REGIONAL ASSESSMENT - LA

Maize situation in Latin America: Outlook and investment opportunities

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Acronyms

AGDP	Agricultural Gross Domestic Product
ASTI	Agricultural Science & Technology Indicators
CAFTA	Central America Free Trade Agreement
CEPAL	Comisión Económica para America Latina
CIMV	Commercial Improved Maize Variety
COPV	Commercial Open Polinated Variety
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo
CRP	CGIAR Research Project
ECLAC	Economic Commission for Latin America and the Caribbean
FAO	Food and Agriculture Organization of the United Nations
FM	Floury or Starchy Maize
GCC	Global Climate Change (
GDP	Gross Domestic Product
GMM	Genetically Modified Maize
GMO	Genetically Modified Organism
HDI	Human Development Index
HYB	Hybrid seed (material)
IAR4D	Integrated Agricultural Research for Development
ICR	Industry Concentration Ratio
IE	Strategic Initiatives
IFAD	International Fund for Agricultural Development
IMF	International Monetary Fund
IITA	International Institute for Tropical Agriculture
LAC	Latin America and the Caribbean
MAEZ	Maize Agro Ecological Zones
MAIZAR	Argentine Association of of Maize and Sorghum
MVCS	Maize Value Chain Systems ()
NARI(s)	National Agricultural Research Institution(s)
NLA	Northern Latin America
OECD	Organization for Economic Co-operation andDevelopment
OPV	Open Polinated Variety
ROPV	Recycled Open Pollinated Variety
SIACON	*Servicio de Informacion Agroalimentaria y pesquera*
STAR	Subtropical Andean region
STNA	Subtropical North America
STSC	Subtropical Southern Cone
SWOT	Strength, Weakness, Opportunities, Threats
TCA	Tropical Central America
TSC	Temperate Southern Cone
UNDP	United Nations Development Program
USDA/FAS	United States Department of Agriculture/Foreign Agricultural Service
WDM	White Dent Maize
YDM	Yellow Dent Maize

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Preface

The maize research program (MAIZE CRP) of the Consultative Group on International Agricultural Research (CGIAR) is part of a concerted effort by the organization to implement new, strategically-oriented results through an array of research programs that take advantage of the maximum potential of International Agricultural Research for Development (IAR4D), in order to improve world food security, reduce poverty and maintain the environment. Administered by the International Maize and Wheat Research Center (CIMMYT), the MAIZE CRP is being carried out under nine Strategic Initiatives (SIs),[1] which are executed through competitive funds acquired by national and regional partners to support research and capacity building that contribute significantly to the vision of success of this research agenda. Specifically, SI-1 addresses "Socioeconomics and policies for maize futures" and involves four different evaluations globally, one for each geographical region - South Asia, Eastern and Southern Africa, West and Central Africa, and Latin America. The purpose of these regional assessments is to document the current situation, prospects and investment opportunities in the maize industry that will ensure food security for the major maize producing and consuming countries in the respective regions.

In the case of Latin America, the objective of the regional assessment project called *"From Tortillas to Polenta: Assessment of the situation, outlook and investment opportunities for maize in Latin America"* is to identify and characterize the current situation of maize, main trends and future prospects, as well as to prioritize threats and investment opportunities facing the value chain of maize in different ecological areas[2] of Latin America. To achieve the objectives of the project and carry out a more in-depth analysis, four countries were selected as case studies: Argentina, Peru, Guatemala and Mexico. These countries were selected based on maize harvested area (more than 450,000 hectares) and representativeness, i.e., at least one country was selected in each agro-ecological environment. The findings and implications of the research generated from these four countries can be generalized by environment and agro-ecological zone studied, and therefore can be extrapolated to the rest of the countries of the region. This regional project is managed by the Inter-American Institute for Cooperation in Agriculture (IICA) and national level activities are conducted through its national offices in each of the countries studied.

Although much research has been done in the field of agriculture and food security, few studies have examined the current situation of the maize sector in developing countries. The most recent FAO documents on this topic were published more than seven years ago. The publications provide statistical data for several years on production, consumption, trade, stocks, freight, food aid, co-products and maize prices. CIMMYT also provided similar information in its most recent publication, *"1999-2000 World Maize Facts and Trends: Meeting World Maize Needs,"* published over 10 years ago. Although there are some recent works on the maize sector globally (Shiferaw *et al.* 2011, UNDP-GCF 2010), they do not provide region-specific information but stress the importance of that type of specific information for a more appropriate analysis. Therefore, there is very clearly a need for a study in Latin America to provide information and analysis that will give a better understanding of the current economic situation of maize, as well as the major factors that have contributed to the evolution of production, consumption and trade over the past decade, and continue to do so. This information will be useful to help formulate policies and develop research for the region, identify investment opportunities and identify the most successful strategies for small farmers in the different systems by country.

1 Details of the SIs are to be found at http://maize.org/our-strategy/crp-maize-proposal.

2 Andean Region, Central America, North America and Southern Cone.

Executive Summary

The LAC Regional Report attached to this Report presents a summary of the main findings of the diagnosis of the Maize Value Chain (MVC) across Latin America different environments. According to the adopted methodology, five Maize Agro Ecological Zones (MAEZs) were recognized and characterized: 1) Temperate Southern Cone (Argentina, Chile and Uruguay); 2) Subtropical Southern Cone (Brazil and Paraguay); 3) Subtropical Andean Region (Bolivia, Colombia, Ecuador Peru, and Rep. Bol. De Venezuela); 4) Tropical Central America (Costa Rica, El Salvador, Honduras, Guatemala, Nicaragua and Panama), and 5) Northern Latin America (Mexico). Four representative countries were selected to deepen the analysis of the MVC in each of the MAEZ: Argentina, Peru, Guatemala and Mexico.[3] The analysis of the MVC recognizes four links: 1) Inputs &services; 2) Grain production; 3) Grain marketing & processing; 4) Trade and consumption, chained by their respective markets. Economic and social indicators of the performance of each sector/market and their evolution were estimated.

Results are summarized below grouped according to the link/market.

i) ***Agrochemical inputs***. With some exception LA is a net importing region of agrochemical inputs (fertilizers and pesticides), so international prices have a substantial impact on grain production costs. Importing markets are not competitive with substantial industry concentration ratios, but with extensive distribution network within a country. Use of fertilizer and pesticides are regulated by prices, and financial disposal including credit access.

ii) ***Improved seed***. Production and distribution of maize improved seed has been subject of intensive change in the past 10 years with larger intervention of the private sector and in particular of large multinational companies. With the exception of the TSC domestic production of improved seed does not match domestic consumption with the gap being imported. Furthermore, the market structure shows deficiencies in the distribution sector in a way that insufficient timely availability of improved seed is often mentioned as a limiting factor for lack of adoption.

iii) ***Grain Production***. During the period 2000 – 2010 maize grain production grew in all MAEZs at a rate higher than that of the population as a result of an increase in maize yield and in lesser degree of an increase in maize acreage. Maize grain production is a small farming business characterized by the existence of a dual structure where a commercial and subsistence/traditional sectors coexist. MAEZs differentiate on the importance of each sector in the total supply with the TSC in an extreme with less than 5% of traditional/subsistence sector. Each sector differentiates by i) the type of maize sown; ii) the capital endowment; iii) the technology used; iv) the yield level achieved and v) The destination of the production. Maize yield shows a substantial yield gap for the subsistence/traditional sector of more than 200%. This difference resulted from deep social, cultural and economic disparities not yet completely understood and not taken into account by the maize research system.

iv) ***Agricultural Research Development & Diffusion***. Again with few exceptions the ARD&D in LA rest on public funding with the NARI in the center. Furthermore, again with few exceptions the NARIs are underfinanced with weak capacity to generate technological innovations. The ARD&D sector suffered a serious reengineering during the 90's with mixed results in the case of the extension responsible for the diffusion of technologies. Public investment in AR&D followed a healthy increasing trend in the past 10 years but still investment intensity measured as percent of AGDP is far below that of developed economies. Even so, some NARIs in LA have been successful in reengineering themselves, not only in the scientific aspect but also in spreading the source of their funding by promoting the participation of the private sector (including the producers) among them: the NARI in Argentina, Uruguay, Chile, Brazil, and Colombia.

v) ***Marketing and transformation.*** With a relative reduced and well organized grain producer sector, TSC countries possess well developed marketing system with adequate storage infrastructure but with less satisfactory road infrastructure.

3 Different difficulties precluded the elaboration of a case study in Brazil.

In the rest of the MAEZs a large amount of small grain producers are atomized and spatially extended making difficult and costly to collect and transport the grain increasing the total marketing cost and reducing the farmer share of the final price.

vi) ***Consumption and trade***. Maize consumption differentiates between MAEZs, while in the Southern Cone, the direct consumption is minimal (as polenta for example), and most of the domestic production goes to the livestock feed industry, in the rest of the MAEZs there is a clear distinction between the maize for direct consumption (mainly white and floury for tortillas and native dishes) and that for the indirect consumption (mainly yellow dent for the feed industry). The region is an exporting region so exports are a form of consumption. It is remarkable the grow rate of production and exports of popcorn maize that make Argentina the first exporter country of this type of maize.

In the rest of MAEZs (NLA, TCA, and STAR) during the period 2000 – 2010 total maize consumption grew at a faster rate than that of domestic production with the gap filled with imports of yellow maize mainly from USA and Argentina. This was the result of the high growth rate experienced by the indirect consumption mainly in the form of animal protein during the period as a response to the growth rate in the income per capita. Yellow maize and sorghum are the main ingredients in the livestock feed industry. It is worth to remark the success in the production and export of the native maize "***Blanco Gigante de Cuyo***" in Peru.

One general conclusion of the diagnosis is that although maize producers in LA face common threats, they also have different circumstances that makes that solutions must be tailored to the different maize environments. The MAEZs analyzed in this work is a possible useful disaggregation. More research is needed but a refinement recognizing the altitude parameter seems necessary.

In the grain production sector it is necessary to recognize both the traditional / subsistence sector and the commercial one. In many case the close association between maize and small poor peasants makes that conclusions or strategies to facilitate the uptake of project outputs go beyond the specific of maize. For instance given the cultural importance of maize in all MAEZs but the Southern Cone, R&D must integrate the cultural values and believes of the native population and descendant. It is recommended that in countries with significant number of indigenous population (maize producers), the NARI incorporates a department or program with a multidisciplinary team specifically focused on that segment of (maize) producers. Members must be enough open minded to allow the blending of both types of knowledge with a common agreed objective that it is not necessarily improving yield as a unique target. This is particularly true for maize breeding programs, it seems that commercial maize producers have no problem in using last generation hybrids, but this is not the case of traditional producers who are not using commercial seed even when substantial effort has been allocated by the public sector.

The main threat to maize producers in LA is the impact of the Global Climate Change (GCC). Although the consequences of GCC will reach all countries in the region, maize producers in the hillsides of CA and other regions of LA will be strongly affected. It is necessary to intensify research and extension program to reduce the vulnerability level of small maize producers in these marginal and sensitive areas.

One of the impacts of the GCC that it is already feeling in many regions of LA is the increase in the intensity of occurrences of biotic and abiotic stresses. For example soil losses by erosion and other climatic sources are common in many maize production areas across LA, and it is expected to worsening as the precipitation intensity increases. The incidence of some pests has also been reported as increasing in parts of Central America.

Price distorting policies are also limiting maize production growth across all MAEZs. More research is necessary in this area to measure the policy impacts and to identify and elaborate alternative less distorting policy instruments.

The atomization and spatially spread of a large amount of small grain producers makes difficult and costly to collect and transport the grain increasing the total marketing cost and reducing the competitively at the processing industry level. More research is needed to explore different alternatives to promote storage at the field or local level in order to concentrate production, aggregate some value by drying it and cleaning it and have enough volume to better negotiate the price.

More competitive and transparent markets at all levels in the MVC are necessary to improve not only the efficiency of the marketing system but also its equity among participants' agents particularly the small producer.

Introduction

Background and problem statement

Many important economic and social indicators of Latin American (LA) countries, such as the level and growth rate of disposable per capita income, the relatively low importance of the agricultural sector in the formation of Gross Domestic Product (GDP), and the negative trend in the absolute and relative size of the rural population, show LA to be a region in transition from the developing to the developed stage (Table 0. 1). In the social area, although LA has been successful in reducing poverty indexes there are still large numbers of poor people, particularly in the rural sector. Furthermore, even though inequality as measured by the Gini Index[4] fell by an annual rate of almost one percent, LA still ranks as the most unequal region in the world**.**

Latin America and the Caribbean (LAC) is a large region with varied climate, ecosystems, populations and cultures, and widely known to be a major player in the global production of staple foods. Although it accounts for only one tenth of the world population, it is estimated that in 2010 the region produced about one third of the world's oilseeds and sugar, one sixth of its meat and about 10% of its dairy products and cereal grains. Between 2000 and 2010, the value of regional agricultural production grew on average by 12%, presenting overall positive growth with a small one percent decrease in 2008-2009. However, due to the slowdown in total population growth, and a relatively low-income elasticity of demand, the growth in demand for food and raw materials has been declining in recent years, and it is estimated that growth in regional agricultural production over the next 30 years will be no more than 2.4% per annum (Dixon *et al.* 2001).

In LAC, the share of agricultural land[5] has been growing at a very slow rate, increasing only 0.05% during the period 1999-2009; clearly, the expansion of the agricultural frontier, largely in response to the liberalization of markets, has slowed down. Cereal production in LAC grew by only 5% from 1999 to 2010 (i.e., from 47 to 50 million tons) but by 16% from 2009 to 2010, mainly due to an increase in yield rather than acreage (the figures for which were 14% and 4%, respectively). Three countries in the region (Mexico, Brazil and Argentina) account for more than 10% of the world's output of coarse grains, a value that is expected to increase to 13% by 2013 (IGC 2012). Furthermore, these three countries account for 80% of regional cereal production and 12% of global maize production, worth over 25 billion dollars in 2010. They are among the top 10 maize producers in the world (FAO 2011, FAOSTAT 2012).

In general, the share of exports to emerging economies increased by ten percentage points over the past decade, reaching 35% of total exports in 2010, which has been particularly strong for Latin America (LA). Increased reliance on trade with Asia and other emerging regions allowed many countries in the region, particularly in South America, to bounce back more quickly from the global crisis (IFM 2011). Southeast Asia countries became major commodity buyers, which allowed food trade in LAC to recover in 2010, particularly trade in cereals and maize. Nevertheless, from 2005-2010 the region had an average annual net trade deficit in cereals of 22 million tons, which is projected to rise to 32 million tons by 2030 - a decline in self-sufficiency from 90% to 87% (FAO, ECLAC and IICA 2011).

Latin America and the Caribbean as a whole is the only net food-exporting region in the world, with exports of soy, sugar, maize and meat leading the way. However, 53 million people (10% of the population) have been suffering from hunger since the beginning of the economic crisis in 2008, marking the first recorded setback since the 1970s. However, hunger and malnutrition in the region are not related to food shortages but to problems in accessing foodstuffs, which are directly related to poverty. The region is considered to possess the skills and resources required to eradicate this situation, since it produces over 60% of the food it needs and has a wide surplus in its food trade balance (with the exception of the Caribbean). Nevertheless, there have been significant achievements in the food situation in LAC as regards the Millennium Development Goals (SELA 2010), since the proportion of hungry people in the region fell from 12% in 1990 to 9% in 2010. According to ECLAC, from 2000 to 2008 the average proportion of the population below the minimum level of dietary energy consumption in the

4 A measure of statistical dispersion intended to represent the income distribution of a nation's residents. The Gini coefficient measures the inequality among values of a frequency distribution (for example, levels of income).

5 The share of agricultural land refers to the share of land area that is arable, under permanent crops, and under permanent pastures (FAOSTAT 2012).

region was 8%. The rate has been slowly decreasing since the 1990s and is projected to fall to 5% (32 million) by 2030, which is only half the current international target, however (Dixon *et al.* 2001).

Even though the rate of regional population growth has declined dramatically in the last 40 years, from 2.8% per annum in the 1960s to about 1.6% in the 1990s and 1.3% between 2000 and 2011, the region continues to grow at a robust pace, led by rapidly expanding domestic demand (FAOSTAT 2012). Economic performance was also less uneven within the region in 2011 compared with the previous two years. South America's commodity exporters (Brazil and Argentina) continue to lead the expansion, though growth moderated in 2011. The recovery from the crisis generally has been slower in most of Central America and the Caribbean countries but is projected to strengthen. Nonetheless, net commodity importing countries in this region will continue to be constrained by the effects of weak employment conditions, less favorable terms of trade, rising global food prices and fuel and, in some cases, high public debt.

