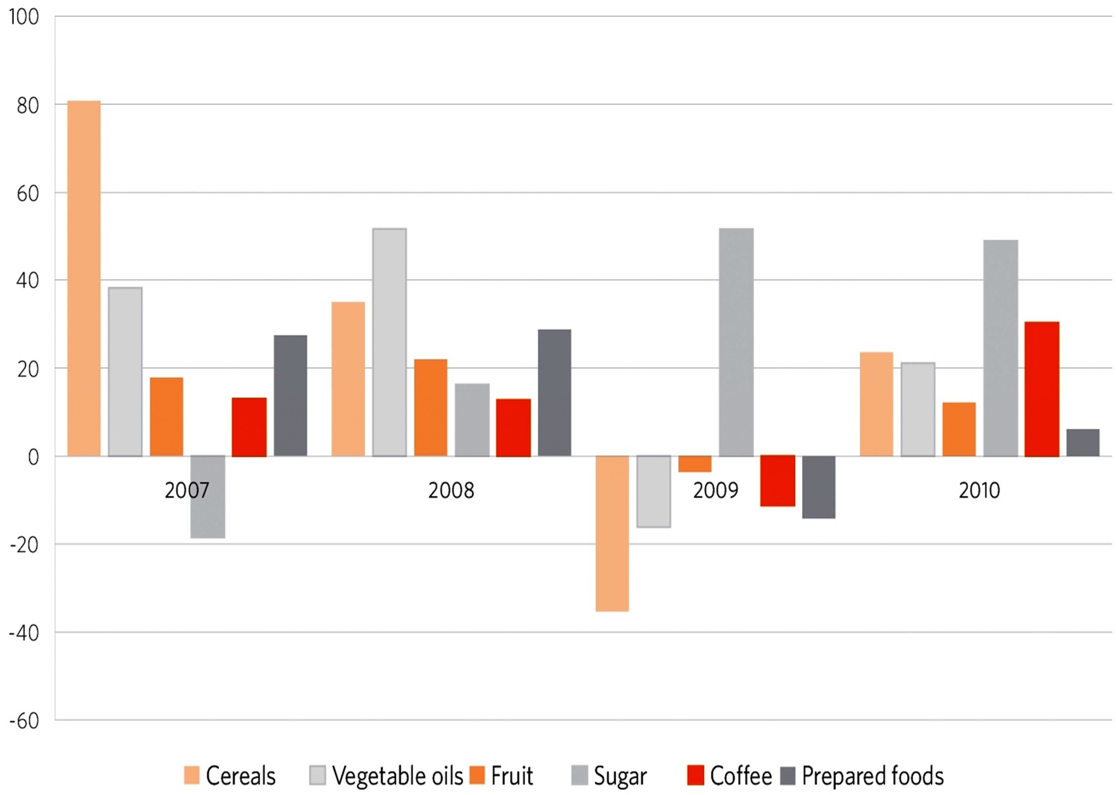


Figure 4: *Variation in agricultural exports of LAC (%, 2007-2010) (FAO, 2013)*

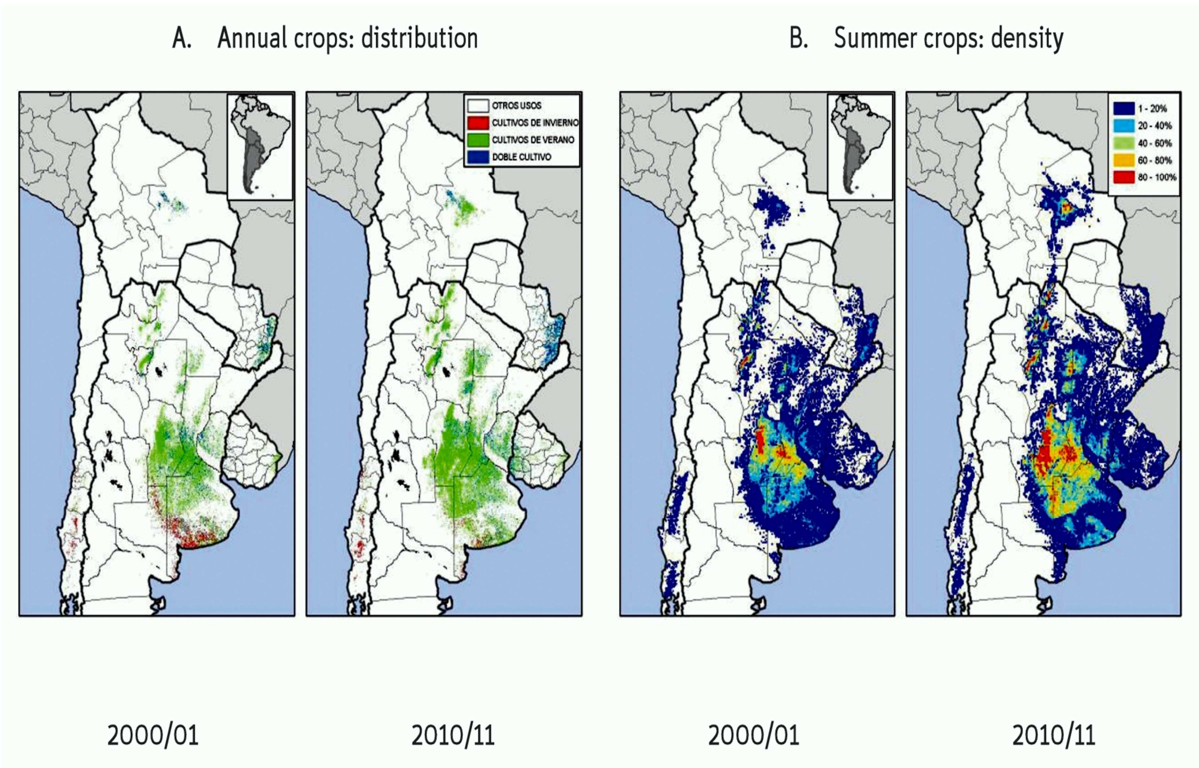


In terms of area under agriculture, the region has frequently been characterized as able to enter more of its land into production and, in fact, it placed an additional 31 million ha into agriculture between 2001 and 2011 (FAOSTAT, 2013). For example, an overall 43% increase in cultivated land was observed in Argentina, Bolivia, Chile, Paraguay and Uruguay between the cropping cycles 2000/01 and 2010/11 (FONTAGRO-BID, 2013). In addition, single-cropping decreased 66% for winter crops while a 59% increase in land planted with summer crops was registered (figure 5). This movement of the agricultural frontier came at the expense of a reduction of natural and cultivated pastures as well as an increase in deforestation. Similarly, an area slightly larger than Costa Rica (54,000 km^2) was converted to soybean cultivation in the agricultural-based states of Goias, Mato Grosso and Mato Grosso do Sul in Brazil (Chomitz et al. 2007). Intact and disturbed forests were the main source of new agricultural land between 1980 and 2000 in Latin America (Gibbs et al. 2010).