Latin America in the global maize market

Although there are several theories that affirm that the center of origin of maize is Asia or the Andean region, particularly Peru, there is strong evidence to suggest that it originated in Mexico, from the native teosinte.[6] In Mexico, maize and teosinte have coexisted since ancient times and both species have a very wide biodiversity. Moreover, the discovery of fossil pollen and archaeological maize cobs in caves in the region strongly suggests that maize originated in Mexico. It is believed that by about the year 1000 AD, the maize plant had been improved by farmer breeders through a process of selection whereby cultivators retained the largest and most desirable ears to use as seed in the next season. The spread of maize from its center of origin in Mexico to various parts of the world has been as remarkable and rapid as its evolution into a cultivated and productive food plant. Native inhabitants of various "indigenous" tribes took this food plant to other regions and countries of Latin America, the Caribbean and then to the USA and Canada. By the year 1492, when Columbus reached Cuba, native farmers from Canada to Chile were growing their improved maize varieties. When Columbus returned to Spain in 1493, he probably carried with him kernels of several Caribbean flint landraces. From there, maize spread rapidly and around 300 years later was being grown in most countries of Europe, Asia and Africa (Dowswell, Paliwal and Cantrell 1996).

World maize production

Maize is one of the world's most important cereals, the third largest planted crop and traded cereal after wheat and rice, with a total production of 840 million tons on over 160 million hectares of land in 125 developing countries by 2010 (FAOSTAT 2012). Maize's most distinctive characteristics (i.e., open pollination, importance of hybrid vigor, multiple end uses and variability of maize production environments) have led to the crop becoming one of the major cereals traded worldwide. Nevertheless, neither the production methods used nor the effects on the environment have been closely scrutinized (UNDP 2010). In general, the production of this crop is affected by the development of advanced technologies, namely mechanized production, use of external inputs and high-yielding hybrid varieties (including genetically modified –GM– varieties). Furthermore, when credit, labor, traction power, information and land markets are imperfect, farmers who lack the necessary capital or family resources (labor, land, oxen) will fail to invest in otherwise profitable technologies (Shiferaw *et al.* 2011).

Even though the area covered by maize has not increased since 2008, production of the crop is far larger than that of the two other major staple cereals. Maize accounted for 34% of global cereal production, 27% of land under cereal cultivation and 50% of the value of total cereal production between 2005 and 2010 (Shiferaw *et al.* 2010). Maize's high yields (relative to other cereals) make the crop particularly attractive to farmers in areas with land scarcity and high population pressure. This is the case in the least developed countries, where, from 2000 to 2010, the area under maize increased by an average of only 2% but yields grew by 4% (USDA/FAS 2012). By 2010, approximately 113 million hectares of the 160 million planted with maize globally were in the developing world.

By 2010, five developing countries accounted for 40% of the world's maize area (i.e., China, Brazil, Mexico, India and Indonesia). If we consider different regions, however, the Americas have the greatest amount of land dedi-

6 Through the study of genetics, today we know that maize's wild ancestor is a grass called teosinte.

cated to maize production, followed by Asia with 39% and 34%, respectively. LAC is the region where most of the tropical and subtropical maize in the world is produced - around 26 million hectares in 2010 (FAOSTAT 2012). Maize has become one of the world's most widely produced crops since it was first cultivated in Mexico around 10,000 years ago. Despite its global significance, however, no country can be said to be the most important. The US undoubtedly defines much of the market environment, however, given that it is world's largest producer and exporter.

Nevertheless, Latin America and the Caribbean (LAC) is among the individual geographical regions of the developing world where maize production is of paramount importance and thus able to influence the global maize sector (Table 0. 2). From 2001 to 2010, maize was the third major crop produced in the region after sugarcane and rice, with production higher than that of the other two major cereals produced (soybeans and wheat). In 2010, maize production in the region was around 120 million tons, or 14% of global annual maize output (FAOSTAT 2012). However, rising demand is expected to outstrip the expansion of production in the years ahead, resulting in a drawdown of worldwide inventories, another factor contributing to price instability (Shiferaw *et al.* 2011). Among the most influential countries in the region are Mexico, Argentina and Brazil (Table 0. 2). Mexico is the center of origin and diversity of maize, and has the highest annual per capita consumption; and Argentina and Brazil are large producers of conventional and genetically modified grains for feed and ethanol, respectively.

In general, the production of maize (as well as of other cereals) has doubled in the last 40 years due to increased yields resulting from the use of improved crop varieties, along with greater inputs of fertilizer, water and pesticides (Evenson and Gollin 2003, Shiferaw *et al.* 2010). From 2005 to 2010, maize production increased on average by 8% in least developed countries, 6% in net food importing developing countries, 6.5% in Latin America and 5% in both Asia and Africa (FAOSTAT 2012). Nonetheless, by 2011 production shortfalls in global maize supplies, due to rising input prices and increased demand for maize for feed consumption, had driven up prices of maize grain by 57% globally and by 79% in LAC (FAO 2011, Shiferaw *et al.* 2010). Such increases will impose great hardship on the poor, especially on importing countries in terms of their purchasing power, food security and nutrition.

Although 70% of global maize area is in the developing world, only 50% of the world's maize production (2010) is grown there (FAOSTAT 2012). Clearly, the countries with the greatest crop areas of maize are not necessarily the most productive in terms of yields. Argentina, for example, ranks tenth in terms of area harvested but it is the sixth largest producer in the world. This is presumably due to the use of high yielding varieties, as well as external inputs. However, in general low average yields in the developing world are responsible for the wide gap between the global share of area and production. As an aggregate, average maize yields among the developing countries are about one third of those of the major maize producers, which are more than 9.5 ton/ha (FAOSTAT 2012). Wide disparities in climatic conditions, employment structures and farming technologies account for the 6 ton/ha yield differential between the developed and developing worlds.

World maize use and consumption

The structure of the market for maize has undergone major changes in terms of production and usage as a result of trade liberalization, the integration of China and India into international maize markets, seed production, use of new technologies, a nearly uninterrupted expansion of feed usage across the globe and, more recently, the sudden surge in demand for ethanol (World Bank 2009). Recent market trends suggest that the two drivers of bioethanol expansion (high oil prices and policies for domestic energy security) are unlikely to weaken during the coming decades, and could even intensify (Shiferaw *et al.* 2010). Additionally, with ethanol consumption potentially approaching 22.5 billion gallons in the next five to ten years, and exports of distillers' grains potentially reaching 22.1 million metric tons, the higher maize prices in 2010 and 2011 may signal an even higher level for maize prices and more price variability in the years ahead (USDA 2012). Should such trends continue, large-scale production of first-generation biofuels, which use maize grain, could prove to be a major disruptive force, possibly benefiting producers but harming low-income consumers and threatening food security (Alexandratos and Bruinsma 2012, Headey and Fan 2010). Nevertheless, according to Shiferaw *et al.* (2010) biofuel production could contribute indirectly to food security and poverty reduction in the developing regions through income growth. Unless the potential trade-offs of using maize to produce ethanol are analyzed, however, any progress towards improved food security and nutrition will be slower and more uneven.

a) Use of maize for food (direct human consumption) worldwide

According to FAOSTAT, 57% of total world maize production in 2010 was used for animal feed, while 14% was utilized for food for human consumption. Interestingly, in the developing countries these figures currently stand at only around 19% and 76%, respectively, because maize still is a staple food in those regions. Furthermore, it is estimated that these percentages will persist in the future since maize plays an important role in the livelihoods of millions of poor farmers, especially in Africa and Latin America where maize provides at least 30% of the food calories of more than 4.5 billion people in 94 developing countries (Shiferaw *et al.* 2011). Most of the maize consumed directly as food is white, which is eaten in a variety of forms that vary both between and within regions. In contrast to yellow maize, white maize is not used for the manufacture of fuel alcohol or in the production of high fructose sugar. As maize research and development systems are increasingly privatized and oriented towards commercialized production and livestock, the needs of consumers who prefer white maize may become a greater challenge, as suggested by some of the trends in public sector releases (FAO and CIMMYT 1997).

Africa, Central America and Asia are the regions where the consumption of maize as food is the highest (in 2009, the first two consumed 67% of their total maize production). The diversity in maize usage stems from its multiple nutritional characteristics, providing on average 235 kcal/capita/day and 6 g/capita/day of protein. Even though in 2009 more than one quarter of production in LAC was used as food for human consumption (58% in Central America), an average of 8% of the population was below the minimum level of dietary energy consumption (ECLAC statistics 2010). While maize consumption continues to rise in the Latin American region, however, per capita consumption is leveling off or even declining in several countries, mainly due to insufficient growth in production. During the period 2000-2009, annual average consumption per person in Central America, South America and the Caribbean was 68 kg, 29 kg and 24 kg, respectively. The Caribbean is the region in which average food consumption per person has increased the most in the last decade, going from 11 to 24 kg/year. Overall, the countries with the highest annual per capita consumption were Mexico (120 kg), Guatemala (86 kg), Honduras (79 kg) and El Salvador (73 kg) (FAOSTAT 2012). Mexico is the world's number one consumer of maize for food, consuming 65% of its own maize production and 12% of all maize consumed across the globe in 2009. On average, Honduras, Panama, Nicaragua and Guatemala consume 85% of the maize they produce. Domestic demand for maize in Argentina, Brazil and Paraguay is met by local production, with the surplus being exported.

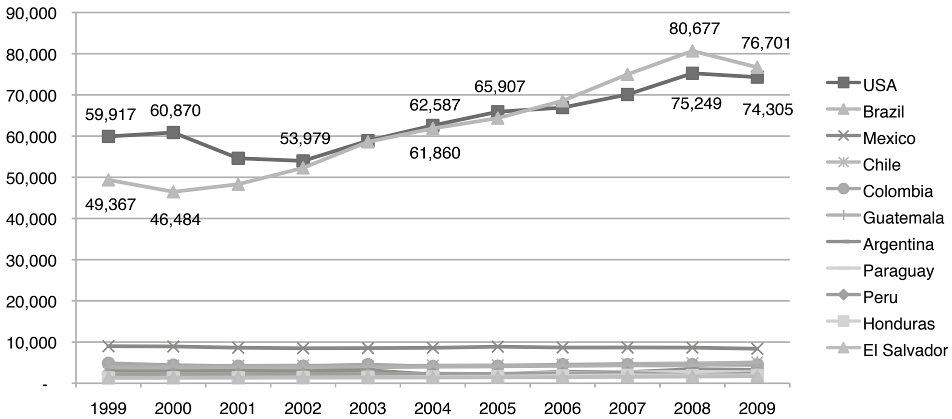
b) Use of maize for feed (indirect human consumption) worldwide

The world's leading users of maize for animal feed are the U.S., China, the EU and Brazil; together they accounted for 70% of the maize used for animal feed worldwide in 2009 (FAOSTAT 2012). In the case of LA, by 2009 around 59 million tons, or 58%, of total regional maize production was used for feed purposes while around 27% was used for food, 12% for other uses, 2% for processing (industrial uses) and 1% for seed (FAOSTAT 2012). The country in the region that makes most use of maize for feed is Brazil, which utilizes 68% of its total production for that purpose. In general, yellow maize is preferred for livestock feeding in most parts of South America and the Caribbean, because it is rich in energy and gives poultry meat, animal fat and egg yolk the yellow color appreciated by consumers in many countries. It is evident that diets in developing regions in Asia, the Middle East and Latin America are changing as incomes rise. So much so, that it is forecast that per capita consumption of livestock products will have increased by a further 44% by 2030, and the demand for maize by 100% by 2050 (Bruinsma 2003, Shiferaw *et al.* 2011, Delgado 2003).

c) Use of maize for biofuel worldwide

Most of the more rigorous analyses to date have concluded that the diversion of the U.S. maize crop from food to biofuel uses constitutes the largest source of international biofuel demand and the largest source of demand-induced price pressure (Abbott, Hurt and Tyner 2008, Mitchell *et al.* 2009). Moreover, given the importance of the US not only as the world's largest producer and exporter of maize but, equally significant, as the largest and most advanced consumer of maize, it is useful to provide an overview of how maize is used in that country. For instance, more than 40% of the increase in global maize consumption from 2000 to 2007 was due to biofuel use in the US. According to USDA (2012), US maize production topped 314 million tons in 2011-2012, with around 127 million tons, or 41%, of the total being fermented into fuel alcohol or ethanol and 19% being used to feed livestock. After ethanol production and feed, the third largest percentage of US maize (14%) was exported. Nevertheless, in 2006 Brazil took over from the US as the world's leading producer (Figure 1).

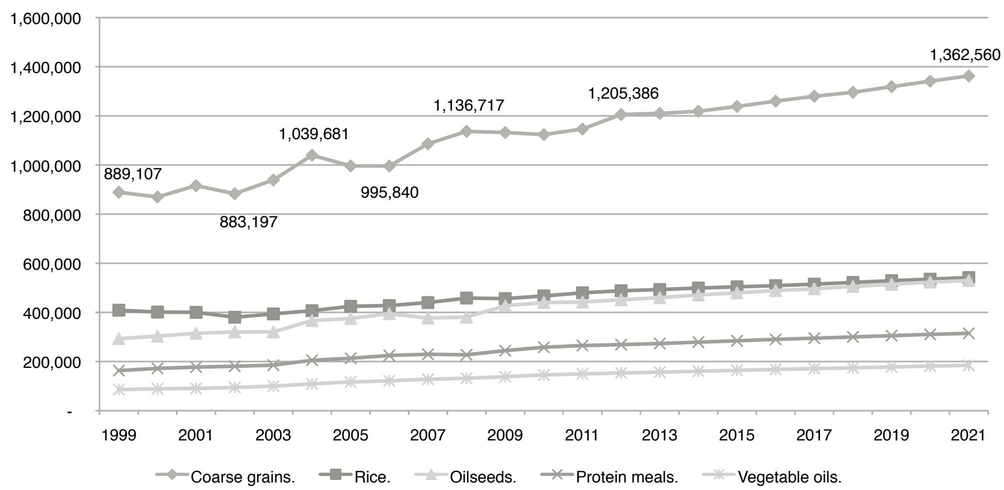
Figure 1. LA: Biofuel production (in kilotons of oil equivalent). 1999-2009



Source: Energy Balances of OECD Countries

The FAO estimates that in 2012 around 137 million tons of maize were used for ethanol, with the US accounting for some 93% of that figure. Most biofuel production uses coarse grain, frequently maize, and production in other parts of the world is either relatively small or involves the use of different crops, such as sugar cane in Brazil (Figure 2). The growth in the use of maize as feedstock or in the production of ethanol has been rapid, increasing by over 20% per year before a sharp slowdown in 2011 and with slower growth of only one percent predicted for 2012. The use of maize for ethanol grew especially rapidly from 2004 to 2007, with 70% of the increase in global maize production being used to produce ethanol (Headey and Fan 2010). At present, almost 40% of the maize produced globally is used for biofuel production, which represents an eight-fold increase in the span of just ten years (FAO Statistical Yearbook 2012) and another source of stress for markets. The rising demand for biofuels is largely explained by policies in developed countries.

Figure 2. World Biofuel production differentiated by crop used, kt (in millions of liters). 1999-2021



Source: OECD-FAO

Most of the more rigorous analyses to date conclude that the diversion of the US maize crop from food to biofuel uses constitutes the largest source of international biofuel demand and the largest source of demand-induced price pressure (Abbott, Hurt and Tyner 2008, Mitchell *et al.* 2009). Moreover, given the importance of the US not only as the world's largest producer and exporter of maize but, equally significant, as the largest and most advanced consumer of maize, it is useful to provide an overview of how maize is used in that country. For instance, more than 40% of the increase in global maize consumption from 2000 to 2007 was due to biofuel use in the US. According to USDA (2012), in 2011-2012 maize production in that country reached 314 million tons, of which around 127 million tons, or 41%, was fermented into fuel alcohol or ethanol and 19% was used for feed livestock. After ethanol production and feed, the third use of maize in the US was for export (14% of total production).

World maize markets and trade

The structure of the world maize market can be characterized as strongly concentrated on exports and not so much on imports. This is because countries that usually have significant maize surpluses for export are relatively few in number (UNDP 2010). With increasing diversification of maize demand and utilization, global trade has become an important strategy for overcoming production shortfalls. Although the US remains the most dominant player, given that it is the world's largest producer, consumer and exporter of maize, other countries such as Argentina, Brazil and Ukraine have also gained ground and become important players in world markets, with the combined production of the three countries having increased by over 30 million tons in just five years (FAOSTAT 2012). Nevertheless, a high production level does not necessarily imply a large export role; China is a case in point. Annual global maize exports are estimated to be about 90 million metric tons by 2012-2013, mainly from the US, Argentina, Brazil and Ukraine to meet the growing demand for maize imports in Japan, Mexico, South Korea, Egypt and Taiwan. Most of the imports mentioned are related to the growing use of maize as livestock feed (USDA/FAS 2012, Maximiliano-Martínez *et al.* 2011, FAOSTAT 2012). By 2010, Japan was the world's leading importer, with an annual intake of around 20% of the world's total production, followed by South Korea, with almost 10% of the global share, a position held by China in 2009 (World Bank 2009).

In 2012-2013, US maize exports are expected to fall by 2.5 million tons to 31 million, the lowest in 40 years, because of intense competition from countries such as Brazil, whose maize production will rise sharply, by 4.5 million tons, to a new record of 19 million (FAS/USDA 2012). Given the sharp run down on maize inventories in the US and only modest overall global production increases, world prices are likely to remain high and volatile. During 2010-2011, increased tightening of the global supply and demand balance of maize pushed international prices above their 2008 peaks (FAO 2011). This situation resulted in a 30-40% increase in the price of maize between 2001 and 2010, which raised maize imports from least developed countries by an average of 42% (OECD-FAO 2011, FAO, ECLAC and IICA 2011, FAOSTAT 2012). In general, price transmission to domestic markets will depend on how much a country relies on maize imports and the importance of this crop in national diets (e.g., Central America) and for the animal feed sector (FAO/GIEWS 2010m, FAO 2011).

The global demand for maize is growing explosively. According to IFPRI projections, by 2020 maize will become the second fastest-growing crop in importance in developing countries, thus displacing wheat. According to these projections, maize demand in Latin America will grow by a little over 60%, while in Asia and Africa maize demand will almost double (Pingali and Pandey 2001). However, the analysis must recognize the difference between white and yellow maize. While yellow maize is produced mainly by large producers in temperate climates and its main market target is the poultry, cattle and pig feed industry, white maize production occurs mostly in tropical and subtropical areas and the crop is mainly used for direct human consumption in the form of tortillas, flours and other derivatives.

Scope, justification and objectives of the project

Scope and justification

Currently there is literature that focuses on forecasting agricultural and food security trends in developing countries, including all foreseeable diet changes, trade, production, research and policies. The FAO is a case in point, having produced many reports that provide its perspective on the future of food, nutrition and agriculture in the developing world by assessing the global prospects over the next 30 years. Some of its latest publications[7] in this field focus mainly on how the world will feed itself in the future and what the need to produce more food means for the natural resource base. Moreover, the FAO's statistical yearbooks provide reliable and timely information on world food and agricultural sectors in multiple contexts, and are considered a reference point for accessible statistical data. The most recent edition, *The FAO Statistical Yearbook 2012*, draws attention to the multiple challenges confronting the agricultural sector and leans towards a thematically driven, statistical snapshot of the major trends and issues related to world food and agriculture.

Further, FAO produced publications on agriculture and food security in the LAC region in 2010 and 2011. These studies offer a basis for comparative analysis, examine prices and food availability in detail and forecast future agricultural trends in the region. Two of the FAO's most recent publications[8] provide information on the performance of commodity prices in 2010, analyze its impact on food security and poverty levels in LAC and also show how the long-term trend of rising prices is an opportunity for agriculture because the region has land available and a relative abundance of water, biodiversity and human resources on which it can capitalize. Moreover, another FAO document[9] follows up on the main actions and measures adopted by LAC at the national, regional and sub-regional levels as regards the issue of food security. Similarly, the World Bank produced two documents[10] in 2008 and 2009 that present the bank's preliminary understanding of rising food prices in the LAC region and describe the recent international trade situation with regard to maize.

Although much has been investigated in terms of agriculture and food security, fewer studies examine the current situation of the maize sector in the developing world. The FAO's three most recent publications on this topic were published in 2006, 1997 and 1992, and entitled *Maize: International Market Profile, White Maize: a Traditional Food Grain in Developing Countries* and *Maize in human nutrition,* respectively. They discuss and describe the significance of maize in the global context, the international maize economy and some of the main factors that have contributed to developments in maize production, consumption and trade over the past two decades. They also provide statistical data for several years on production, use, trade, stocks, freight rates, food aid, co-products and prices. Similar information is also provided by the International Maize and Wheat Improvement Center (CIMMYT) in its most recent maize publication, *World Maize Facts and Trends 1999/2000: Meeting World Maize Needs,* published more than 10 years ago.

Nevertheless, there are some recent papers regarding the maize sector. One of them is from Shiferaw *et al.*, published in 2011. This paper summarizes the importance of maize for food, nutrition and livelihood security and details the historical productivity of world maize, consumption patterns and future trends by reviewing research challenges for ensuring global food security in maize, particularly in the context of climate change; and it also shows how crop breeding will play a key role in meeting future maize demand. Another recent paper,[11] published by the UNDP Green Commodities Facility (GCF) in 2010, provides a general description of the global importance of maize total production and trade, as well a clear description of the supply chain dynamics. However, there is no specific analysis by region, even though the paper suggests that such analysis would be more appropriate. Finally, information regarding the grain market and trade is published monthly by the International Grains Council (IGC) and the Foreign Agricultural Service of the United States Department of Agriculture (USDA/FAS), including world markets, trade and present and historical data series for maize among other grains in selected regions and countries. The most recent reports provide convenient statistical information regarding maize production, consumption, trade, stocks, prices and national policy developments for 2011 and 2012, and forecasts for 2013.

What is currently missing, therefore, is a platform/stage that brings together all of the data in a coherent and systematic way, and improves the quality, quantity and scope of agricultural and development statistics. Thus, having this platform will provide a better understanding about the breadth of maize's role in the Latin America

7 Strategic Framework for the period 2000-2015 and World agriculture: towards 2030/2050.

8 Outlook and Perspectives for Food Security and Nutrition in LAC and The Outlook for Agriculture and Rural Development in the Americas: A perspective on Latin America and the Caribbean 2011-2012.

9 Food Security and Food Prices in Latin America and the Caribbean: Current Situation and Prospects (SELA 2010).

10 Rising Global Food Prices: The World Bank's Latin America and Caribbean Region, and Building Response Strategies to Climate Change in Agricultural Systems in Latin America.

11 Global Maize Production, Environmental Impacts and Sustainable Production Opportunities: A Scoping Paper.

region today. Therefore, there is clearly a need for a study at the Latin American level that contributes with information and analysis for a better understanding of the current maize economy and the main factors that have contributed to developments in maize production, consumption and trade over the past decade and that continue to do so. This information will be useful to formulate policies, develop research for the region and identify investment opportunities, as well as to pinpoint the most successful strategies for small farmers in different systems. Therefore, the main purpose of this paper is to ascertain and understand better the current situation of the maize sector in LA, in order to identify the greatest potential for poverty and hunger reduction and economic growth in the next few decades.

It is expected that this regional assessment will help to fill the gap that exists by providing reliable and timely information on the current situation, outlook and investment opportunities in relation to maize in multiple contexts within the LA region. We feel certain that this study will be useful to address issues related with poverty, climate change, environmental pollution and land degradation in a more efficient and effective way, and thus help to achieve sustainable agricultural development in the region to ensure food security. Consequently, it is vital to concert efforts to enhance Latin American countries' capacities for providing more and better statistical information to raise awareness of the multiple challenges confronting the maize sector in the region.

This study leans towards a thematically driven statistical snapshot of the maize situation, major trends and outlook as well as investment opportunities in LA that will help to ensure regional food security. It employs information drawn from data sources within FAO, sister UN agencies, World Bank, ECLAC, USDA and other international organizations. It also relies on the most recent evaluation of data from LA countries' agricultural resources, how they are used now and what may be available for meeting future needs. This report is, as well, a synthesis of a series of interviews, discussions, literature review and action plans on how maize can continue contributing to food and livelihood security of poor producers and consumers at the regional level.

Objectives of the Project

The goal of the current project is to identify and characterize current and future threats and opportunities faced by the maize value chain in the different Latin American (LA) environments suitable to be addressed by targeting agricultural research. In order to accomplish them, this project pursues the following specific objectives:

i) Characterize Maize Value Chain Systems (MVCS) in terms of economic, social and environmental indicators across the different environments in LAC;

ii) Identify the main drivers responsible for productivity differences across regions;

iii) Identify and characterize main investment opportunities (public and private, for export and local market) to boost productivity, reduce poverty and increase system resilience to the impacts of global climate change (GCC);

iv) Analyze and compare constraints versus opportunities related to production and markets in order to identify trade-offs and their effects; and

v) Document the information generated in order to use it as a guide/tool for research intervention and policy decisions that address the target needs for technology and market development.

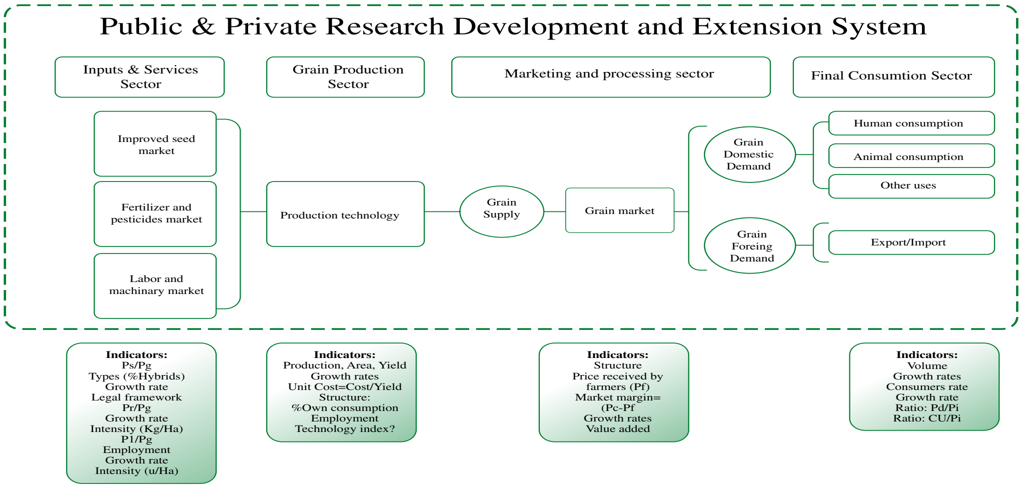
Methodology

Characterization of the Maize Value Chain System (MVCS)

The MVCS can be seen as a system encompassing all the agents and their activities and products involved in the production of maize grain (raw materials) and of all the products obtained from the maize grain (value added), and of all the services necessary to put the final product in the hands of the consumer.[12] The MVCS comprises five main sectors or links: i) R&D, ii) Maize inputs and services, iii) Primary grain production, iv) Processing and transformation, and v) Consumers. These sectors are connected by market systems on the inputs, R&D and outputs sides. On the inputs side, the seed market is crucial, while for the R&D side the extension system is the important one. In the case of the output side, there are two markets that are essential: a primary product market (maize grain and sub-products) and a secondary market system where transformed products (mainly oil and animal feed) are transacted Figure 3 illustrates the concept as well as some performance and trends indicators across its components.

To perform an analysis of the MVCS across all LAC environments to identify research priorities, it is necessary to define the performance indicators for each of the chain links and those of the MVCS as a whole. In what follows, some of the key indicators used in the analysis are defined in terms of a conceptual framework borrowed from the economics theory of production, demand, growth theory and industrial organization.

Figure 3 Components (sectors) of Maize Value Chain System



Source: Elaborated by authors

12 This definition is consistent with previous ones that defined the MVCS as comprising the full range of activities required to bring a product or service from production to consumers (Kaplinsky and Morris 2001).

Performance indicators for links in MVCS

a) Inputs and services

Inputs and services enter into the maize production function and their efficiency and prices determine the cost structure of the grain production sector. Key indicators of the efficiency of the input and services link are:

i. Inputs / services provision
ii. Inputs / services consumption
iii. Inputs / services prices
iv. Inputs / services market structure.

In the case of the market structure, the selected indicator was the Industry Concentration Ratio (ICR) of order "*m"* of the industry defined as the percentage of market share held by the *"m"* largest firms in an industry (Carlton and Perloff. 2000). Two ICRs were estimated where available information exists: the Two-Firm Industry Concentration Ratio (ICR2), which measures the total market share of the two largest firms in an industry, and the Four-Firm Industry Concentration Ratio (ICR4) that takes into account the cumulative share of the four largest firms. With the values of these indicators, an industry was classified according to the following scale: *Total concentration*: if the ICR = 100%; *High concentration:* if the ICR is between 80% and 100%; *Medium concentration:* if the ICR is between 50% and 80%; and *Low or no concentration:* if the ICR is between 0% and 50%.

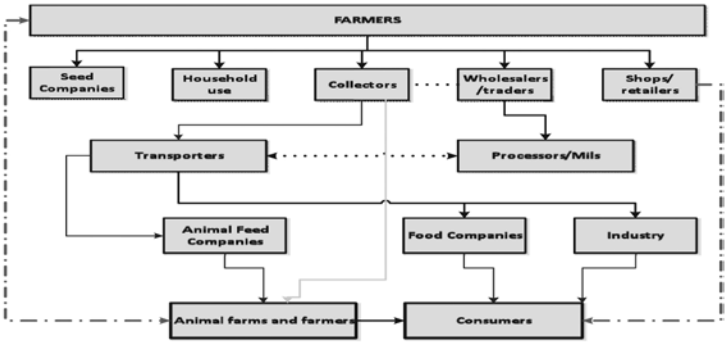
b) Grain production

The indicators of the grain production sectors refer to the land's physical productivity (yield) and economic efficiency (average production cost). Another set of indicators refer to the dynamic of the sector (Production growth rate, Acreage growth rate, Yield growth rate and Production growth anatomy).

c) The marketing and processing sector

Given the nature of the world's maize production and markets, the supply chain of maize may vary. According to the UNDP (2010), however, there are common aspects, which are depicted in Figure 4. Depending on how strong the economy is and how well the market structures for imports/exports are set up, the links in the chain would vary in strength. There are hundreds of products and co-products derived from maize, thus the chain can be extended still further. Given that maize production is so broadly supplied and distribution and trade hinges on different routes, transportation systems and port facilities are critical in the competition for markets within and outside national boundaries.

Figure 4. General description of the commodity chain flow of maize



Source: UNDP 2010

The set of indicators relates to the efficiency of the marketing system reflected by:

i. The marketing margin defined as the percent increase in farmers' price represented by the price to the consumer.

ii. The market structure reflected by the ICR2 and ICR4 indicators.

d) Final Consumption

The set of indicators relates to the volume and dynamic of maize consumption.

e) Social and economic indicators

The MVCS does not work in isolation but imbedded in a wider national, and even international, system whose characteristics may influence and be influenced by the MVCS. It is necessary to identify and characterize this wider system to properly understand the performance of the MVCS in a given country or region.

Two key benchmarks of the national environment are the population growth rate and per capita income. Both indicators are key determinants of maize consumption/demand for maize products, so production and productivity growth rates on the supply side must at least match them in order for the system to grow.

Another indicator of the national environment relates to economic policy, either pricing policy or government investment policy in public goods supporting the performance of the MVCS (RD&D, infrastructure, etc.).

Production geography and data sources collection

The methodology used to carry out this research relied on a combination of secondary data and semi-structured interviews with key informants at different links in the maize value chain system. This methodology provided a quick, flexible and effective way of collecting, processing and analyzing data. This information made it possible to determine trends and main drivers of performance indicators, as well as to identify constraints and opportunities that can be released effectively through research. The complementarity of secondary data and qualitative analysis helped to make the results more understandable and build confidence in them. These results allowed us to recognize investments opportunities and main research priorities differentiated by environment and region. By conducting this kind of analysis first, it becomes possible to add more accurate questions to future household surveys to be conducted in the region, and thus to get better results.

Maize production geography

Application of the methodology to the real data gathering activity needs to recognize from the outset LAC variability with respect to agro ecology and socioeconomic characteristics that influence, or are influenced by, the performance of the MVCS.

There are many ways LAC countries can be grouped according to the classificatory criterion adopted. Geographically LAC is divided into five regions. From south to north, they are: 1) Southern Cone, 2) Andean Region, 3) Central America, 4) North America and 5) the Caribbean. This classification it is not accurate enough to reflect the agro climatic factors that would condition maize production (mainly, radiation, temperature and altitude). Taking temperature, as the classificatory criterion LAC countries can be divided into three groups: Temperate, Subtropical and Tropical. They are often also divided into three groups according to altitude: lowland, transition and highland (Doswell *et al.*1996).[13]

With the ability to grow in diverse climate and conditions, maize is sown in every country in LAC, although the scale and importance of cultivation varies greatly. Table 0. 3 shows maize acreage and production across LAC countries grouped according to these two categories. Brazil, Mexico and Argentina account for the lion's share of total maize acreage and production in LAC (86% and 87%, respectively). Furthermore, Brazil alone accounts for 47% of total maize output and total maize acreage in the region. Mexico and Argentina each produce 20% of the region's total maize output but Argentina accounts for only 10% of the harvest area and Mexico 25%, showing the differences in land productivity. At 8 ton/ha, Argentina's yields are among the highest in the region after Chile's 11 ton/ha (FAOSTAT 2012).

However, these figures on the concentration of the grain production sector do not reflect the enormous social and cultural importance that the entire MVCS has for countries in the Andean Region as well as in Central America. To take into account this variability in the analysis, the countries were grouped into the following five Maize Agro Ecological Zones (MAEZ):

i. **Temperate Southern Cone (TSC)**. *Argentina, Chile and Uruguay*

ii. **Subtropical Southern Cone (STSC)**. *Brazil and Paraguay*

iii. **Subtropical Andean Region (STAR)**. *Bolivia, Colombia, Ecuador, Peru and Venezuela*

iv. **Tropical Central America (TCA)**. *Costa Rica, El Salvador, Honduras, Guatemala, Nicaragua and Panama*

v. **Subtropical Northern America (STNA)**. *Mexico*

Secondary data was gathered from the seventeen countries in order to identify and characterize main drivers that affect productivity in the region, as well as the different MVCS in LA differentiated by agro ecological zone and environment.