However, and while there remains a considerable potential for further expansion of agricultural land in the region, both in terms of potential arable land and freshwater availability, further increases of this magnitude may collide with land conservation and avoided deforestation efforts unless these concerns are carefully addressed or expansion of agricultural activity is directed to restore already degraded lands.

The region has experienced continuing long term increases in yields, resulting from improved practices, better seeds and increased use of fertilizers and pesticides. Although yields may be already reaching a plateau in developed countries for many of the agricultural commodities (Grassini et al., 2013), productivity gaps still leave some room for yield gains in the region (Alston et. al., 2010). There is potential for future productivity gains among small and medium producers where significant efficiencies in the production system can be achieved. This requires enhanced management as well as increased investment in agricultural research, technical assistance and plant genetics.

Figure 5: *Movement of the Agricultural Frontier, Selected South American Countries (FONTAGRO-BID, 2013)*



Irrigation is an important channel to increment agricultural productivity and crop diversification (FAO, 2000; Mollinga and Bolding, 2004). Today, almost 90% of farmed land in LAC is rain-fed (Wani et al., 2009). Other regions, like the Asia-Pacific region have a much higher rate of irrigated area in agriculture (ECLAC et al., 2012). Expanding the use of irrigation can thus increase LAC's food production, but it will require substantial additional infrastructure and capital.

From a *social perspective*, the economic impact of agriculture is small relative to other sectors, but farming activities employ a significant share of unskilled labor −a segment which ranges from 48% of total labor in Argentina to 91% in Nicaragua (Bambrilla et al., 2010) and are a dominant livelihood strategy among subsistence farmers, accounting along with the rural nonfarm economy, 70% of total income of poor households (World Bank, 2007).

Producers in the region are highly heterogeneous, ranging from subsistence farmers, who use few or no external inputs, to commercial farmers who make more intensive use of agrochemicals and are closely linked to international trade (Altieri and Toledo, 2011). Smallholder farms are highly relevant for food security purposes. Across the region there are 15 million family farms, covering almost 400 million ha (Berdegué and Fuentealba, 2011). These units practice traditional or subsistence agriculture and produce 51% of the maize, 77% of the beans, and 61% of the potatoes consumed in the region (Altieri and Toledo, 2011; Altieri, 1999). In Mexico, for instance, family farmers account for 70% and 60% of the total land devoted to maize and beans respectively (Altieri and Toledo, 2011; Altieri, 1999); whereas in Colombia −where coffee represents almost 22% of agricultural GDP− coffee plantations of five hectares or less represent 95% of all producers and 62.2% of the total area (Fonseca, 2003).

Agriculture is also relevant from a *climate perspective* on account of its share of regional greenhouse gas (GHG) emissions. Agriculture, land-use, land-use change and forestry accounted for nearly two-thirds of LAC’s emissions in 2005 (WRI, 2012). This is almost a mirror image of the world’s emissions profile dominated by energy use. About one third of the land-use change emissions are linked to net deforestation.

There is now hope that this contribution can be quickly reduced as avoided deforestation programs continue to succeed in the region and programs to recover degraded land take hold. The footprint from agriculture activities per se, on the other hand, is linked to practices and technologies representing long-held traditions and might be more difficult to address. Even under aggressive carbon emission reduction scenarios, agriculture will continue to contribute to the regional carbon signal in a significant way (Vergara et al., 2013). The sector is therefore key for any mitigation efforts. Furthermore, interventions in this area have the potential to simultaneously assist towards the achievement of a low-carbon, climate-resilient sustainable development.

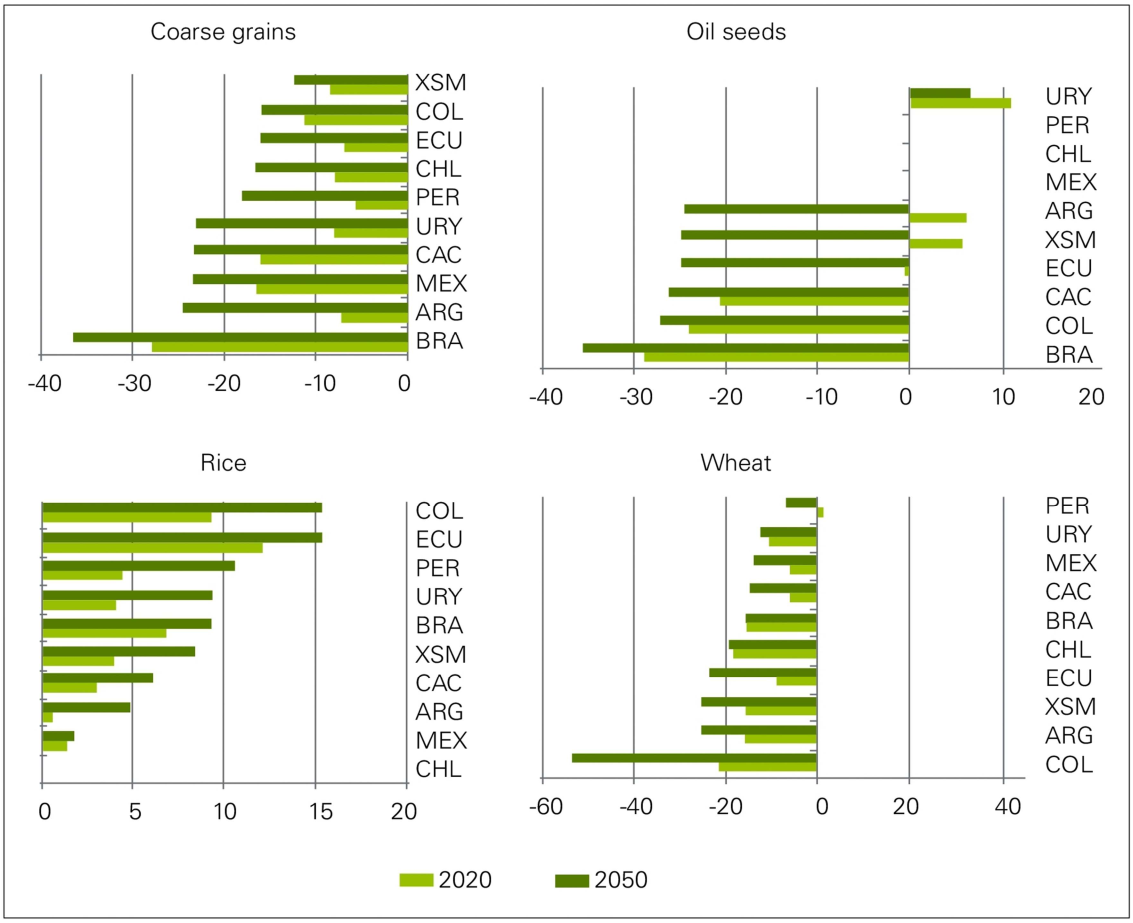
3.2. Impacts on agriculture caused by warming, reduction of soil moisture, and changes in rainfall patterns

Overall, the impacts of climate change on agriculture must be seen in the contexts of increasing demand for food and agricultural products (Dawson and Spannagle 2009) and exports to the global market. Specifically, impacts on agriculture are expected to reduce food supply and increase food prices, with potentially negative impacts on income, food security, poverty, and nutrition (Ahmed et al. 2009; Nelson et al. 2009).