In order to conduct a deeper analysis, and given the enormity of the task of data collection, four countries were selected as case studies: Argentina, Peru, Guatemala and Mexico. These countries were selected based on two criteria: *Area cultivated,* selecting countries with more than 450,000 hectares harvested with maize; and *Representativeness*, i.e., at least one country from each MAEZ identified in LAC. Table 0. 4 provides some basic information on the MAEZ and the selected country (in bold). Data collection and fieldwork were carried out by IICA researchers and local consultants hired in the corresponding case-study countries. The first step was to conduct a review of relevant literature and secondary data using the SWOT analysis framework at the country sample level. The analysis of this information provided a general description and understanding of the maize situation, outlook and investments opportunities in each case-study country selected. The literature review also allowed us to identify eventual gaps and unknowns that were addressed through semi-structured interviews with a small but purposely selected sample of stakeholder in each of the case-study countries. Once primary and secondary data were collected and studied, a consultative discussion with regional stakeholders, experts and research team were held in each case-study country to validate the findings and analyze the data.

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13 Radiation is approximated by the country latitude.

Findings, research implications and development from these four representative countries were extrapolated to the rest of the countries in the MAEZ. In each of the case-study countries, secondary information was collected to assess the current maize situation, outlooks and investment opportunities in LA, focusing on: i) maize production situation, ii) maize input provision and R&D and iii) maize value chains and consumption. Missing information from secondary data collection was filled out using semi-structured interviews in each case-study country. Consultants hired in each case-study country conducted both secondary data collection from local sources at the country level, as well as semi-structured interviews. Using this information, consultants were able to perform a descriptive-analytical study of the maize chain in each country studied. The identification of specific areas within each of the selected countries is part of the process of participatory research. The reports provided by the consultants help us to determine differences and similarities between the countries analyzed and also to distinguish policy and research interventions accordantly.

Organization of the report

This report discusses the significance of maize in the LA region context and is organized into three main parts. The first part presents an analysis of the MVCS for LA recognizing the variability among each of the MAEZ. The analysis is based on a synthesis of the country case studies and on secondary data collection and previous findings reported in the literature. This part contains a first section with general social and economic conditions surrounding the MVCS and the representative country, followed by four sections corresponding to the links of the MVCS.

Part II focuses on maize investment opportunities for R&D and policy recommendations, i.e., priorities for further public and private sector R&D and policy, including technological, economic, social/equity and environmental considerations. The first section presents a synopsis of the outlook for maize, including medium-term (next 5-10 years) and longer-term perspectives based on the main trends and projections of supply and demand key drivers. Maize research investment opportunities are highlighted by the analysis of the information gathered and analyzed in Part I and the information and analysis in Part III, which in turn rest on the information and analysis in the National Reports.

Part III provides a detailed description of the MVCS in each of the MAEZ, based mainly on the findings of the representative country case studies and other additional information. In this sense, this part can be thought of as an annex supporting the findings of Part I and II. The information in Part III focuses on the current situation of maize production, input provision and R&D, as well as maize value chains and consumption, respectively; that is, it focuses mainly on what is known and has been done in the recent past, i.e., the last 5-10 years. The depth of the analysis varies according to the level of information available in each MAEZ.

The report includes a set of regional- and country-level maize production, consumption and trade statistics; and is accompanied by a set of four country case studies (in Spanish).

This study is intended to have a positive impact on the debate over research strategies and policies, and thus serve better the interests of maize farmers and consumers throughout the Latin American region; and to inform research investment and management decision makers. Information in the study can make a vital contribution to increase awareness of what needs to be done to cope with problems likely to persist in the near future, and how to deal with new ones as they emerge in the maize sector in Latin America; and, consequently, to guide corrective policies at national and international levels, setting priorities for the years ahead.

Tables for the Introduction

Table 1. General economic and social indicators by MAEZ. 2000-12

Key Indicator	Temperate Southern Cone		Subtropical Southern Cone		Subtropical Andean Region		Tropical Central America		Subtropical North-ern ALC		LAC	
	Value	Growth	Value	Growth	Value	Growth	Value	Growth	Value	Growth	Value	Growth
Income per capita (us$)	6,144	4.51	3,123	2.4	4,957	10.8	3,077	2.8	8,017	1.3	5,173	2.8
GDP (M de us$)	121,104	6.08	478,655	4.0	93,302	6.3	17,040	3.8	863,173	2.3	2,818,275	4.0
AGDP	7,477	2.70	23,612	3.5	5,496	2.5	1,717	2.8	28,336	1.9	141,998	2.7
AGDP / GDP (%)	7	-2.12	12	0.7	8	-1.9	10.9	-0.8	3.3	-0.3	5.0	-0.8
Gini coefficient (National)	0.49	0.00	#DIV/0!	0.0	0.51	0.0	0.52	-0.9	0.51	0.0	0.53	-0.8
Total Population (M of hab.)	59	**0.9**	193	**1.1**	119	**0.9**	39	**1.8**	108	**1.0**	518	**1.0**
EAPagric/tota-lEAP (%)	11	-1.6	20	-2.4	22	-1.3	24	-2.5	18	-3	20	-2.2
Indigenous population (%)	2	0.0	1	0.0	27	-0.1	12	0.0	6	0	13	0.0
FemEAPagric/ EAPagric (%)	13	0.0	16	0.0	26	0.0	#DIV/0!	0.0	12	0	16	0.0
Population in poverty (%)	6	-26.0	17	-11.0	22	-7	21	-7.6	11	-4	17	-9.8

Table 2. World: Top ten nations in terms of maize area harvested, production and yield. 2010 & 2011

	Area Harvested ('000 Ha)			Production ('000 Tons)			Yield (Tn/Ha)	
Country	2010	2011	Country	2010	2011	Country	2010	2011
USA	32,960	33,986	USA	316,165	313,918	Israel	29.24	33.82
China	32,518	33,561	China	177,541	192,904	Qatar	20.76	12.56
Brazil	12,679	13,219	Brazil	55,364	55,660	Kuwait	19.42	20.17
India	8,553	7,270	Mexico	23,302	17,635	Jordan	19.39	20.68
Mexico	7,148	6,069	Argentina	22,677	23,800	Austria	12.06	18.39
Nigeria	4,149	6,008	India	21,726	21,570	Tajikistan	12.05	12.12
Indonesia	4,132	3,861	Indonesia	18,328	17,629	Belgium	11.93	11.94
Tanzania	3,051	3,288	France	13,975	15,703	Netherlands	11.77	12.34
Argentina	2,903	3,748	South Africa	12,815	10,360	Greece	11.34	11.91
South Africa	2,742	2,372	Ukraine	11,953	22,838	Chile	11.08	12.00

Source: FAOSTATS 2012.

Table 3. LAC: Maize production and area harvested by Maize Agro-ecological Region. 2010.

Region	Country	Area Harvested (000 Ha)				Production (000 t)				Total Area		Total Production	
		Highland	Subtropical	Temperate	Tropical	Highland	Subtropical	Temperate	Tropical	000 Ha	%	000 t	(%)
Andean Region	**Peru**	**497.2**				**1,500.0**				1,997.2	1.4	1,500.0	1.3
	Bolivia	314.3				718.0				1,032.3	0.7	718.0	0.6
	Venezuela	650.0				2,100.0				2,750.0	1.9	2,100.0	1.8
	Colombia	464.8				1,500.0				1,964.8	1.4	1,500.0	1.3
	Ecuador	440.3				984.1				1,424.4	1.0	984.1	0.8
Central America	**Guatemala**				**821.4**				**1,600.0**	2,421.4	1.7	1,600.0	1.4
	Honduras				469.8				508.9	978.7	0.7	508.9	0.4
	Nicaragua				341.2				457.0	798.2	0.6	457.0	0.4
										0.0	0.0	0.0	0.0
	El Salvador				252.9				798.0	1,050.9	0.7	798.0	0.7
	Panama				51.3				87.6	138.9	0.1	87.6	0.1
	Costa Rica				9.6				18.8	28.4	0.0	18.8	0.0
North America	**Mexico**	**7,100.0**						**23,000.0**		30,100.0	20.8	23,000.0	19.8
Southern Cone	**Argentina**			**2,900.0**				**23,000.0**		25,900.0	17.9	23,000.0	19.8
	Uruguay			96.0				1,400.0		1,496.0	1.0	1,400.0	1.2
	Chile			122.5				529.1		651.6	0.5	529.1	0.5
	Brazil		**13,000.0**				**55,000.0**			68,000.0	47.0	55,000.0	47.3
	Paraguay		794.0				3,100.0			3,894.0	2.7	3,100.0	2.7
Total										**144,626.8**		**116,301.5**	

Source: FAOSTAT, 2012

Table 4. LAC: Agro-ecological regions and environments

Region	Ecology	Country	Main features
Andean Region	Subtropical/ Highland	Venezuela Bolivia, Colombia, Ecuador, Peru	Low economic development (low income per capita) Lower endowment of agricultural land Stronger importance of cultural aspects Farm household economy based
North America	Subtropical	Mexico	Good level of economic development measured by income per capita. Large endowment of agricultural land with respect to regional average. Commercial productive sector using modern technology, with a well-developed agro industrial sector. Mexico has a commercial advantage due to short distance to US market.
Southern Cone	Subtropical	Brazil, Paraguay	
	Temperate	Argentina, Chile, Uruguay	
Central America[1]	Tropical	Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama	Low economic development (income per capita). Subsistence agricultural, diversified supply Dual type (traditional – modern) of productive sector. More rural, lower endowment of agricultural land Commercial advantage due to short distance to USA market

Source: based on Sain and Ardila (2009), and Doswell et al.1996.

PART I:

OUTLOOK FOR THE MAIZE VALUE CHAIN IN LATIN AMERICA

1. General economic and social conditions of MAEZs and representative countries

1.1 Economic and social conditions in Temperate Southern Cone (TSC)

The Southern Cone of Latin America comprises five countries: Argentina, Brazil, Chile, Paraguay and Uruguay. As one of the world's major food-producing regions, it affects food security across the globe. Thus, the agricultural sector is an import contributor to the Southern Cone region's economy and the commodities produced are mostly traded within the region as well as being exported worldwide. As founders and members of MERCOSUR[14] (Southern Common Market), the Southern Cone countries benefit from a free trade agreement among the member countries making it the fourth largest free-trade zone in the world. The Southern Cone is also one of the few regions with temperate and subtropical temperatures, which expands significantly its agricultural frontier and therefore it has one of the largest reserves of arable land in the world. Two climate-based areas can be identified within this region, one temperate and one subtropical. Argentina, Chile and Uruguay are located in the first area, and Brazil and Paraguay in the second.

The focus of this section is in the Temperate Southern Cone (TSC) region where Argentina is the representative country chosen.

In general, TSC countries compare favorably with the rest of LA in terms of key economic indicators (Table 1). These countries have performed significantly better than the typical country in the rest of LA, being the most prosperous macro-region in the area in terms of per capita income, a key factor in the demand for food. However, the key economic indicators related with agriculture are falling. The sector's shares of GDP and as a creator of employment have dropped to 7% and 12%, respectively, and continue to decrease. Another noticeable characteristic of the TSC is its relatively high standard of living and quality of life. In 2011, Chile, Argentina and Uruguay had a Human Development Index (HDI)[15] rating of 0.862, 0.843 and 0.828, respectively, and were the highest in Latin America. From an economic and liberal standpoint, the region has been praised for its significant participation in global markets, and its profile as an emerging economy.

Poverty indicators also show a region that has been successful in reducing poverty and extreme poverty to one digit level (Table 1). However, when social indicators are examined certain concerns emerge, such as the high levels of income inequality. Rural poverty in the TSC is deepest among indigenous people such as the Mapuches in southern Chile and some 15 ethnic groups in Argentina. Rural women are among the poorest of the poor and suffer the consequences of internal conflicts, migration of men and structural adjustments (IFAD 2012). Another favorable indicator is the low population growth rate (less than one percent per year), which is key driver of food demand and economic development.

Grain production has steadily increased during the last decade in the Southern Cone, with Brazil and Argentina leading the way, and the crop is now third in importance after sugar cane and soybean. Although most of the maize produced is used by the animal feed industry, a certain percentage of the maize grown is for human consumption; the cereal is the third most used for this purpose, after wheat and rice. Since maize flour is not a major consumption item as it is in Mexico or Central America, the mills producing maize flour in the region are doing so in large part for the export market.

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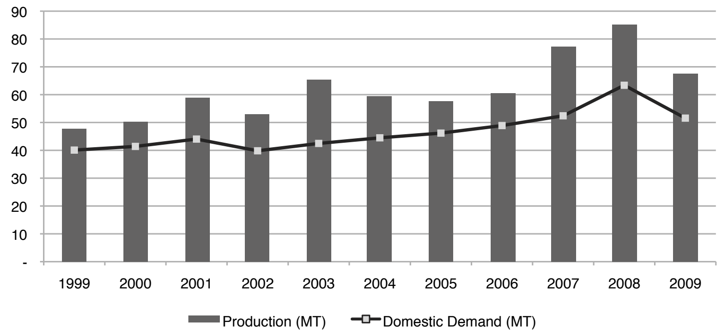
14 Its full name in Spanish is Mercado Común del Sur.

15 A comparative measure of life expectancy, literacy, education and standards of living for countries worldwide.

Figure 5. Southern Cone: Maize production and domestic demand. 1999-2009



Source: FAOSTAT 2012

Representative country: Argentina

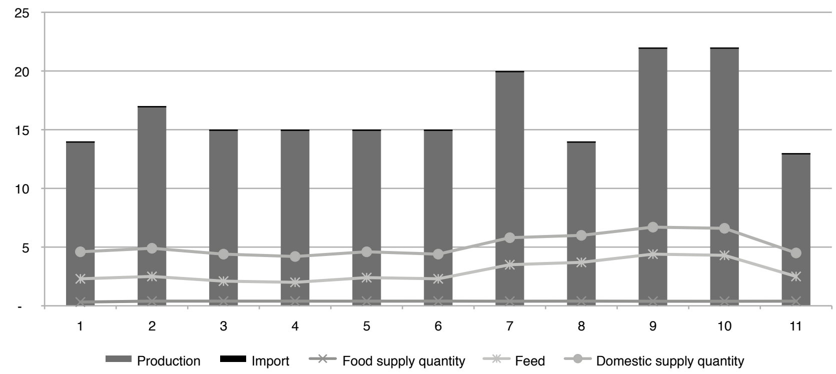
Argentina is the world's eighth largest nation, covering an area of 2.8 million square kilometers. However, with a population of just 40.76 million in 2011, the country is relatively sparsely populated. It has the third largest economy in Latin America after Brazil and Mexico. After slowing rapidly in 2009, the Argentine economy resumed robust growth in 2010, with a rate well above the regional average at 9.2% (ECLAC 2011). Its real GDP growth averaged 8.9% during the period 2008-2012 (World Bank 2012), bolstering government revenues and keeping the budget in surplus. Argentina benefits from rich natural resources, a variety of climates (ranging from the subtropical north to the sub-polar south), a highly literate population, an export-oriented agricultural sector and a diversified industrial base (Micronutrient Initiative 2007).

However, the benefits do not appear to be enjoyed by the whole population. It is estimated that poverty affects 30% of Argentines, with the incidence much higher in rural areas. Rural poverty in this country is mainly due to lack of access to productive resources such as land, credit, knowledge and new agricultural technologies. Lack of training, both agricultural and non-agricultural, is a determinant of poverty of households headed by women and young people. Adverse environmental conditions and erosion of natural resources represent additional challenges for residents of regions like Patagonia, Chaco or Puna (IFAD 2012). Argentina spends more than its Latin American counterparts on Agricultural R&D as a percentage of agricultural GDP and research capacity per capita, (ASTI 2012).

Argentina's economy has traditionally been based on farming and it is one of the largest agricultural producers in the world. Though industrial (28%) and services (69%) output make up a much higher percentage of the Gross Domestic Product (GDP) than the agricultural sector (3%), the latter accounts for close to one-third of all exports and employs 7% of the population (World Bank 2012). Around 10% of the country is cultivated, while about half of it is used for livestock grazing. Soy (and its by-products) is the country's principal export crop, followed by cereals (maize, wheat, and sorghum) and fruits. Argentina is the second largest exporter and third largest agricultural producer in Latin America. As an important exporter of wheat and maize, Argentina rivals the United States, Canada, and Australia. Its other agricultural exports products include oilseeds, soybeans, rice and sugar (Micronutrient Initiative 2007).

Maize is the third most important crop produced in Argentina. With an average production of 20 million tons between 2006 and 2011, it is the fourth largest producer of maize in the world, after the US, China and Brazil (FAOSTAT 2012). In this country, maize average annual yield growth was higher than 6.5%, going from 5.37 tons per hectare in 1999 to 6.35 tons in 2011, a situation that nearly doubled its production, going from 14 to 23.8 million tons. Maize is grown in the central region of Argentina, with the province of Buenos Aires producing 54% of the nation's total maize supply. Average maize consumption in Argentina during the period 2004-2009 was 5.66 million tons, making the country the twentieth largest consumer of maize worldwide. Of the total volume for domestic consumption, since 2005 more than 60% goes to animal feed and the rest to human consumption. Due to its high level of exports, this country is also the world's second largest exporter of maize after the US, exporting on average 70% (i.e., 8.6 million tons in 2009) of its production during the period 2000-2009 (FAOSTAT 2012). Even though a great quantity of Argentina's maize production goes to the international market, this country is able to satisfy its domestic demand.