As temperature, moisture, and rainfall patterns change, so will crop yields and the distribution of agricultural production (Dawson and Spannagle 2009). Shifts in climate variability (the intensity/frequency of floods, rainfall, drought, and storms) are expected to reduce yields.

More difficult to assess is the long term increase in the temperature of the top layer of soil, which may eventually surpass the genetic ability of many crops to adjust to different environmental conditions. In the short run, yields of certain crops may increase or decrease in different areas, according to projected rainfall, temperature, and weather variations. Over the longer term, LAC's agricultural output is expected to fall because of combined changes in rainfall patterns and soil conditions (ECLAC 2010; Tubiello et al. 2008; Mendelsohn and Dinar 2009).

Figure 6: Projected Impact of Climate Change on Key Crop Yield Losses (in %) by 2020 and 2050 under the A1B scenario (Fernandes et al. (2012)

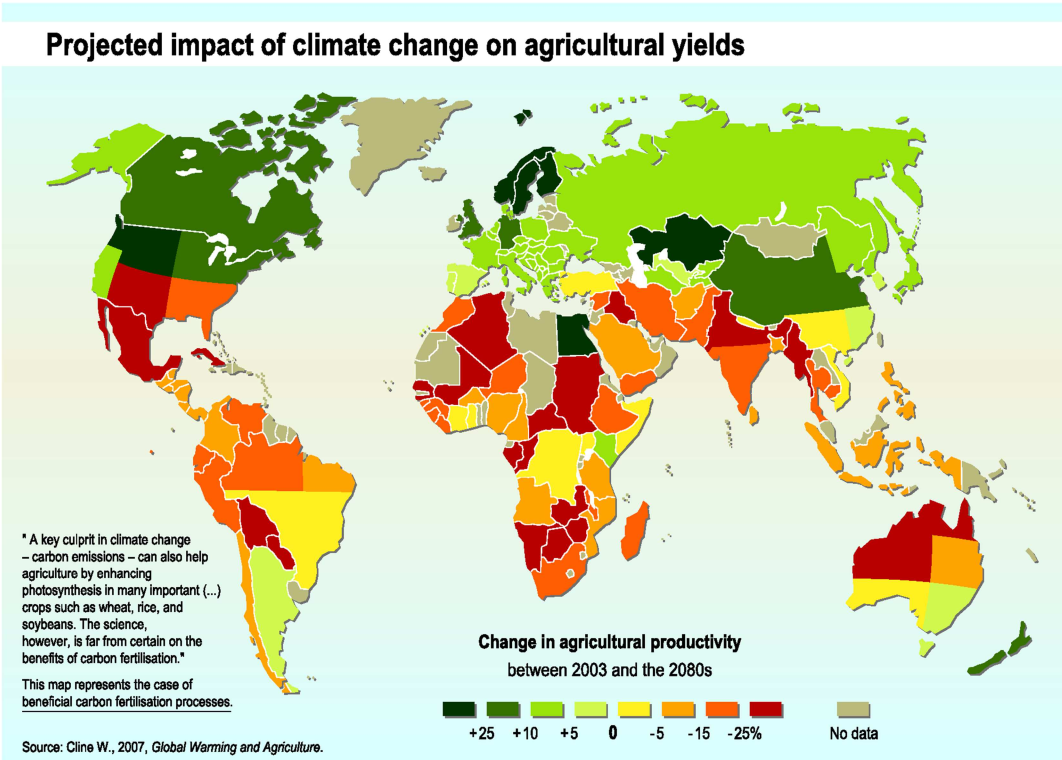


Legenda: ARG: Argentina, BRA: Brasil, CAC: Central America & Caribean, CHL: Chile, COL: Colombia, ECU: Ecuador, MEX: Mexico, PER: Peru, URY: Uruguay, XSM: Rest of South America.

A recent study concludes that the negative impacts of climate change on key crops could be significant for LAC and are expected to play a major role in the global food supply chain

(Fernandes et al. 2012). The analysis also suggests significant impacts over much shorter time frames than those previously reported (see figure 6). Simulated responses to the use of simple adaptation alternatives (improved varieties, change of sowing dates, and modest irrigation) suggest that these strategies are not sufficient to overcome the projected impacts of climate change but could dampen the yield shocks to a degree. The report also estimates that these impacts will reduce the value of annual agricultural exports in the region by $32 billion–$54 billion by 2050. Impacts of this magnitude, particularly in the context of a tight global food supply-demand balance, may also trigger other consequences, including food market speculation and threats to food security (Vergara et al., 2013)

4. Impacts of climate on agriculture Latin America



The impacts of climate change in Latin America are of an increasing concern; particularly, those impacts that involve the agricultural, livestock and forestry areas, due to their high dependence on climatic conditions. This leads to a situation of economic, social, environmental and political vulnerability, putting at risk food safety, human security and the basic conditions necessary to reduce poverty.

The agricultural, livestock and forestry areas have a great relevance for the countries of our region, because of their contribution to Gross Domestic Product, to the employment generation and to exports (Ryan, 2012), as well as their key role in food production for the whole word, among other things. Thus, the climate impacts affect the contribution of these areas to the national and regional economic growth, reducing in turn the capacity of the State to support sustainable development policies. Moreover, climate impacts may bring inflationary consequences in the food markets, influencing negatively the human security standards in the region and in the world.

The regional, national and sub-national policies aimed to the climate issue have been rarely effective in reverting the present situation and the discouraging projected scenarios. Although improvements have been carried out in policy-making, particularly in those policies regarding the creation and development of a specific institutional framework in the area, there is still a strong deficit in achieving the effective implementation of those policies.

The vulnerability analyses regarding climate change in the region indicates, among other things, that i) the periods of droughts and floods are exacerbating; ii) disaster phenomena are and will be not only be more extreme but also more recurring; iii) the loss of glacier surface is reducing the availability of water for human, agricultural and livestock consumption and for the generation of energy; iv) soils are in a sustained process of erosion and degradation in parallel with an alteration of the process of primary production; and v) it will impact on different environmental services, among other impacts.

Moreover, the available information indicates that Latin American and Caribbean countries are particularly vulnerable to climate change impacts, especially the agricultural, livestock and forestry sectors. For example, the case of Uruguay, where the 2009 drought caused a loss equivalent to 1.5% of the Gross Domestic Product; or the case of Colombia, where in 2012 La Niña phenomenon caused extraordinary levels of rainfall and floods that affected more than 2.27 millions of people in 775 different districts of the country (National Planning Department of Colombia, 2010 in Sarmiento, Ramos and Arenas Wightman, 2012), resulting in substantial material damage. The case of Paraguay is also paradigmatic: the climate performance in the last years, mainly the extended droughts, has put rural producers into a situation of severe food insecurity forcing the Executive Power to declare food emergency for the indigenous familiar agriculture in 2012. Other case is Ecuador, where the droughts (2002-2007) caused the loss of 45% of transitory crops and 11% of permanent crops (Ministry of the Environment of Ecuador, 2011 in Albán and Prócel, 2012). The list can be extended to all Latin America showing that specific measures should be taken urgently in order to maintain the benefits that these areas provide to society as a whole.

Two thirds of the greenhouse gas emissions in Latin American are produced by changes in land uses, and forestry and pastoral activities. Any strategy in this direction requires specific policies in the agricultural, livestock and forestry sectors. Gradually, the countries of the region are increasing their commitment to reduce gas emissions as it is evidenced in national communications and climate policies both at local and national level. Particularly in the last decade, it has been possible to observe the development of a specific institutional framework in relation to climate change. Only some countries still lack the necessary tools and policies to face this issue. In those countries which have progressed on the issue, it is possible to observe some common patterns and characteristics (Ryan, 2012).

From the moment of design, some limitations are observed. Mainly, there is a strong weakness in the integration and articulation of climate policies with other sectorial or macroeconomic policies. The lack of articulation is not only perceived in the absence of operational coordination but also in the contradiction between the purposes and the objectives of each of the policies. This situation threatens the fulfillment of both policies, often sending confusing signals to the society and to the market, and wasting, therefore, opportunities and synergies. Particularly, the lack of articulation between forestry protection policies and those of promotion of the agricultural and livestock activity generates deficiencies in the design and implementation of the policies. This situation is repeated in various countries of the region. The lack of coordination needs to be tackled by environmental land use planning schemes which is a key integrating tool in order to achieve the objectives of the proposed climate policy.

4.1. Systemic climate impacts in agriculture in LAC

Systemic impacts, those affecting the agriculture sector at large and over time, are linked to the projected unidirectional changes in:

a) Atmospheric and soil temperatures
b) Decreases in top soil moisture
c) Sea level rise, and
d) CO_2 fertilization.

There are also other changes such as modification in rainfall patterns, changes in pests and disease distribution and intensity, and changes in weather variability (incidence of droughts and floods), about which there is less consensus on the magnitude of the impacts and their evolution over time, but that are likely to exert significant pressure on the agriculture sector.

4.1.1. Atmospheric and soil temperatures

The anticipated changes in atmospheric and soil temperatures are a concern for agricultural yields. The major problem is that key crops might not be able to maintain photosynthesis activity as temperatures continue to rise. While higher temperatures could generally promote growth, photosynthesis activity is known to drop rapidly once its optimum is reached. As the temperature rises above 35°C, photosynthesis slows, dropping to zero when it reaches 40°C (Brown 2004). For example, higher than normal atmospheric temperatures were the main factor for a significant drop in yields −18% for corn and about 10% for soybeans− in the U.S. during the summer of 2012 (Wescott and Jewison 2013).

The average temperature anomaly for this century is now projected in the range of 2-6°C. However, warmer summer temperatures in agricultural areas particularly those in tropical latitudes may reach these thresholds with more frequency and earlier in the coming decades.

Also, for some crops −such as grains−, faster growth reduces the amount of time that seeds have to mature, thus reducing their yields (USGCRP 2009). Moreover, climate change is inducing long term changes in the hydrology and ecology of ecosystems that could in turn affect agricultural production. Warmer temperatures are affecting evaporation and evapotranspiration rates, as well as water storage in lakes and reservoirs. They are also changing the altitude of dew points, therefore affecting water balances in mountainous areas (Vergara et al. 2011).

4.1.2. Decreases in top soil moisture

For most LAC, extended periods of drought and lower moisture levels have been anticipated as a consequence of climate change. A projection for Latin America, made in the context of an assessment of climate temperatures in tropical forests estimates a lengthening of dry periods in most of the region, and a significant decrease in top soil moisture.

However, some of the major reductions were found to be forecasted for major food producing areas, such as the south eastern area of the Amazon basin in Brazil, the delta of the River Plate and coastal plains in northern South America. Water for agriculture already accounts for about 67% of total withdrawals in LAC (FAO 2013). A considerable reduction in land suitable for rain-fed agriculture could be the result of a decrease in top soil moisture and could be exacerbated by extended periods of drought. Irrigation requirements would then escalate placing pressure on existing infrastructure for water supply and increasing production costs. In addition, reductions in top-soil moisture are linked to an increase in soil aridity. This is particularly relevant in LAC given its heavy reliance on rain-fed production systems, and small-scale agriculture in marginal areas.

4.1.3. Sea level rise

Agriculture in coastal areas and deltas is susceptible to the impact of sea level rise (SLR) through inundation of land, erosion, salinization of wells and land, and loss of ecosystems. Increases in sea water intrusion may affect coastal aquifers, making them unsuitable for use in agriculture and promote gradual salinization of coastal strips. SLR is of significant economic relevance as a number of productive areas are located near the coastline in the region. There is however no comprehensive assessment of the systemic impact that sea level rise would have in agricultural areas in costal zones and deltas.

Low lying areas in the region, where intensive agriculture is practiced, include the northern coastal plains of Colombia and Venezuela; the Gulf of Mexico and coastal areas in the Sea of Cortez, in Mexico; as well as the deltas of the River Plate in Argentina, the Magdalena River in Colombia and the state of Maranhao in Brazil. Guyana exemplifies the impacts of sea level rise due to climate change in countries with high concentration of economic activity in their coastal plains. About 25% of the coastal plain territory (142,500 ha) in this country would be affected by sea level rise, including the intensification of storm surges, of which 59% are dedicated to agriculture (Government of Guyana 2012).