Figure 6. Argentina: Maize production, consumption and imports in MMT. 1999-2009



Source: FAOSTAT 2012

1.2 Economic and social conditions in Subtropical Southern Cone (STSC)

The STSC comprises only two countries, Brazil and Paraguay, which together have an average per capita income of approximately USD 3100 and an annual growth rate close to 2.4 % per year during the period 2000-2010 (Table 1).

Representative country: Brazil

Although Brazil was not included in the four case studies, the country is an important player at the continental, and even at the world, level and for that reason, an effort was made to include the main characteristics of the economy and the MVCS in the study. The relative importance of the size of its MVCS with respect to that of Paraguay means that the considerations regarding this country are valid in the whole STSC.

According to the country reports of the World Bank, Brazil, with a Gross Domestic Product (GDP) of USD 2.223 trillion in 2012[16], is the world's seventh wealthiest economy. It is also the largest country in Latin America and the Caribbean in terms of area and population. The Brazilian economy slowed significantly over 2011 and 2012. GDP growth of 7.5% decelerated to 2.7% in 2011 and fell further, to 0.9%, in 2012. The slowdown was driven by both domestic and external factors. While the stimulus measures undertaken have so far failed to lift economic activity, recent signs suggest that the business cycle may finally start to gather forward momentum.

Brazil experiences extreme regional differences, especially in regard to social indicators such as health, infant mortality and nutrition. The richer south and southeast regions where much of the maize is sown enjoy much better indicators than the poorer north and northeast. Poverty (people living on USD 2 per day) has fallen markedly, from 21% of the population in 2003 to 11% in 2009. Extreme poverty (people living on USD 1.25 per day) also dropped dramatically, from 10% in 2004 to 2.2% in 2009. Between 2001 and 2009, the income growth rate of the poorest 10% of the population was 7% per year, while that of the richest 10% was 1.7%. This helped decrease income inequality (measured by the Gini index), which reached a 50-year low of 0.519 in 2011. Despite these achievements, inequality remains at relatively high levels for a middle-income country. There has been enormous progress in decreasing the deforestation of the rain forest and other sensitive biomes, but the country faces important development challenges in combining the benefits of agricultural growth, environmental protection and the sustainable development.

16 http://www.worldbank.org/en/country/brazil/overview

Maize production in Brazil

Brazil is the world's third largest producer of maize and the volume is expected to remain strong, with more than 55.7 million tons produced in 2011 (FAOSTAT 2012). Around 40% of maize produced in this country is demanded by the poultry industry and 20% by the swine industry. Brazil is also the third largest consumer and exporter of maize in the world. During the period 2004-2009, maize consumption reaches on average 42 million tons per year; and in 2010, the country exported around 11 million tons. Brazil has been importing some maize from Paraguay, mainly for the meat industry in the south. More than 90% of the maize produced and traded is yellow dent maize.

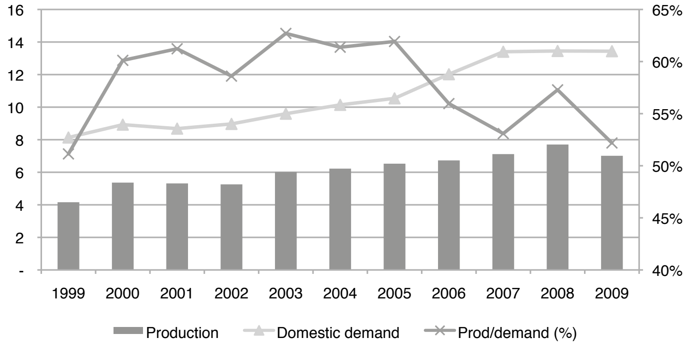
1.3 Economic and social conditions in Subtropical Andean Region (STAR)

The Subtropical Andean Region (STAR) comprises Bolivia, Colombia, Ecuador, Peru and Venezuela, which together have average per capita income of USD 5000 and a high annual growth rate of close to 10% per year (Table 1). The agricultural sectors of the Andean countries have similar characteristics, such as low levels of productivity, predominance of small-scale farmers, weak presence of the State in rural areas, sizeable population sectors living in poverty, limited access to external markets, little private investment and insufficient services, among others (Micronutrient Initiative 2007). In the period 2008-2010, agriculture accounted, on average, for 9% of the region's GDP, and approximately 38% of its population was living below the poverty line. In all the countries in this region, except for Venezuela, almost 30% of the population is comprised of rural dwellers, where agriculture is the main source of income and food (World Bank 2012). The harsh Andean environment is home to 35% of the poorest people in the region, and 55% of the rural population were living below the national rural poverty line (World Bank 2012). Rural poverty in the region is mainly associated with lack of access to and unequal distribution of productive land, and inadequate access to information and productive assets for smallholder farmers. In rural areas, poor people also face the consequences of geographic isolation and limited public investment in education, health services and housing. The poorest inhabitants of the Andean Region are indigenous peasant communities in remote mountain areas of Bolivia, Peru and Ecuador. Market-oriented policies adopted by governments during recent years have led to a decrease in investments in rural areas, contributing to the growth of rural poverty (IFAD 2012).

Under the Andean Community of Nations agreement, the region is taking steps to improve agriculture, productivity, food security and their international trade competitiveness. Although there are several developed industries in the region, such as grains, oilseeds, edible oils and rice, they are being imported to meet demand. Trade within the region is advantageous as the Andean community offers preferential import duties to member states. It is important to note that recently there has been a huge increase in the demand for industrial maize for the production of ethanol, which inevitably pushes up the price of foodstuffs (Micronutrient Initiative 2007).

Maize production in the Andean Region ranks fifth after sugar cane, bananas, rice and potato production. Even though maize is consumed throughout the Andean region, consumption is much lower than in other parts of LA. Nonetheless, maize flour consumption has increased in this region in recent years in response to lower real incomes. Maize is the main grain produced in Venezuela, with average production of around 2.24 million tons between 2006 and 2011, 70% of which was white maize (FAOSTAT 2012). In the case of Bolivia, maize production represents 52% of total grain production, making the crop the most important domestically produced food grain in the country. Both white and yellow maize are grown in Bolivia. Small farmers consume approximately 50% of white maize locally, with the rest being used by the livestock and poultry feed industry. Most of the maize consumed in Colombia is imported, because production levels of this crop are low. In fact, imports meet 75% of total maize needs, i.e., both food processing and animal feed requirements (Micronutrient Initiative 2007). In the case of Ecuador, maize consumption is quite low, mostly in the form of pre-cooked flour produced industrially.

Figure 7. Andean Region: Maize production and domestic demand. 1999-2009



Source: FAOSTAT 2012

Representative country: Peru

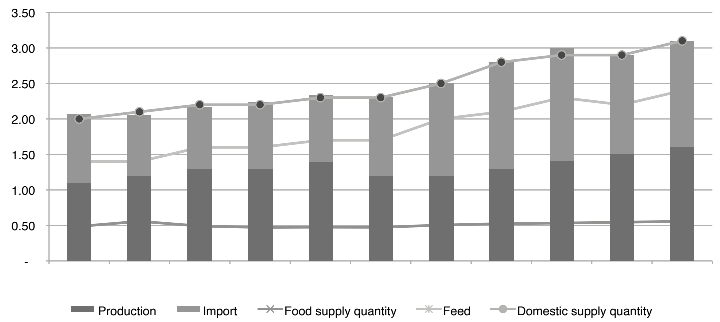
Peru, with a population of 30.1 million inhabitants, is the third largest country in South America and one of the 17 countries with the greatest biodiversity in the world, having 84 of the 104 life zones (áreas de vida) that exist in the world. This country is located in the inter-tropical and western part of South America facing the Pacific Ocean, bordering to the north with Ecuador and Colombia, to the east with Brazil, to the southeast with Bolivia and to the south with Chile. Peru is a middle-income country with a growing GDP. In 2011, Peru's GDP grew by 6.9%, driven by robust domestic consumer and investor demand and by a process of inventory restocking. This performance was fuelled by the upturn in the global economy and improved access to various markets following the signing of several free trade agreements and more vibrant export growth (ECLAC 2011). It ranked 77th out of 187 countries on the 2011 Human Development Index (HDI) of the United Nations Development Programme; its value in 2012 was 0.741, close to the average for LAC. Despite the strong macroeconomic performance, underemployment and poverty have stayed persistently high, particularly in rural Andean highlands where most of the native population lives. Of the total 29.4 million people living in Peru by 2011, more than 8 million lived below the poverty line, compared with around half in the early 2000s (World Bank 2012). This geographical distribution of poverty is common to the other countries in the STAR region.

The poorest of the poor in Peru are located in the arid Andean highlands, where a large majority of the indigenous Quechua and Aymara communities live below the poverty line. Rural poverty rates still remain disproportionately high, food insecurity is chronic and many smallholder farmers produce basic food crops at a subsistence level. Most rural women are poor or extremely poor, even as they play a central role in the subsistence economy. Women work in agriculture, tend livestock and engage in income-generating activities, representing as much as 80% of a family's labor**.** Rural poverty in Peru has its roots in high rates of illiteracy, lack of essential services, limited access to resources (land, water and forest), inadequate agricultural research, training and financial services, and poor transportation infrastructure and marketing systems (IFAD 2012*)*.

Economic growth continues to be driven by exports of minerals, textiles and agricultural products. Farming provides a livelihood for the majority of Peruvians, some of whom remain outside the money economy (Micronutrient Initiative 2007). With around 1.5 million hectares, the Andes contain the main part of Peru's arable land, where the choice of crops depends on the climate conditions, since the opportunities for cultivation are limited above 3200 meters. With the exception of the big extension of pasture and the great importance of animal keeping, maize, especially the so-called *maíz amilaceo* (with a high starch content), rice, potatoes, sugar cane, plantain, wheat and coffee are the most important crops there (FAOSTAT 2012). Although in economic terms coffee is the most important crop; around one million persons work in the coffee sector and it is the most important agricultural export product, maize is Peru's most important crop by cultivated area. Two types of maize are grown in Peru. The most important varieties are starchy maize (with a production of 255,000 tons in 2011), which is used directly for human consumption; and yellow maize (with a production of 1.24 million tons in 2011), which is primarily used in the animal feed industry. Yellow maize production in Peru has been increasing steadily since international prices began rising (USDA 2012).

In 2011, maize production in this country was 1.51 million tons, an increase of 26% over the production level in 2000. This significant increase is due to good weather conditions, sufficient water supply and higher prices and strong demand from the poultry industry. Maize harvested area in 2011 was 475,671 hectares, 53% of which were yellow maize and the rest starchy maize. In the same year, maize yield was around 3.2 tons/ha, the highest since 1999 (FAOSTAT 2012). In general, yellow maize yield is higher than that of starchy maize, with yields varying greatly depending on the production region and the producers' level of technology. Maize domestic demand in 2009 was 3.1 million tons, the highest in the last decade. Approximately 77% of the demand was from the feed industry and only 18% from consumers. Peru's maize production is not enough to satisfy local demand, 50% of which is met with imports. In 2011, Peru imported 1.9 MMT of yellow maize, with Argentina the principal supplier. United States maize exports to Peru dropped significantly from 626,428 million tons in 2010 to only 63,130 million tons in 2011 as a result of Peru's unilateral elimination of import duties for maize, causing the United States to lose the trade preference granted under the US-Peru Trade Promotion Agreement (USDA 2012).

Figure 8. Peru: Maize production, consumption and imports in millions of tons. 1999-2009



Source: FAOSTAT 2012

1.4 Economic and social conditions in Tropical Central America (TCA)

Although the Central American countries[17] are comparatively small and diverse, they face similar socioeconomic and agricultural challenges, share common agro-ecological and climatic conditions, and collectively represent about 40 million people of a common cultural heritage. During the period 2000 – 2010, population grew at a rate of almost two percent per year (Table 1). Poverty is still widespread in every country in the region and income distribution remains highly uneven, with indigenous communities among the poorest segments of the population. All Central American countries have higher rates of poverty in rural areas than in urban areas. In 2011, around 43% of Central America's population lived below the poverty line and 57% of the rural population were living below the national rural poverty line. Honduras is the most dramatically affected country, with 72% of its rural population living in poverty and 60% of them in extreme poverty. Next in rank is Guatemala, with 71% of rural people living in poverty; and Nicaragua and El Salvador with 63% and 47%, respectively. Panama and Costa Rica have lower incidences of poverty, with figures of 37% and 29%, respectively (World Bank 2012).

In 2011, agriculture accounted for 11.5% of the region's Gross Domestic Product (GDP), down 27% from the previous year, with the figures for the different countries ranging from 4% in the case of Panama to 20% in the case of Nicaragua (World Bank 2012). Agriculture is also an important source of employment in the region. Most producers in lowland tropical zones are small-scale farmers, for whom agriculture is the principal source of income and food. The Economically Active Population (EAP) involved in agriculture in the region accounts for almost one fourth of the total EAP. By 2012, approximately 27% of the rural labor force in Central America was employed in agriculture, encompassing 40% of the national labor force in Guatemala, 25% in both El Salvador

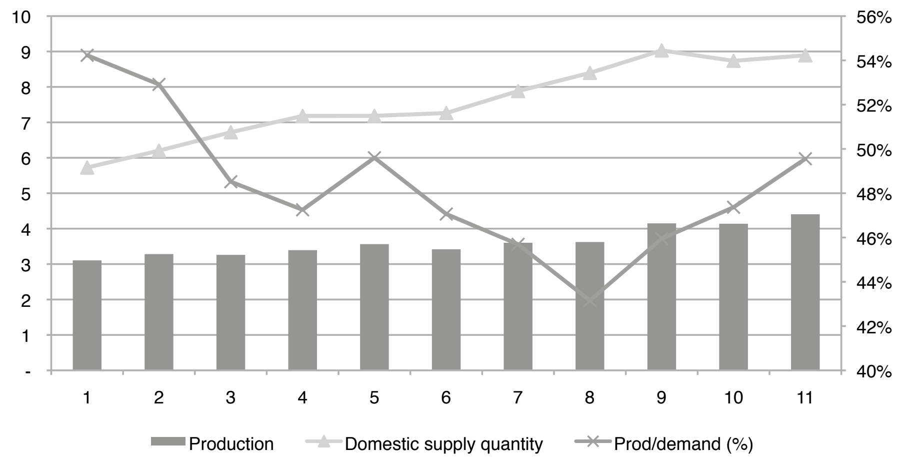
17 Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama

and Honduras, 23% in Belize, 17 % in Panama, 15% in Costa Rica and 14% in Nicaragua (FAOSTAT 2012). As is the case in other developing regions of the world, Central America's strong focus on agriculture is accompanied by persistent rural poverty.

Central America is struggling with the need to increase food production, which is failing to keep up with the burgeoning demand; the shortfall, mostly grains, oilseeds, edible oils and rice, is generally imported from the USA and Mexico. On the other hand, agricultural exports are also a significant contributor to the Central American economy, although concentrated in the hands of relatively few people (large landowners and entrepreneurs). Between 2002 and 2004, agricultural exports accounted for close to one third of the region's total exports, with coffee, sugarcane, bananas, tobacco and oil palm leading the way. In Belize, Panama and Nicaragua, agricultural products accounted for as much as 45% of national exports. Since the mid-1990s, Central America has undergone a trade liberalization process, with the countries—either individually or as a group—entering into free trade agreements with Mexico, Chile, the US and Canada, as well as the European Union and a number of Asian countries (ASTI 2012).

Agricultural production in Central America is based primarily on cereals and legumes, including maize, beans, rice and sorghum, which are part of the basic diet of the population. Maize production in the region is second only to sugarcane and higher than production of vegetables, sorghum and bananas. However, domestic maize production is nowhere near to satisfying local demand, with approximately 35% of the maize consumed in 2009 being imported (FAOSTAT 2012). In general, maize production in the region is affected by low adoption of technology (e.g., use of improved seeds), high transaction costs and restricted access to water and land (most producers own less than five hectares). Even though maize is still an important component of the population's diet, especially in Guatemala, El Salvador and Honduras, some countries (e.g, Costa Rica and Panama) are switching to the production of non-traditional goods for export whose prices in international markets are more attractive. Moreover, given maize's importance in the region, it was excluded from the tariff reduction program of the Central America Free Trade Agreement (CAFTA). Moreover, in some countries where the tariff structure for maize has been quite protectionist—Guatemala is a case in point—regional agreements have been signed recently to lower tariffs (Micronutrient Initiative 2007).

Figure 9. TCA: Maize production and domestic demand. 1999-2009



Source: FAOSTAT 2012

Representative country: Guatemala

Guatemala is the largest and most populous of the Central American countries with a total population of 14.76 million in 2011, 60% of which lives in rural areas. Income distribution remains highly unequal, with about 54% of the population below the poverty line in 2011 (World Bank 2012). Young people and rural dwellers are the most vulnerable, and poverty is highly concentrated among indigenous communities, which comprise over 40% of the total population (IFAD 2012). Guatemala's per capita GDP is around half that of Brazil, Argentina and Chile; and in 2011the country ranked 131st out of 187 countries on the Human Development Index (HDI) of the United Nations Development Programme.[18] Although Guatemala has made significant progress with the problem of chronic malnutrition, it still lags behind all other Latin American and Caribbean countries (Micronutrient Initiative 2007).