4.1.4. CO_2 fertilization

CO_2 concentrations have increased from about 280 ppm before the industrial revolution to about 400 ppm today and are anticipated to continue to increase under most climate scenarios. The consensus of many studies is that the CO_2 fertilization effect on plants is real: crop photosynthetic rates respond to increased levels of CO_2 until about 700 ppm, depending upon species and other variables (Allen et al. 1996). This effect begins with enhanced CO_2 fixation. Reproductive as well as vegetative biomass growth is usually increased by elevated CO_2. The net result of CO_2 fertilization is expected to be an increase in biomass production and therefore yields. In climate change scenarios, however, temperatures are predicted to increase following CO_2 increases. Temperature increases in a higher CO_2 world could increase vegetative growth; but, the interaction of these two variables may result in opposite effects on yields, if temperature thresholds are reached. Additional analysis is required to ascertain the net impacts on yields in a warmer world with higher atmospheric concentrations of CO_2.

4.1.5. Other impacts

Cumulative climate change impacts will affect the distribution of plants and animals, phenology, and ecological interactions.

- ***Distribution of plants and animals*** Alteration in the distribution of plants and animals includes the shift of tropical species and movement of altitude boundaries (Parmesan 2006, Laderach et al. 2009) as temperatures increase. Coffee may undergo a geographical redistribution in Brazil with an overall decrease in suitable land. Haggar and Schepp (2012) estimate that up to 33% of the current coffee area in Sao Paulo and Minas Gerais in Brazil (two main coffee producer states) may be lost while suitable area in Paraná, Santa Caterina and Rio Grande do Sul may increase. Similarly, suitable land for coffee production in Nicaragua may be reduced as the optimum altitude for coffee production rises from 1200 masl to 1400 masl and 1600 masl by 2020 and 2050 respectively (Laderach et al. 2009).11 This trend towards more intense cultivation at higher elevations is leading in some instances to land use changes in upper water-sheds, displacing critical areas for the conservation of water regulation.

  The diversity of the genetic resource pool is being threatened by climate change. Endemic varieties are less capable of moving and surviving as the agro-ecological conditions change. Around 20% of crop wild relatives of three major crops (peanuts, cowpea, and potato) could be threatened by extinctions by 2050 (Jarvis et al. 2008). Seven out of the 25 most critical places with high endemic species concentrations are in Latin America and these areas are undergoing habitat loss (Jarvis et al. 2011). There is a need not only to conserve genetic resources but to undertake research aimed at identifying genetic traits which are key for adaptation (CGRFA 2011).
- ***Phenology*** This aspect includes inter alia, acceleration of growth, flowering and fruit ripening due to warmer temperatures (Root et al. 2003, Menzel 2005, Cleland et al. 2007,

Sherry et al. 2011), and alterations in seed germination (Walck et al. 2011). Evidence indicates that spring has been advancing globally since the 1960s (Walther et al. 2002) at a rate between 2.3-5.1 days earlier per decade (Parmesan and Yohe 2003, Root et al. 2003), with observed changes in the timing of seasonal activities of animals and plants (Walther et al. 2002). This may affect production in southern areas of the continent.

- ***Ecological interactions*** Warmer temperatures may also result in changes in the geographical range of pests, alterations in population growth rates, extension of the development season, and increased risk of invasion by migrant pests (Porter et al. 1991). As an example, an increase in pests and diseases due to climate change is reported in Colombia for bananas, plantain, coffee, potato, cacao, maize and cassava (Lau et al. 2013). However, management of the impacts of climate on beneficial insects and pests requires further research. Topics that have been suggested include the influence of climatic variables on beneficial and pests insects, long-term monitoring of population levels and possible implications of climate changes for insect management strategies.

5. Agriculture in South America

Agriculture constitutes a large sector of South America's economy in both its tropical and its temperate regions. Livestock production also occupies large parts of rural South Americe (see figure 7), especially cattle ranching. Most of the commercial livestock production, especially for the export sector, occurs on huge *estancias* (estates) that have been the source of economic and social dominance for their owners for many generations.

Only about one-eighth of South America's land is suitable for permanent cropping or grazing. It is broadly agreed that agricultural land use throughout the continent is less efficient than it might be. Farm and ranch productivity could be enhanced by measures such as providing adequate agricultural credit, improving marketing, storage, and transportation systems, and expanding the educational system in rural areas. Such changes would benefit the large number of small farm-holdings (*minifundios*) three-fourths of South America's farmers own less than 25 acres (10 hectares) making it possible for those farmers to improve their living standards and contribute to national development. The changes also would help to alleviate the widespread under and unemployment prevalent in some densely populated rural areas. Unemployment is a problem in such areas, even though less than one-third of South America's working population is employed in the agricultural sector, as compared with nearly one-half of the population for the world as a whole.

Figure 7: *Milk production in rural zone Cayambe - Ecuador at altitude 3200 amsl.*

(http://www.btcctb.org/en/news/2000-productores-leche-logran-mejorar-su-producci%C3%B3n-en-cayambe-video)

The agricultural sector is affected negatively as well by the unfavorable terms of trade between agricultural commodities and manufactured goods that have existed in general since World War II. The rise in the cost of farming has outstripped the rise in the prices paid for agricultural commodities, and this imbalance substantially lowers the investment potential in the agricultural sector (Encyclopedia Britannica- Griffin, 2014).

6. Agriculture in Ecuador

Ecuador is predominantly agricultural (Ecuador, 2001), despite oil having become its main source of revenue and industry having expanded substantially. The per capita gross national product ranged between USD 1 200 and USD 1 600 in the last decade. Ecuador's human development index was 0.726 in 1999 (UNDP, 2001). Agriculture employs 32% of the workforce and provides 13–17% of the gross national product. Animal production contributes approximately a third of this amount (SICA/ MAG, 2002). Agricultural imports over 1999 - 2001 ranged between USD 199 and 267 million FOB, whereas exports amounted to USD 1 462 - 1968 million FOB (SICA/MAG, 2002). Half of the agricultural exports are bananas and plantains; shrimps, coffee, cocoa, cut flowers and fish make up the rest.

6.1. Livestock and poultry

Livestock raising represents an important part of agricultural output and has grown significantly in the last 20 years. Livestock was produced primarily for domestic consumption and was one of the few agricultural products found throughout the country. Although animal husbandry was widespread, it was generally practised on small plots of land.

Ecuador produced a total of 2 M and 2.5 M tonnes of milk in 2000 and 2004 respectively (FAO, 2006) and 170 620 and 212 000 tonnes of beef and veal. Both products grew in the 1900s at rates of 4.1% and 4.5% per year respectively, whereas the stock of cattle grew at only 2.97% per year. On the other hand, the stock of goats has remained nearly stagnant, while that of sheep grew 2.9% over the same period. Milk equivalent imports are still substantial with 5 042 Mt in 2000 and 6 243 Mt in 2004, although these have fallen from 11 650 in 1995 and a high of 53 158 in 1998 (presumably reflecting the earthquake of 1997).