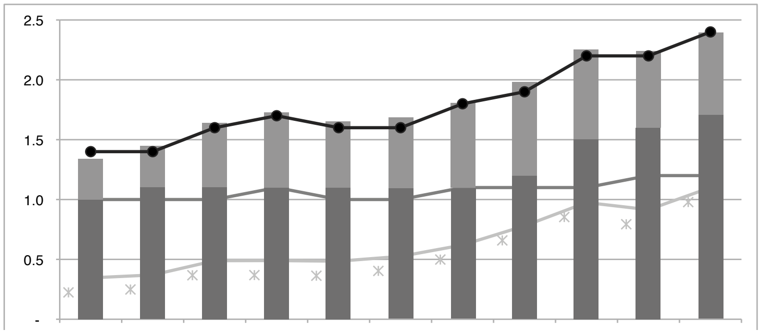
Agriculture plays an important part in the national economy, accounting for 11% of GDP and employing about 50% of Guatemala's total labor force (FAOSTAT 2012). Approximately 80% of the population is directly or indirectly involved in agricultural activities, contributing approximately 25% of GDP (López *et al.* 2006). Indigenous and rural communities are primarily involved in small-scale family agriculture, i.e., the subsistence economy. The rugged terrain and lack of roads represent important challenges for farming, since they have kept rural communities isolated from the rest of the country. The overexploitation of land and water resources has resulted in lower productivity of basic crops, which has increased food insecurity for poor smallholder families (IFAD 2012).

Coffee, sugar and bananas are the leading commercial and export crops in Guatemala's agricultural economy. There is some manufacturing, primarily of refined sugar. In 2010, around 70% of all sugar production was exported, making Guatemala Latin America's largest and the world's fifth largest sugar exporter (i.e., accounting for around 2% of net world exports). The US, Mexico, El Salvador, Venezuela, Germany and Japan are Guatemala's major trading partners. Mexico is a major player in Guatemala's food import market. The existence of a free trade agreement between the Central American countries provides a great opportunity for the constant exchange of products. Mexico has been expanding into the Guatemalan market and recently signed a free trade agreement with the northern triad of Central America (Micronutrient Initiative 2007).

Guatemala is the largest producer of maize in Central America, with an annual average of 770,000 hectares harvested and production of 1.5 million tons, or 44% of the region's maize production from 2005-2011. The importance of maize to the Guatemalan economy is demonstrated by the fact that its production accounts for approximately 10% of the total value of national agricultural production. Maize yield grew at an annual rate of 2.8% from 1999 to 2010, peaking in 2007 at 2.53 tons/ha, which represented an increase of 42% from the 2000 level (FAOSTAT 2012). With the harvested area growing at a modest annual rate throughout the same period, the decline in the growth of maize production is clearly associated with changes in productivity. Total maize consumption in Guatemala has grown steadily over the past 30 years, at an annual average rate of 3%. Maize production and imports in Guatemala are predominantly for human consumption, since maize is the main source of calories in the diet of the country's poor population.

18 A comparative measure of life expectancy, literacy, education and standards of living for countries worldwide

Figure 10. Guatemala: Maize production, consumption and imports (in millions of tons). 1999-2009



Source: FAOSTAT 2012

1.5 Economic and social conditions in Northern Latin America (NLA)

Economic growth over the last decade has made Mexico an upper middle income country, but tremendous disparities and social exclusion remain, with more than 51% of the population living below the national poverty line in 2010 (World Bank 2012). Moreover, 60% of rural households were poor and half of them were extremely poor, with incomes amounting to less than the cost of a basic food basket (ASTI 2012). Rural poverty in Mexico is concentrated in areas with the highest density of indigenous population, mostly located in the southern states, such as Oaxaca, Chiapas and Guerrero, where extreme poverty affects 50% of the population. It is estimated that in rural areas 61% of the native population lives in extreme poverty, in contrast to 19% of the non-indigenous population. The vulnerability of female-headed households is higher because women have fewer job opportunities and limited access to productive resources. Most of the main causes of poverty are structural, determined by limited access to basic services (e.g., education, health and housing), and productive resources (e.g., land, water, technology, information and credit) (IFAD 2012).

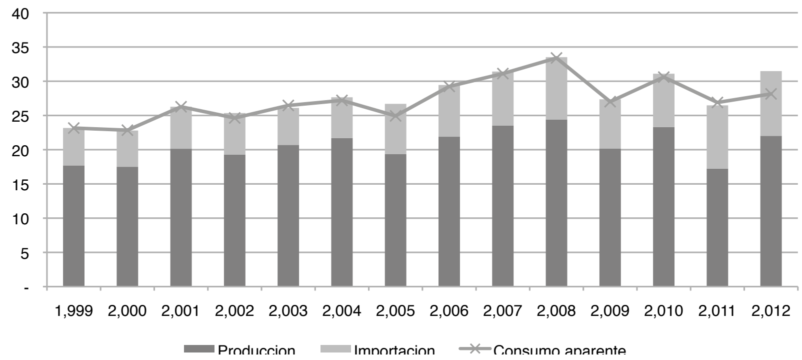
Much of the farming in Mexico is done on plateaus at altitudes of 1500 meters or more. This, coupled with a general lack of economic opportunity in rural areas, has made it difficult to raise the productivity standards of Mexico's subsistence farmers. Currently, market conditions are characterized by strong growth in the demand for imported food products, as only 13% of Mexico's land area is arable and 3% irrigated (FAO 2012). Nonetheless, Mexico is on the way to becoming a developed country, with a mix of modern and outmoded industry and agriculture, increasingly dominated by the private sector. The country has a very strong food-processing sector and is an exporter of certain commodities, such as maize flour, within LAC. Mexico's trade regime is among the most open in the world, with free trade agreements with the US, Canada, the EU, and many other countries. Mexico has 12 free trade agreements that encompass more than 90% of its trade and involve over 40 countries, including Guatemala, Honduras, El Salvador, the European Free Trade Area and Japan (Micronutrient Initiative 2007).

In Mexico, no other crop is as important as maize. It is the main crop and the main cereal produced in the country. Maize is the only agricultural commodity that is produced in all Mexican states and is the major staple and main source of calories for most of Mexico's population, especially the lowest income groups. In the period 2006-2011, Mexico was the world's fourth largest consumer of maize, with average consumption of 29.71 million tons (SIACON 2012). In 2009, annual per capita consumption in the country was 121 kilograms, the highest in the world (FAOSTAT 2012). During the same period, maize production averaged 21 million tons, making Mexico the world's fourth largest producer of the crop. In 2011, around 90% of the maize produced in Mexico was white and the remainder yellow. It was mostly produced in Chihuahua, Jalisco, Sinaloa, Chiapas and Zacatecas (SIACON 2012). Average maize yield in Mexico during the period 2000-2010 was about 3.1 tons/hectare.

For several decades now, Mexico's maize production has been insufficient to satisfy domestic consumption, which in the last five years has grown significantly. The shortfall has been met mostly by importing maize from the US. Since US maize is subsidized, it is much cheaper than in Mexico, where the poor storage infrastructure used for commercialization is more expensive (Maximiliano, Rivera and Franco 2011). In the period

2006-2011, Mexico imported an annual average of 7.96 million tons of maize, making it the third largest maize importer in the world. Mexico's exports during the same period were significantly lower, averaging only 270,920 tons per year, making the country the world's twentieth largest maize exporter.

Figure 11. Mexico: Maize production, consumption and imports (in millions of tons). 1999-2012



Source: FAOSTAT 2012

2. Maize Production in LAC

2.1 Importance of maize production in LAC

Maize has become one of the world's most widely produced crops since it was first cultivated in Mexico around 10,000 years ago. Despite its global significance, however, no country can be said to be the most important producer. The US undoubtedly defines much of the market environment, however, given that it is world's largest producer and exporter. Nevertheless, Latin America and the Caribbean (LAC) is among the individual geographical regions of the developing world where maize production is of paramount importance and thus able to influence the global maize sector. From 2001 to 2010, maize was the third major crop produced in the region after sugarcane and rice, with production higher than that of the other two major cereals produced (soybeans and wheat). In 2010, maize production in the region was around 120 million tons, or 14% of global annual maize output (FAOSTAT 2012). Among the most influential countries in the region are Mexico, Argentina and Brazil). Mexico is the center of origin and diversity of maize, and has the highest annual per capita consumption; and Argentina and Brazil are large producers of conventional and genetically modified grains for feed and ethanol, respectively.

Maize is grown throughout the Latin American region and, together with rice, wheat and beans, makes up the core of the diet for thousands of poor rural and urban households.

Maize is among the five most important crops in terms of the volume produced in all the agro-ecological regions of Latin America (Table 1). Maize ranks third in importance in the (temperate and subtropical) Southern Cone behind soybeans and sugarcane; it ranks fourth and fifth in the Andean and Central American regions, respectively; and second in Northern Latin America (Mexico), behind only sugarcane production. Although in all the regions considered except Mexico the volume of maize production increased substantively over the past ten years, the growth rate in the Southern Cone was not higher than that of other, competing crops (e.g., soybean and sugarcane), as reflected in the loss of relative importance of maize in terms of crop volume. These trends reflect the impact of high energy prices on crop production, which has led to a change of focus towards the use of crops for the production of bioalcohol and biodiesel, an aspect that is explored further later on in this report.

At the continental level, the value of maize production represents almost 9% of Agricultural Gross Domestic Product (AGDP), with the level in the Subtropical Southern Cone Region (mainly Brazil) close to 20%

(Table 1. 2). Although the importance of maize in the formation of the AGDP may not be large, its economic importance lies in the fact that maize is grown by millions of poor small farmers across the continent.

2.2. Maize production dynamics in LA

Maize production geography

During the period 2000-2012, maize production in LA averaged 5.6 million tons per year and grew at an annual rate of almost 4%, well above that of the population; however, the main question is whether this growth rate will be high enough to keep pace with rising demand in the years ahead, an issue that is also explored further later in this report.

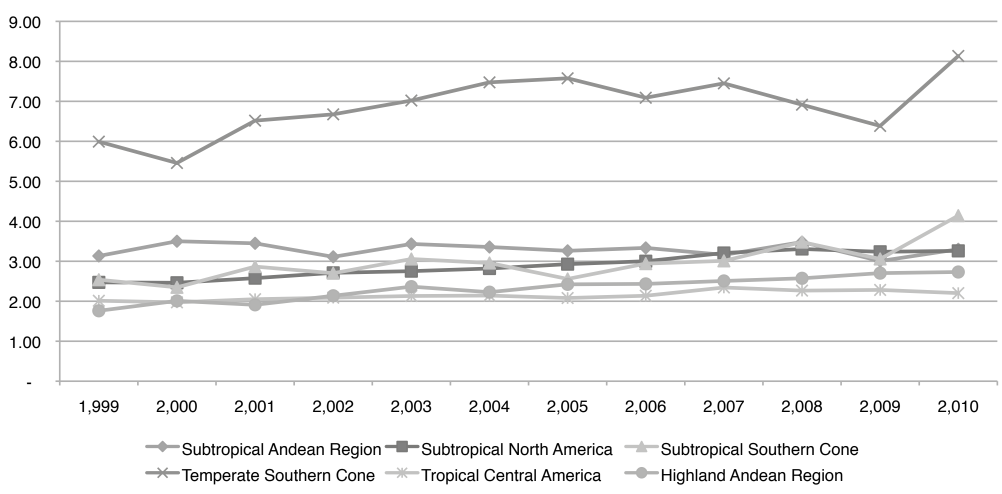
The maize production growth rate was mainly driven by productivity-enhancing technological change that led to maize yields growing at an annual rate of 2.3%, associated with a small increase in the cultivated area, and resulting in a Growth Anatomy Index of 2.5 (Table 3). This pattern was common to all MAEZs, with the exception of the STNA (Mexico), where maize acreage fell slightly and maize yield grew at annual rate of close to 3%.

Many factors have been mentioned in the literature to explain the increasing production trends across LAC, the more common of which are higher maize prices pushing the maize acreage up (Secretaría de Economía de México 2011, FAOSTAT 2012), as well as some key innovations in the production technology that boosted land productivity (yield).

Factors explaining maize yield trend and differences across LA countries

One important characteristic of maize production in Latin America (LA) is its great diversity, in terms of not only maize agro-ecologies but also with regard to economic, social and cultural aspects. This diversity is reflected in maize yields across LA countries and over time. We can observe that although the trend in overall maize yield has been positive over time, the growth rate has not been the same for all countries. A significant part of the differences is due to biophysical factors related to the environment, such as temperature, precipitation and solar radiation. The influence of these factors can be observed in Figure 12 where the yield level of the TSC region is higher than that of the other regions.

Figure 12. LA: Average maize yield, differentiated by maize agro-ecological and environment zone. 1999-2011



Source: FAOSTAT 2012

In order to test some of the hypotheses on factors affecting maize yield in Latin American countries, a generalized Cobb Douglas production function was estimated using time series data on a sample of the 17 Latin American countries. In the model, average maize yields per hectare in country *i* and year *t* was hypothesized as a function of: i) a set of agro-ecological (environmental) variables that vary across countries but not in time; ii) a set of social and cultural variables that characterize each country and that are associated with maize production and its consumption; *iii)* a set of variables that characterize maize production technology that varies across countries and time, and iv) a set of economic and policy environment variables specific to a country and that vary over time (Sain *et al.* 2013). The results confirmed the importance of agro-ecological and social/cultural factors in determining maize yield. For example, the results show that, all else constant, average maize yields for countries whose indigenous population accounts for more than 10% of the total population will be 8% lower than a country with almost no indigenous population. Another social/cultural variable that is significant is the type of maize cropped by country, e.g., if the predominant maize grown in a country is YDM, the predicted maize yield for that country will be 15% greater than in a country where WDM or FM is the principal type. As expected, technological factors like the use of hybrid seed and investment in maize R&D are also important drivers of yield differences among LAC countries. For countries that have a cropped area with hybrid seed larger than 75% of the total cultivated area, compared with countries that do not use this type of seed, increases in maize yield can be up to 30%, all else constant. Surprisingly, providing incentives via prices did not show a significant impact on maize yields (Sain *et al.* 2013).

Factors explaining maize acreage and differences across LA countries

Maize acreage allocation is basically linked to biophysical factors (suitability and availability) as well as to economic and policy ones. For example maize profitability relative to that of land-competing activities hinges on relative prices, cost structure and economic policy. The results for the estimation of a maize acreage response function using time series data on a sample of the 17 Latin American countries show that prices of competing activities, crops and pasture relative to the maize price plays a significant role in the land allocation decision taken by maize growers across LAC (Sain *et al.* 2013).

2.3 Maize production systems

Types of maize sown and their importance

Three main types of maize are sown in LAC and the crop's importance varies according to the MAEZ: 1) Yellow Dent Maize (YDM) is predominantly sown in the TSC, STSC, STAR and center and north of Mexico; 2) White Dent maize (WDM) is sown in the SCA and the south of Mexico; and 3) Floury or Starchy Maize (FM) is sown in the Highlands of the STAR, Mexico, and to a lesser extent in Guatemala. The type of maize sown depends of the market orientation of the farming system, and the importance of the indigenous population. While YDM is produced for the feed market (indirect consumption), WDM and FM are used for direct human consumption. In terms of production systems, maize is sown as a single crop in the commercial, market-oriented subsector of agriculture, and in association with other crops (usually beans) in small-scale farming systems. In the tropical and subtropical environments, maize is mainly sown in the first rainy season (*primera*), and to a lesser extent in the second season (*postrera*). In temperate regimes, maize is grown during the summer, when the long days and high temperature favor maize yield. Table 8 shows the importance of these systems in each of the LAC MAEZs.

2.4 Maize producers across LA

It is estimated that 11% of maize cultivated in LA is grown by small and medium-scale farmers and that most of it is grown in the lowland subtropical environment. During the period 2006-2010, it was estimated that on average 71% of total LA production was produced in that environment, which represented 10% of global maize production, and 14% of the world's total maize acreage (FAOSTAT 2012). In general, White Dent Maize (WDM) and improved open-pollinated varieties (OPV) are associated with smaller, subsistence or semi-subsistence farmers, while Yellow Dent Maize and Hybrids are associated with large, more commercially oriented producers. Thus, as the developing world's preference for the use of maize as livestock feed increases, breeding is shifting somewhat towards yellow maize and hybrids (Lopez-Pereira and Morris 1994). This is the case of maize grown by the members of MERCOSUR,[19] where mainly commercial large-scale farmers are to be found, e.g., Argentina and Brazil.

In the temperate zone, producers are medium-sized and market-oriented, and characterized by the use of technology spillovers from the temperate regions of the USA and Europe (Fundación Chile 2007). On the other hand, in the subtropical and highland countries a mix of small producers and medium-sized commercial farmers can be found, who still combine household consumption with marketed surpluses (Romero 2007). Finally, most producers in the tropical zone are small-scale farmers who consume most of their production, selling any surplus locally.