The Costa and Oriente regions produce mainly beef and dual purpose cattle with dairy cattle found mostly in the Sierra. Cattle graze on Costa land otherwise unsuited for agriculture, such as the hilly terrain in Manabí Province, seasonally flooded river plains or semi-arid parts of the far south. Dairying in the Sierra is carried on typically in fertile valleys, particularly between Riobamba and the Colombian border. Beef cattle are relatively new to the Oriente, although large areas of land are suitable for grazing. The beef industry in the Oriente suffered a serious setback in 1987 when an earthquake damaged roads used to transport the beef. Ecuador had about 3 700 000 beef cattle in 1985, but by 2005 the number had increased to almost 5.0 M (4 951 390 according to FAOSTAT).

The 1980s saw an improvement in stock with the introduction of European and Asian breeds. The native Creole breed represented about half of all cattle, with the rest being crosses between Creole and Holstein, Brown Swiss, or Jersey for dairy, and Creole and Santa Gertrudis or Charolais for beef. The absence of veterinarians and medicines remained a problem, however, and diseases and parasites plagued many herds.

Besides cattle, livestock include pigs, sheep, and some goats. For pigs, FAO data indicates 1.4 M in 2001, whereas the latest country survey (2000) records 1.53 M; the greatest concentration was in coastal areas. The FAOSTAT figure for 2004 was 1.77 M pigs and 1.95 M in 2005.

In early 2001, the stock of South American camelids was estimated (White, 2001) to include 1 700 vicunas (*Vicugna vicugna),* 10 000 llamas (*Lama glama*) and 4 600 alpacas (*Lama pacos*). The last two are domesticated. Camelids are largely grazed on high altitude commons, including national parks and reserves.

6.2. Typ of Soils in Ecuador

The extremely variable topography of the country is associated with a complex mosaic of soils.

- ***The coastal littoral***, located between the Pacific Ocean and the western Andes, possesses an abundance of hydromorphic soils particularly in the well-watered parts, which have moderate to low drainage and moderate fertility. It contains soils derived from deposits of diverse origins influenced by volcanic activity of the Andes, aeolian transport of volcanic ashes and alluvial deposits, all subjected to intense weathering.

- ***In the temperate Andean ecozone*** (see below under ecozones), soils vary somewhat depending upon rainfall. It should be noted that classification of Andean soils is notoriously complex; details and equivalencies between systems of classification are available (Quantin, 1986; FAO, 2001; FAO-CSIC, 2002). The portion of the temperate area frequently classified as a low montane spiniferous steppe, with rainfall of less than 500 mm, includes the following soils (León-Velarde and Izquierdo, 1993): (a) Durandept, sandy loams, with a calcareous layer located above a duripan placed at a depth of 70 cm – these are soils that if irrigated support a variety of annual crops, lucerne, oats and Kikuyu grass; (b) Durustoll, generally located on slopes, over fine ashes and also with an underlying duripan; (c) Eutrandept, loamy soils with very fine ash, low water retention, pH 7; and lastly (d) Torripsamment, very sandy soils, with less than 1% organic matter and pH 8. Farms surveyed in this area by Ramírez *et al*. (1996) had soils with pH 5.2 to 6.7, acidity increasing with altitude, generally low in organic matter (OM), and always very low P (< 4 ppm). When rainfall increases to 500–1 000 mm, the zone is classified as low montane dry forest, and includes very variable soils, most frequently derived from volcanic ashes. These are clayey loams, black soils that support productive stands of lucerne if irrigated. The low montane humid forest zone is encountered in areas with 1 000 to 2 000 mm, and has similar soils to the previous one.
- ***The cold temperate ecozone*** (see below) is found at high altitudes. Within it, the Paramo (or cold high steppe) is the typical landscape, receiving 250–500 mm rainfall. In general terms, Paramo soils are of volcanic origin; these include soils derived from recent volcanic ashes, and those derived from metamorphic and igneous rocks (Medina and Mena, 2001). Those of the northern and central Paramos are generally Andisols, young, undifferentiated, high in organic matter, with high water retention capacity, highly permeable and resistant to erosion. Nevertheless, once they lose these physical properties as consequence of compaction, they begin to repel water. Soils of the southern Paramos are generally Inceptisols, derived from metamorphic rocks, older than the previous one, less fertile but have less capacity than the former to immobilize P.

  Soils in farms surveyed by Ramírez *et al*. (1996) in the Paramos had pH 5.8–6.2, high OM (6–15%), high K and trace amounts of available P. Soils in the interandean regions are highly eroded (de Noni, Viennot and Trujillo, 1989–90) and it has been estimated that 48% of the national territory has some degree of erosion (Ecuador, 2001, see below).

  Soils of the Amazon piedmont, on the eastern slope of the Andes, are mostly Inceptisols of low to medium fertility (Hicks *et al.*, 1990). Thus, farms surveyed by Ramírez *et al*. (1996) had soils with pH 5–5.8, frequently high OM (> 5%) particularly if associated with poor drainage, P < 3 ppm and moderate to low K. In the lowland plains three main types of soils are recognized (Estrada *et al*., 1988): (a) alluvial sandy soils in the flatter portions along the rivers, seasonally cultivated with a variety of crops; (b) black, fertile volcanic soils, in the plains located N of the Napo River, and (c) red ultisols in broken hills, characteristically acid and of low fertility

6.3. The pastures resource

According to census data (SICA/MAG, 2002) the agricultural land of Ecuador in 1999–2000 amounted to 12 400 000 ha, 27% of which was under sown pastures, 9.1% under native grasslands, 4.9 covered by Paramos and 3% fallow. If all of these are considered as grazing resources, nearly half of the usable land was available for grazing. Although the data reveal that there is trend for larger farms to have more of the land covered by the above resources, even farms under 5 ha dedicate 32% of the land to grazing and 24% to sown and native pastures. In farms over 200 ha, these percentages increase to 48% and 33% respectively. The Sierra and Costa have 51 and 36% of Ecuador's cattle stock respectively, with the reminder in the Oriente. Cattle are evenly distributed across farm sizes, oscillating very little between 12% of the stock in farms of 100–200 ha to 19% in farms of 20–50 ha; farms of less than 5 ha own 17% of the cattle stock. The previous data show the extreme importance of livestock raising in Ecuador across regions and farm sizes.
The area of sown, native and naturalized pastures of Ecuador has been variously estimated between the 5 510 000 ha reported in SICA/MAG (2002) and FAO databases and the 6 500 000 ha reported by some analysts (Hervas, 1985). These are distributed as follows: 3 070 000 ha in the coastal area (48%), 180 000 ha (3%) in the Amazon basin, 1 865 460 ha in the high Paramos (29%), 883 400 ha of naturalized pastures where *Pennisetum clandestinum* (Kikuyu grass) is a very important contributor (14%), and close to 400 000 ha of sown pastures, including lucerne (*Medicago sativa*) and other temperate forages.