2.5 Maize technology use

In general, maize production has been impacted by the development of advanced technologies, namely mechanized production, use of external inputs and high-yielding hybrid varieties (including genetically modified varieties), and this continues to be a constraint for developing countries. Furthermore, when credit, labor, traction power, information and land markets are imperfect, farmers who lack the necessary capital or family resources (labor, land, oxen) fail to invest in otherwise profitable technologies (Shiferaw *et al.* 2011).

For instance, adoption of a technological package (e.g., zero tillage and cropping systems) in Southern Cone countries has reduced production costs and increased yield for commercial farmers, allowing them to grow enough maize to produce biofuel for self-consumption and exports. In the case of Argentina, investments in R&D, hybrid and transgenic maize have enabled this country to become one of the most important maize oil producers and exporters in the region. Similarly, increased investment in technology (e.g., improved seed, irrigation and fertilization) in Peru, El Salvador, Venezuela and Colombia has raised maize yields (Sain 2011, Bolaños 1997 and Secretaría de Economía de México 2012). However, in the tropical zone in LA, most technology used for maize production is still traditional and manual, generally on marginal lands where restricted use of conservation practices, improved varieties and limited access to inputs constrain maize productivity (Morris and Smale 1997).

In the general model where Productivity (Y) results from the interaction of Germplasm (G), Environment (E) and Management (M), technology plays the role of allowing G to express its potential productivity to the economic maximum. The next section explores the G part of the equation, and the following ones the Management one.

Use of improved maize seeds

In general, the varieties of maize that farmers use in developing countries range from local/traditional, farm-saved seed, improved open-pollinated varieties (OPV) and hybrids to transgenic (UNDP 2010), with the adoption of improved seed varieties less widespread in non-temperate areas than in temperate ones. Deployment of improved maize hybrids and new varieties is crucial, since most of the required increases in maize production in the foreseeable future are likely to come from yield growth rather than area expansion. Thus, given the fact that fresh seed must be acquired for each cropping cycle, it is important to have a viable, efficient seed industry that adequately serves small farmers, who cannot produce genetically pure maize seed.

Although in the past OPV yields have increased considerably under national and international breeding programs, they remain below those of hybrids, which are 30%-100% higher, with an average of perhaps 40%-50%. However, when hybrids have replaced OPV, the yield advantage has usually been no more than 15%-25% (FAO and CIMMYT 1997). It is estimated that in LA some 55% of the total maize area at the end of the 1990s was planted using farm-saved seed and the rest with improved materials, i.e., hybrids or improved open-pollinated varieties (Shiferaw *et al.* 2011). Major consumers of hybrid seed in LA include Argentina, Chile, Uruguay and Brazil, where more than 50% of all seed used is of improved varieties. The use of hybrids in Central America is not significant, being less than 20% of the total seed used, while in the rest of the countries their use varies from 30%-40% (Morris and Pereira 1999). However, there is wide variability across countries, ranging from a low of 21% in Honduras to a high of 95% in Chile.

19 Full members: Argentina, Brazil, Paraguay and Uruguay. Associate members: Bolivia and Chile.

There is ample evidence supporting the positive and substantial impact on maize yield of the use of improved germplasm, particularly hybrid seed. However, adoption of this input varies across LAC. In general, maize producers use a wide range of seed types, including local/traditional, Recycled Open Pollinated Variety (ROPV), Commercial OPV (COPV), hybrid material (HYB) and transgenic hybrid material. In the literature, COPV and HYB are usually grouped as Commercial Improved Maize Varieties (CIMV).

The empirical evidence in Table 9 shows a slow growing trend in the use of CIMV in all LAC MAEZs. For LAC as a whole, it is estimated that some 58% of the total maize area at the end of the 1990s was planted with Commercial Improved Maize Varieties (either OPV or Hybrids), however there is wide variability across MAEZs ranging from a low of 22% in NLA (Mexico) to 100% in the TSC region.

Modern maize hybrids and associated crop management practices have the potential to bring about significant increases in productivity, yet the impact of seed-fertilizer technologies has been relatively disappointing in maize-based cropping systems. Even though adoption of hybrids has been extensive in some areas, such as the TSC region, and to a lesser extent in the STSC and the STAR regions, in more tropical environments like Mexico and Central American the diffusion of hybrid materials has been low (Table 9).

a) New generation seeds. GMM

Of the 158 million hectares of land planted with maize in 16 of the 25 biotech crop countries worldwide in 2010, 46 million hectares were used to grow transgenic or genetically modified maize (GMM). This represented an increase of 10% over the previous year, the second highest increase after GM-cotton. The countries that grew more than one million hectares of biotech maize in 2010 included, in decreasing order of acreage: the US (31.7 million ha), Brazil (7.3 million), Argentina (3 million), South Africa (1.9 million) and Canada (1.3 million) (James 2010). Despite the higher cost of GM seeds,[20] GM-maize (mostly Bt-maize) promises lower production costs, because the use of chemical pesticides is reduced and/or eliminated altogether. However, such reduction is said to be temporary only, with significant increases of over 7% in pesticide use (UNDP 2010, FAO Statistical Yearbook 2012). Further benefits from GM crops include less pressure for cropland development and deforestation, as well as increasing opportunities to take marginal land out of production for set-aside or to cultivate some crops less intensively (Bruinsma 2003). However, the propagation of GM-maize and hybrid to satisfy the burgeoning demand for feed and fuel in developed countries constantly ratchets up the pressure on the environment, as well as the technological package associated with the crops.

Even though the number of maize GMM varieties and species and the area sown has increased rapidly, adoption across countries has been very uneven, with almost the entire expansion taking place in developed countries. Despite the growing variety of GM products available (e.g., herbicide-resistant maize varieties with higher oil content) commercial success has been concentrated on a few varieties or traits, notably herbicide-tolerant (Ht) maize and *Bacillus thuringiensis* (Bt) maize. While the rapid market penetration of these first GM crops is impressive, particularly when compared with the introduction of similar technologies (such as hybridized varieties), the growth of the area under traditional GM crops (e.g., *Bt maize*) is likely to slow down (Bruinsma 2003, James 2010). Modern maize hybrids and associated crop management practices have the potential to bring about significant productivity increases, yet the impact of seed-fertilizer technologies has been relatively disappointing in maize based cropping systems.

Non-seed inputs use

a) Fertilizer use

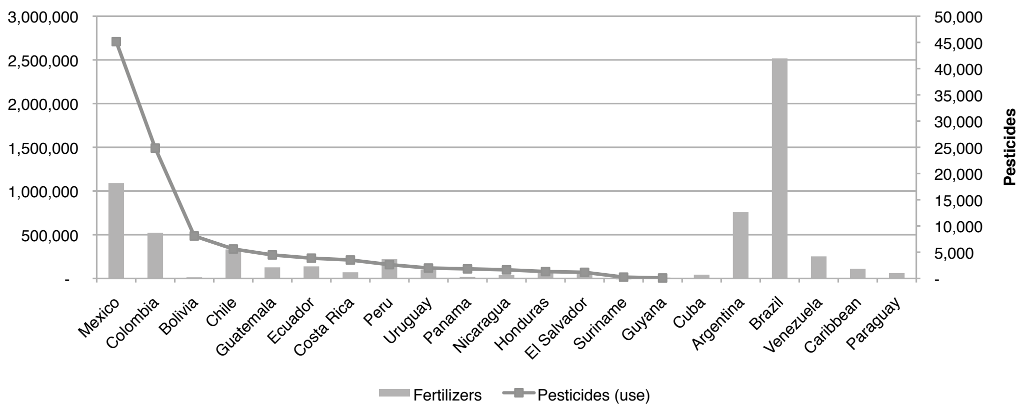
Maize is a crop highly dependent on external inputs, especially when planted in a mono-cropping system. In particular, it is very dependent on nitrogen-based fertilizers, and several types of herbicides, with Atrazine being one of those mostly commonly used. Apart from these two, phosphate and potash are also applied as fertilizer and some insecticides as well (UNDP 2010). Overall, fertilizer use on maize also varies widely among countries and regions within a country. For instance, in maize-producing developing countries in Central America, South America

20 According to the Soil Association, the cost of GMM-maize seeds is double that of conventional seeds, accounting for, for instance, 34% of the per-acre operating costs of US farmers.

and Asia (excluding Argentina, Brazil and China), on average two-thirds to three-quarters of the total maize area receives some fertilizer (FAO and CIMMYT 1997).

Fertilizer consumption in Latin America grew at an annual rate of 2.6% per year during the period 2000-2010, although most of the growth must be attributed to the increment in Nitrogenous consumption. Fertilizer use intensity in Latin America during that period averaged 182 Kg/ha/year, growing at an annual rate close to 3%. Brazil and Mexico consume about 65% of the fertilizer used in Latin America, although consumption in Brazil increased during the 1990s while in Mexico it declined. The decline seemed to bottom out in the 2000s. It is estimated that from 2005 to 2010, fertilizer consumption in LA averaged 6558 tons, 38% of which was consumed by Brazil, 17% by Mexico and 12% by Argentina (Figure 13).

Figure 13. LA: Average use of Fertilizer and Pesticides (Tons). 2005-10



Source: FAOSTAT

Table 10 shows that in the year 2000, the average maize fertilization intensity in LAC was 94 Kg/ha of N, 40 Kg/ha of P and 20 Kg/ha of K, giving a total use of N,P,K of 155 Kg/ha, with Mexico and the Andean Region showing the highest intensity of the three nutrients, at almost 200 Kg/ha, while the TSC has the smallest use intensity (almost 90 Kg/ha). There is no annual data on the specific nutrient use on maize; however, aggregated figures, Table 11. 7, show an increasing trend in nutrient consumption in the past decade in LAC as a whole and for all the MAEZs, but in particular in the TSC and the STAR. Although the figures in Table 1.7 refer to nutrients applied to all crops and pastures, it is expected that the growth rates also apply to maize, particularly those of Nitrogen and Phosphorous, two nutrients widely applied to the crop.

Nutrient consumption can rise as the result of an increase in maize acreage and/or an increase in use per hectare. The growth rates of both maize acreage and maize yield over the past decade, presented in a previous section, support the hypotheses that fertilizer use intensity has had a stronger effect on fertilizer consumption than that of maize acreage.

b) Pesticides

As in the case of all non-specific inputs, the data on pesticides refer to that used in all agricultural activities. The total amount of pesticides consumed during the period 2000-2010 was around 107 tons/year, mostly consumed by Mexico (42%) and Colombia (23%), with growth rates of 2.4%, 0.6% and 3.6%, respectively.

Table 12 shows the average annual intensity use of pesticides (herbicides, fungicides and bactericides, and insecticides) during the period 2002-2010. Although LAC presents intensification in pesticide use intensity in aggregate terms, especially in the case of insecticides, the trend has not been the same for all MAEZs. In particular, the use intensity of all pesticides in Central America decreased during the period, with insecticides showing the deeper fall. This last trend reflects the underlying wish of the Central American countries to reduce pesticide use intensity in order to adjust to international markets.

c) Water use

Irrigated maize cropping is not common in LAC. It is estimated that in 1999-2000 about 10% of total maize acreage was irrigated in LAC (Table 13). There are, however, countries with significant maize irrigated area, including Peru and Chile, which have made considerable investments in irrigation infrastructure. Other countries lag well behind in this regard, although Brazil and Colombia report considerable levels of maize irrigated area (around 20%). In 2010, the total area ready for irrigation in the region (i.e., 6.7 million hectares) represented only 0.02% of the total maize area harvest in that year (FAOSTAT).

d) Labor use

In general, labor intensity of maize is related to the variety used and the production system associated with it, even among small-scale farmers. Under such production schemes, family members usually make up the majority of the workforce in the different stages of production, with the workload being especially intense and important in the planting and harvesting stages (UNDP 2010). This is the case of most producers in Central America who grow maize for subsistence.

2.6 Factors associated with maize technology use

Maize yield gap

The yield gap is defined as the difference between farmers' current yield and what they could achieve if they adopted the available technology (yield potential) (Pingali 2001). The size of the gap is an indicator of the level of production system efficiency and its importance lies in the premise that the removal of factors that impede reaching potential yield productivity becomes a fundamental element in order to achieve economic efficiency (Sain *et al.* 2001). Table 1.4 shows the absolute and relative size of the gap estimated in the literature for different MAEZs. Although the figures suggest the existence of great opportunities to increase maize productivity in the region, it must be recognized that it is not an easy task, particularly in the case of the peasant and indigenous economies, where the influence of structural, social and cultural constraints is often greater than that of the efficiency paradigm (Sain and Calvo 2010).

The adoption and diffusion of new maize technologies depend on many factors related to both the characteristics of the new technology and the internal and external farmers' circumstances. In the case of the use of LA, these factors include poor access to improved seed due to an inefficient seed industry, limited extension provision (i.e., training and technical support), lack of "modernization" in seed production and optimization of breeding programs, as well as limited access to resources (land, water, labor, capital, input markets, machinery and information) (Shiferaw *et al.* 2011, FAO and CIMMYT 1997, WABS 2008, Mitchell, Keane *et al.* 2008).

Biotic and abiotic constraints to maize productivity growth

The size of the yield gap is an important indicator of the level of efficiency of the production system. The importance of this indicator lies in the fact that the removal of factors affecting its size becomes a fundamental element in the identification of research investments opportunities; this topic will be explored further in Part III. Table 14 shows that there are large yield gaps in all the MAEZs (ranging from 150% to a high of 450%) with the exception, perhaps, of the TSC. These yield gaps represent challenges and opportunities to maize production improvement in LAC.

Table 15 shows the results of a recent analysis of the main biotic and abiotic constraints for increasing maize production in LAC (Pingali 2001). The study ranked drought/moisture stress and soil fertility/erosion as the main abiotic constraints, with the annotation that the importance of constraints varies with the environment. Furthermore, the negative consequences of some of these abiotic constraints are likely to worsen as a result of the impact of GCC. The study also identifies some biotic constraints (diseases and insects) that affect maize production across LAC environments.

Factors affecting improved seed use

The reasons for the low use of commercial (first generation) maize seed are complex, but several possible explanations have been advanced in the literature. The most frequently cited reasons include improved varieties that are not appropriate to farmers' circumstances, inefficient extension services or insufficient/too expensive seed at the small farm level. This question warrants further research but in light of the fact that hybrids comprise 75% of the area under improved varieties, it seems clear that higher diffusion levels will only be achieved through further integration of the public and private sector components of the system.

Using data on 18 LAC countries and a Tobit model to explain the percentage of maize area cultivated with hybrid seed, Kosarek *et al.* 2001 found that the area planted with hybrid maize is highly sensitive to seed-to-grain price ratios and to policy factors such as government protection for maize production, measured by the nominal protection coefficient for maize (P_d/P_i), and the presence of plant varietal protection laws. A structural factor that was also found relevant was the percentage of total production marketed.

Furthermore, cultural factors have also been found associated with the use of improved seed, particularly in the case of small farming and Floury Maize (FM). Thus, according to Sain and Calvo (2009) the proportion of indigenous population in a given country has a strong influence on technology adoption in general, and of improved maize seed in particular, mainly due to deep cultural differences rooted in the different way of viewing the world, and the relationship with the earth (different worldview).

Other results shows that in LAC the greatest constraint to the diffusion of better germplasm to farmers has been the failure of seed industries to evolve to meet the needs of a wide variety of maize producers, many of them subsistence-oriented farmers. This is the case of hybrid seeds, whose low adoption in developing countries (especially in tropical areas) is due to insufficient understanding of farmer preferences. In general, the major bottlenecks in the seed industry are the lack of awareness of the availability and value of existing varieties, the high relative price of seed because of poor and uncompetitive grain prices, lack of credit and deficient provision of quality seed to farmers (i.e., pre-basic and basic seed used in the production of certified seed). (Langyintuo *et al.* 2010)

It is important to note that extension provision plays a key role by making promising technology options available to farmers or by linking them to new networks that may play important roles in facilitating their access to new technologies and services (Shiferaw *et al.* 2011). However, because of deep cuts in publicly funded extension services in many LAC countries, the private sector took over the provision of such services. In the majority of cases, though, this sector has proven to be incapable of replacing previous state services due to high transaction costs, dispersed clientele and low (or non-existent) profits. Clearly, there is a risk that private sector providers will serve only the better-off farmers and ignore those living in less favored areas (Kirimi *et al.* 2009). Nevertheless, the potential to increase maize production, even with existing technology, seems considerable. Therefore, provided that the appropriate socio-economic incentives are in place (e.g., combination of relevant technology with input delivery systems and market opportunities), it is still possible to reduce the gap between agro-ecologically attainable and actual yields through the use of new technologies (Bruinsma 2009).

Several factors have been mentioned in the literature to explain the predominance of a relatively low use of modern technology for maize production in LAC. The low use of CIMV has been linked to lack of seed availability, lack of knowledge of improved seed characteristics and inappropriate cooking and tasting characteristics of the new material. In the particular case of hybrid seed, the fact that the seed must be bought each planting season is other factor that must be added to the list.