6.3.1. Coastal pastures

Pasture development along the tropical, wet, coastal belt relies on sown tropical grasses, and to a much lesser degree legume species, some of which have become endemic. Where soil fertility allows, grazed pastures are based on star grass (*Cynodon nlemfuensis*), Pangola grass (*Digitaria decumbens*) or Guinea grass (*Panicum maximum*), while elephant grass (*Pennisetum purpureum*) is used for cut-and-carry systems, particularly in dual purpose systems. Legumes such as *Centrosema pubescens*, *Stylosanthes* spp., *Desmodium* spp., *Dolichos lablab, Neonotonia wightii* and numerous others have been tried but their contribution to sward composition is generally unimportant. Following the trend observed across all of tropical Latin America, the last 15 years have witnessed the expansion of Brachiaria-based pastures (*Brachiaria decumbens, B. humidicola, B. brizantha*) in the area. Extremely limited information regarding the animal production potential of all of these pastures is available for Ecuador, but it can confidently be estimated that their potential is similar to that observed in neighbouring countries, meaning that carrying capacities for directly grazed pastures will range between 1 - 4 AU/ha, whereas elephant grass can supply forage for 7 - 12 AU/ha over limited periods of time. A potentially important niche for one of the newest legumes, *Arachis pintoi*, is as a cover crop under plantains, cocoa and coffee, as shown in numerous other tropical countries of the region.

Ramírez *et al.* (1996) describe a recent survey of pastures in a subregion of the coastal area, located at 150 - 260 m, latitudes between 0 11' S and 0 28' S, mean temperature of 25 °C and rainfall of 1 560 to 2 000 mm. The area surveyed included 55 000 ha of sown pastures, 95% of which was P*anicum maximum* and 5% *Cynodon nlemfuensis* with a token presence of native *Desmodium* sp. and some broadleaf weeds such as *Sida acuta* and others. Across 11 on-farm experimental sites, aboveground yields averaged over three years were estimated at 15 400 kg DM/ha.year, with two-thirds being produced during the wet season. This annual yield was nearly 50% less than that obtained under controlled, well managed conditions in a nearby experimental research station. Clippings taken at 60-day intervals during the wet season and 78 days in the dry season showed 10.4 and 7.2% crude protein, and 55 and 52.8% IVDMD, respectively.

Milk yields were recorded in a subsample of two farms that had dual-purpose systems. As is typical of these systems elsewhere, milk yields averaged 3 kg/milking/cow/day/year using stocking rates of 1.5 - 1.8 cows/ha. The authors consider that stocking rates could be significantly increased if provision for summer feeding was available, as farmers stock their pastures based on the predicted carrying capacity during the dry season. Weight gains in beef production systems of seven farms averaged 0.35 kg/steer/ day, also highly typical values for tropical systems in the lowlands of Latin America. Similar comments regarding efficiency of utilization of pastures apply as for dual-purpose systems.

The potential of these pastures under optimal conditions has been determined in controlled, experiment station-run, grazing experiments. Ramírez *et al.* (1996) report that carrying capacities on *Panicum maximum* alone, or with a mixture of legumes (most notably, *Centrosema pubescens*, contributing 40% of the botanical composition), were 4 and 2.5 steers/ha for the rainy season and 3.5 and 2 head/ha for the rainy season, respectively.

Andean pastures are complex, their composition depending upon the altitude and climate of the site considered, and they have been modified by human interventions. A recent classification of these pastures recognizes two main types of ecozones, the temperate and the cold temperate zones, respectively (León-Velarde and Izquierdo, 1993), each of which includes a number of subtypes described below.

6.3.2. The Andean temperate ecozone

The first subtype corresponds to native and naturalized grasslands and shrublands located in dry interandean plateaus and valleys, estimated to cover 0.45% of Ecuador's surface area. They are between 2 000 and 3 000 m, with mean temperatures of 12–18 °C and 250–500 mm annual rainfall, including a dry period of 3–5 months, extending from May to September. If irrigation is available, these areas can grow cereals, fruits and vegetables, as well as lucerne, forage oats and Kikuyu grass. The steeper slopes are used for grazing goats and forestry.

At similar altitudes, but with rainfall ranging from 500 to 1 000 mm, the region includes a large number of valleys that, although representing only 3% of the country's area, are extremely important from the point of view of population density, and agricultural and livestock activities. Here the main forage resource is lucerne wherever irrigation is available, followed by Kikuyu grass and lupins (*Lupinus* spp.) in a variable land-use mosaic that includes wheat, barley, beans, green beans and various other vegetables.

In numerous other valleys of similar altitudes but with rainfall of over 1 000 mm, milk production is based on Kikuyu grass, ryegrass, *Melinis minutiflora* and *Panicum coloratum,* frequently located in mixed production systems that include potatoes, maize, and wheat. Ramírez *et al.* (1996) described farm surveys carried out in an area corresponding to the drier part of the temperate ecozone, with a 6–8 month dry season. The study area covered 87 000 ha at latitudes 3 59' to 4 26' S, and between longitudes 79 18' to 79 37' W. Farms averaged 53 ha each, with 31% of this area under pastures and 50% in fallows used for grazing and dominated by *Paspalum humboldteanum* and Kikuyu grass under a sparse cover of *Acacia* sp. and *Mimosa* sp. trees. Further detailed characterization of 13 farms located at 1 600 to 2 400 m within this area, and with slopes ranging between 10 and 65%, was carried out. Five of the 13 farms had irrigation available. Native or naturalized pastures were composed of grasses (88%, either *P. humboldteanum* and/or Kikuyu), legumes (6%) and broadleaf weeds (6%). Pastures were used to graze dual-purpose cattle. Unirrigated pastures yielded on average 2 548 kg /ha/year (range 500 - 7 000), and yields were inversely related to slope ($r=-0.62$, $P<0.05$). Trampling by cattle in the wet season left patches of bare soil, the size of which was positively related to slope ($r=0.65$, $P<0.05$). Irrigated king grass (*Pennisetum purpureum x P. typhoides*) used to provide cut-and-carry forage yielded 15 - 18 tonnes DM/ha/year, whereas if unirrigated yields fell to 6 - 8 tonnes.

Fifteen farms averaging 26 ha each, located at altitudes of 3 000 to 3 500 m, and with slopes ranging from 0 to 55%, had 71% of their area under pastures. One half of the pasture area was under naturalized and sown *Dactylis glomerata- Lolium multiflorum-Trifolium repens* associations, and 37% under Kikuyu, *Holcus lanatus* and *Paspalum pigmaeum* native populations. In this case, aboveground yields ranged from 4 tonnes DM/ha/year in *Paspalum pigmaeum* pastures to 15 tonnes in well managed lucerne stands. These results coincide well with a study conducted across 17 sites by Paladines and Jácome (1999), who measured dry matter production under exclosures placed in a variety of pastures in the extreme north of the Andes (Carchi). Pasture components included all of the above-named species in various proportions. The authors found that 93% of the variation in yield (ranging between 3 and 18 tonnes DM/ha) was explained by just two variables: hours of irrigation applied per month, and soil apparent density, which had a negative effect on yields.

6.3.3. *The Andean cold temperate ecozone*

The ecozone is located at 3 000 to 4 000 m, and has mean temperatures of 6 to 12 °C. Three subtypes can also be identified based on rainfall availability, although grassland species are fairly common to all. Common species include (Hervas, 1985; León-Velarde and Izquierdo, 1993): *Agrostis perennans*, *Agrostis tolucensis*, *Agrostis alba*, *Calamagrostis vicunarum*, *Poa pratensis*, *Holcus lanatus*, *Bromus catharticus*, *Stipa ichu*, *Stipa obtusa*, *Muhlenbergia emesrleyi*, *Lupinus alopecuroides* and numerous others. Naturalized Kikuyu grass (introduced from Colombia in 1947), frequently associated with white clover, is common in the better soils below 3 200 m.

The first of the subtypes is dry steppes, with < 500 mm rainfall distributed over 10 months. The dry months are July and August. The area has been estimated to cover 0.4% of Ecuador. Extensive sheep production systems make use of these grasslands, which are based on a variety of species of *Festuca, Agrostis, Poa, Bromus, Calamagrostis, Stipa (*most notably *Stipa ichu)* and *Lupinus*.

The second, humi, subtype receives 500 - 1 000 mm rainfall and constitutes close to 4% of Ecuador's surface area. Rainfall is distributed year-round, and evapotranspiration at these altitudes is very low. Grasslands here are dominated by species of *Stipa*, *Calamagrostis* and *Festuca*, and constitute the main land use. Cattle, both beef and dairy, are the mainstay of the economy of these regions.

Ramírez *et al.* (1996) reported studies aimed at characterizing native grasslands above 3 500 m, receiving 500–1 000 mm rainfall and on slopes > 12% where mean temperatures ranged between 3 and 12 °C. *Calamagrostis* sp. dominated pastures (> 35% of the botanical composition) located at higher altitudes within the region, whereas lower-lying areas were characterized by mixtures of *Bromus* sp., *Holcus lanatus*, *Poa* sp., *Stipa ichu*, *Festuca pratensis* and others.

Areas with rainfall in excess of 1 000 mm (over 4% of Ecuador) are extremely humid, and wetlands abound. The better drained areas, as well as the slopes, are dominated by the same species listed in the previous case, but the livestock industry here is marginal.

6.4. Introduced pastures in the Andes

Artificial pastures in the well-watered high Andes of Ecuador vary between the naturalized Kikuyu stands and sown pastures of species such as lucerne, *Dactylis glomerata* and *Lolium* spp., frequently associated with naturalized *Trifolium repens*. *Lolium multiflorum* stands are very common. The potential of these pastures in the best parts of the Ecuadorian Andes is extremely high if well managed. Experimental yields of 20–30 tonnes DM/ha have been obtained, which could potentially yield 10 000 litres milk/ha/ year (Estrada et al., 1997).

6.5. Pastures of the eastern region

The Amazon basin of Ecuador, to the east of the Andes chains, includes the piedmont region, and the less populated lowlands. The latter are also of much less importance from the point of view of ruminant production than the piedmont. More limited studies have been carried out in this ecozone than in the previous two. Ramírez *et al.* (1996) summarized the results of farm surveys carried out over 213 000 ha of piedmont, with rainfall in excess of 3 700 mm. The average area of 185 farms surveyed in the region was 122 ha (range 50–186 ha), and 75% of this area had been cleared of forest, with 90% of it converted to pastures. *Axonopus scoparius* was the main (83% of the cases) species, followed by small percentages under *Brachiaria decumbens, Echinochloa polystachia* and others. Legumes contributed no more than 1% of the botanical composition. Average yields of these pastures were 13 tonnes DM/ha/year.

Pastures in the lowlands are far less common. Estrada *et al.* (1988) surveyed farms located in the area at 450 m, averaging in excess of 3 000 mm rainfall, and with the driest month averaging 140 mm. Farms had a mean of 46 ha each, including 4–11 ha under pastures. Elephant grass and *Brachiaria decumbens* were the two main species, although *Brachiaria humidicola* was expanding at the expense of the latter. Scarcity of cattle probably explained why average stocking rates were 0.93 head/ha, while experimental results suggest that *Brachiaria humidicola* should be able to support 2 head/ha.

7. How the Migration effected on Agriculture Highland of Ecuador

As the scale and pace of international migration have increased in the past two decades (Castles and Miller, 1998), so has concern for the effects of this migration on agriculture and agrarian landscapes. Agriculture in less developed countries (LDCs) has long been influenced by extra-local processes (de Janvry, 1981; Grossman, 1993; Turner, 1989), but today, more so than ever, smallholder agriculturalists (hereon smallholders) are becoming integrated into the global economy by emigrating to more developed countries (MDCs) where even low-paying jobs in New York or Paris exceed what can be earned in Ecuador or Morocco.

Some of these rural emigrants lead transnational lives, dividing their time and labor between home community and host country; others remain primarily in the host country, sometimes for decades. Most emigrants, however, return a steady stream of remittances to their household of origin, and many return permanently to their home country at the end of their labor experience. The medium to long-term loss of labor and infusion of funds homeward carries significant implications for rural landscapes and agricultural change.

Two opposing conditions are typically postulated for the early phases of migration: (i) the removal of labor threatens the capacity of households to respond to labor demands, leading to a decline in cultivation and agricultural production and (ii) remittances overcome labor shortfalls and provide capital inputs to make agricultural improvements. A majority of studies support the former, concluding that migration undermines agricultural systems; labor loss deprives households of necessary labor, and remittances are seldom invested in landesque capital or other improvements needed to maintain and improve the agricultural sector (Black, 1993; Mines and de Janvry, 1982).

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