Fertilizers are applied by almost all maize producers, in different doses. Farmers recognize that soils nutrients are exhausted and the soil is less productive, so there is a good crop yield response to fertilizer application, particularly nitrogen and phosphorous. The main limiting factors in this case are: i) the lack of knowledge about the appropriate doses and ii) financial restrictions. Lack of knowledge and financial constraints are also mentioned as factors influencing the low use of pesticides. In the case of herbicide, a crucial factor is the relative high endowment of family labor that makes it possible to perform all weed control manually.

Furthermore, a recent literature review of the factors affecting technology adoption in maize and beans in Central America (Sain 2011) found the following seven factors to be important in the farmer's decision to adopt a new technology:

i) *The farmer's lack of total or partial information about the technology, its features and/or advantages over the farmer's normal practice,*

ii) *The relatively high adoption cost of the technologies,*

iii) *The farmer's limited resources,*

iv) *Compatibility with the farming system,* i.e., *when the characteristics of the technology do not match the farmers' circumstances.*

v) *Land tenure and soil quality*

vi) *The lack of training, motivation and involvement of the different social actors at the local level.*

The first four factors point to a symptomatic dissociation or flaws in the process of technology generation, where important characteristics of the technologies generated and promoted fail to dovetail with the farmers' circumstances. The last two factors are particularly important for the adoption of soil conservation practices and other natural resources.

Besides these direct factors, government policy with respect to basic grain (including maize) production also played a key role in the level of technology use.

2.7 Economics of maize production

No systematic data on farm gate prices is currently available, so it is unclear to what extent higher retail prices in developing countries are being translated into higher farm gate prices. Moreover, the rising demand for agro-fuels worldwide will likely increase the demand for synthetic inputs, thus raising production costs for small and mid-sized farmers (UNDP 2010), which vary by country and among regions within a country. Evidently, this issue is both an important policy question and a longer-term research question (Headey and Fan 2010). For detailed information about production costs and margin benefits, see previous sections.

A key efficiency indicator of the entire grain production sector is the Unit Cost of Production (UCP), which represents the average cost of producing one unit (kg, ton, etc.) of grain. The UCP must be greater than the farm price for the production unit to be profitable; and the larger the UCP, the less competitive the productive unit, and vice versa. The UCP can be reduced by cutting the production cost per unit of land and/or by increasing maize yield (land productivity). The importance of the indicator also lies in the fact that maize grain is an important component of the diet of millions of producers/consumers across LAC but also is the main input (raw material) of the feed industry and, as such, a key determinant of the MVCS competitiveness.

Table 16 shows the maize unit (average) production cost for the different regions (countries). The numbers are useful as a reference only, since comparison is not possible due to differences in cost calculation methodologies and calculations dates. The amounts are consistent with the trade pattern, however. Countries (regions) with the lower average cost are those that are exporters.

3. Maize Inputs Services Provision and R&D

3.1 Maize seed supply industry in LA

Seed supply encompasses domestic seed production plus net seed imports (Seed imports less seed exports).

Domestic production of improved maize seed

From an institutional point of view, the maize seed production and distribution industry is a complex system with a large number of different institutions involved in the process. It encompasses a diversity of participating agents, such as small farmers, national and regional companies, international corporations, public national research institutions, international research institutions, national extension institutions, the agricultural banking system and national regulatory institutions (Jaffee and Srivastava 1993).

From an economic point of view, it is useful to break down the seed production and distribution process into three main stages: 1) the research and development (R&D) stage, 2) the commercial seed production and multiplication stage, and 3) the seed marketing and sales stage. Institutions may choose to focus on a particular type of scientific activity for economically rational reasons related to appropriability limits and the desire to free ride on spillins (Traxler and Pingali 1999, Maredia, Byerlee and Eicher 1994). Public sector activity, including investment choices and policy actions, can have a major influence on private sector incentives to participate in a given seed market (Sain, Wilson and Traxler 2001).

To better understand the economics of the seed production and distribution industry, it is necessary to briefly discuss two crucial characteristics of improved maize seed: rivalry[21] and excludability. The first characteristic refers to the degree to which the use of a good by one agent precludes its use by others, while the second refers to the degree to which the owner of a good can charge a fee for its use. Improved maize seed can be characterized as a non-rivalrous good embodied in a rivalrous good, the physical seed. The non-rivalry characteristic of the seed comes in its genetic component. When a farmer uses a bag of seed, he/she can exclude others from using the specific bag in question but not from using the germplasm characteristics embedded in the seed.[22] Non-rivalry is an important characteristic to understand the functioning of the maize seed industry. Contrary to what is normally the case with rivalrous goods, non-rivalrous ones need to be produced only once. This is because their production entails a very high fixed cost and zero marginal cost (Jones 1998). The production of the first seed of a new improved breed calls for a complex and costly research process, but once the first new seed is produced, subsequent units are produced at a very low per-unit cost. Note, however, that the only reason for a nonzero marginal cost is that the non-rivalrous good (the improved germplasm) is embodied in a rivalrous good (the physical seed input).

Under the R&D stage of the seed production and distribution stages outlined above, it took considerable time and research effort to develop the first indivisible saleable unit (bag or kg) of improved germplasm at a fixed cost R. Once the first unit has been developed, additional units can be produced in the subsequent stages (seed production, multiplication and marketing) at a constant return to scale process. In other words, the seed production and distribution industry is characterized by increasing returns to scale due to the high fixed cost structure. This structure leads to contestable markets that are characterized by monopolist or oligopolistic structures.[23] The empirical evidence collected from the country reports supports the hypothesis that an oligopolistic seed supply market structure predominates in the different LAC MAEZs (Table 17). The dominance of few firms is common to both the seed production sector and the seed import/export sector of the market. The Table also shows that the demand for improved seed

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21 Some authors use the term subtractability to refer to the rivalry characteristic of the seed (Morris and Smale 1997).

22 Morris and Smale 1997 categorize the seed as composed of “two things in one”: a consumable input and a source of germplasm.

23 ETC Group conservatively estimates that the top three seed companies in the world, i.e., Monsanto (US), DuPont (US) and Syngenta (Switzerland) control 65% of the proprietary maize seed market worldwide and, with Aventis and CropScience, are in the forefront of R&D of genetically modified maize. Clearly, the maize seed industry has seen growing horizontal concentration, accompanied by increasing vertical concentration between seed producers and agrochemical companies (Bruinsma 2003).

has grown at a faster pace than domestic production, with the gap being filled with seed imports. This is particularly true for the YDM.

Typically, OPVs are supplied in the subtropical zone by public seed agencies (subsidized) and private extension agents, who provide technical assistance to smallholder farmers (Hellin *et al.* 2007). In the tropical zone, on the other hand, the seed market is poorly developed, with farmers obtaining most of their seed from local markets and retailers (Romero 2007). Lastly, in Argentina, Chile and Uruguay (temperate zone) usage of hybrid and OPV seeds is intensive, with most being supplied by a well-developed private seed sector. Moreover, seed suppliers located in Chile and Argentina can provide certification of non-transgenic seed and GMO (Fundación Chile 2007).

Evidently, in many developing countries there is a need for an effective seed industry that can offer farmers sufficient varieties of seed when and where they are needed and adequate quantities of quality seed at prices that encourage optimal levels of seed use (Morris and Smale 1997).

Even though private sector breeding capacity is not distributed evenly throughout the developing world, maize seed divisions have grown and prospered and are still big business, in LA, where a large number of private seed companies are established and operating (Morris and Smale 1997).

Finally, CIMMYT, along with IITA and national partners, is developing various maize technologies and policy and institutional innovations to help raise maize productivity and enhance adaptation options for farmers (Shiferaw *et al.* 2011).

Conclusions on the improved seed market in LAC

Empirical evidence reviewed in this report supports the conclusions from a study carried out at the end of the 1990s (Morris and Lopez-Pereira 1999):

i. *The primary focus of maize breeding research has shifted to the private sector*.

ii. *Commercial maize seed production is now dominated by private companies.*

iii. *The maize seed industry (production/trade) has become increasingly concentrated.*

iv. *The total area planted to improved germplasm continues to expand, but the pattern of adoption of improved germplasm has been uneven across LAC regions/countries.*

v. *Use of hybrids has increased dramatically relative to use of improved OPVs.*

vi. *Use of GMM is extensive in the Southern Cone (temperate and subtropical), but is scanty in the rest of the MAEZ.*

3.2 Non-seed agro-input and services supply

The other major forces besides seed that shape longer-term location and extent of maize production include access to resources (land, labor, information and capital), markets, and technology (hybrid seed, fertilizer, etc.) as well as the combination of agro-ecological conditions and availability of irrigation, which makes commercially viable production possible (Shiferaw *et al.* 2011). For instance, maize is known to require between 2.5 and 8.9 ml/ha of water, depending on the dry or rainy season. Fortunately, most of the production worldwide is done with rainwater so the pressure on local aquifers is not so great. However, increasing demand for maize for feed is leading to expanded production on land that requires irrigation. In terms of water needs and usage, it is estimated that 900 liters of water are needed to produce one kilogram of maize, so irrigated crops can exert heavy pressure on aquifers (UNDP 2010). Given the high international prices, high technology irrigated maize with yields of more than 10 t/ha is being cultivated in Chile and Peru. The influence of these irrigated areas and high crop technology is reflected in the high average maize yield reported in Chile.

Fertilizer supply industry

Fertilizer production in LA increased at 1.4%/year over the period 2002-2010. Brazil and Mexico account for about three-fourths of all fertilizer production in the region, which represents about four percent of global fertilizer production. During the period mentioned, the region produced an average of 987,186 tons, 47% of which were nitrogenous, 28% phosphate and 25% potash. Potash and phosphate fertilizer production increased faster than that of N fertilizer during the past 10 years, at annual rates of 4.6% and 5%, respectively (Table 1.13).

Nutrients production in the region is not enough to satisfy the growing domestic consumption, and the gap is imported. Nutrients imports increased in the last 10 years at an annual average rate of 2.8%. Total nutrients imports averaged almost 722,000 tons per year, a far larger figure than the average of 127,000 tons that were exported annually, making Latin America a net fertilizer importing region.

3.3 Maize research and development system in LAC

Although there is plenty of empirical evidence attesting to the positive impact of investment in Agricultural R&D on agricultural productivity, there is less evidence on the specific impact on maize productivity, since it is very difficult to specifically assign this investment to it. However, it is a fact that if maize is important for a specific country, the impact of any change in R&D investment will be reflected in its aggregate agricultural productivity. Currently, R&D in LAC is conducted by a broad set of institutions that work at the local, national, regional and international levels (Table 18). Other organizations, particularly NGOs and associations of producers, presented an even lower level of participation in such a system. Among the most notable features of the current system, it is worth mentioning that national agricultural research institutions (NARIs) are still at the heart of the system. However, as far as their role and the environment under which they perform are concerned, their functions have moved toward their integration into a national innovation system that is interconnected with other regional and international systems (Alarcón 2001, Palmieri *et al.* 2009, Ardila 2009).

Furthermore, it is important to note that the importance of the role of universities, NGOs and private groups in the regional research system is growing, especially with regard to new technology. Much of the administrative and financial decision-making in the majority of countries is decentralized. Given that the research agenda is driven by the demand side, it is highly influenced by consumers' preferences. In addition, this research system is characterized by low development and considerable underinvestment in the generation of new technology or second-generation technology, including biotechnology, computer science and precision agriculture, among others.

Evidence indicates that in most LAC countries Agricultural R&D funding still comes mainly from the government (Table 1. 15). This financial and institutional over-reliance on the public sector results in budget fluctuations, subject in many cases to ups and downs in government policies, which undermine the effectiveness and efficiency of the research process. A small group of new or second-generation NARIs began to emerge in the region in the 1980s and 1990s, and these have been consolidated over the last 12 years. They have started to implement a set of new financing instruments, the most common of which include: 1) funding by farmers, 2) sales of services, 3) joint public-private ventures and 4) competitive funds.

Role of the public and private sector

Because of the greater location specificity of crop management research, it is more difficult to characterize the worldwide effort in crop management research for maize than the resources employed for maize research in general and, in particular, for germplasm development. Nonetheless, data on numbers of scientific staff doing public sector research in developing countries suggest that across the globe considerable resources are expended on crop management research on maize. According to the Agricultural Science and Technology Indicators (ASTI), in 2006 there were more than 33,000 researchers, most of whom worked for public and higher education institutions in Brazil (32%), Mexico (24%) and Argentina (24%).

Expenditure on Agricultural R&D in LA totaled USD 2,526.3 million, most of which (98%) was funded entirely by governments. Brazil, Mexico and Argentina were the countries that spent the most, accounting for 52%, 20% and 13% of the total, respectively. Institutional changes during the 1980s and 1990s were accompanied by modest increases in the levels of public investment in Agricultural RD&D in most LAC countries, although about 30% of them reported negative growth rates during the period 1991-2001 (Table 19), further deepening the regional gap in development capacity. Unfortunately, this upward trend was not sustained in the first decade of the new century; more than half (53%) of the countries sampled reported negative growth in public investment during the period 2000-2006.

Another indicator of public investment in R&D that is often used is the relationship between expenditure and Agricultural GDP. In 2006, LAC countries invested an average of 1.14% of their AGDP in R&D, while in 1996 the figure was 1.34%. This rate is below the average in developed countries and in other maize growing regions competing in international markets. Table 20 shows LAC countries grouped according to investment intensity in Agricultural R&D. All the Southern Cone countries (with the exception of Paraguay) belong to the group with the highest intensity level (i.e., above 1.2%/year), as does Mexico (NLA). The other LAC countries, with the exception of Costa Rica, Belize and Nicaragua, invest less than 0.75% of AGDP.

In general, cumulative investment in maize improvement research has been far greater for yellow maize because it is the dominant germplasm adapted to temperate environments in the developed world. Conversely, in maize research for developing countries, development and improvement of white-grained varieties and hybrids have been greater than in developed countries, where nearly all plant breeding research has focused on yellow maize. However, one institution that includes both white and yellow materials in its breeding programs, mostly for developing countries, is CIMMYT (FAO and CIMMYT 1997).

Overall, the national and international public sectors continue to be the leading source of technology supply and the responsible for the collection, characterization and preservation of genetic resources, as well as the sole source of research and technology supply for geographic areas that the private sector considers unprofitable. This is particularly true in subsistence maize production areas in South of Mexico, Central America and the Andean Zone.

Nevertheless, the evidence about the performance of the public sector in the seed production and distribution business shows that it has been unsatisfactory being among the first activities targeted for privatization in LA (Morris and Smale 1997). Additionally, considerable shrinkage in research and extension budgets in real terms has been observed at both the national and international levels. Interestingly, as public support for agriculture has declined, the participation of private companies in research has increased—in maize breeding, for example (Dixon and Guilliver 2001).

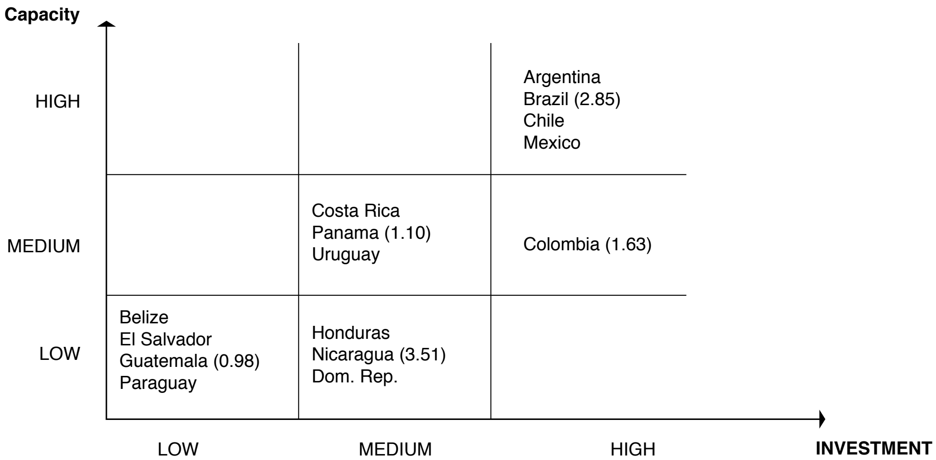
Currently, several breeding efforts aimed at higher yields/low inputs, disease resistance and drought/flood tolerance and increasing farm diversity of maize are being carried out by a wide range of private and public agents. The latter include international CGIAR centers, development NGOs, universities, IIAs, SNIAs, private seed companies, etc. (UNDP 2010). However, for better or for worse, there is a need to rethink maize R&D strategies, to come up with a new consensus on the role of the public and private sectors, and also to identify potential areas of collaboration between them in order to minimize duplication of efforts (UNDP 2010).

Knowledge leverage

Investment in R&D is only one side of the research capacity needed to generate agricultural technology, which is a function of a complex interaction of multiple factors, such as the number and quality of scientists, infrastructure development and the flow of information among stakeholders in the system, among others. Recently, two papers have analyzed various indicators and classified countries according to their scientific capacity (Avila and Evenson 2004, Traxler 2008). In Table 21 Latin-American countries are grouped according to their capacity to generate and/or take advantage of technology spillovers.

Figure 14 shows the relationship between the level of R&D investment and the ability to generate and adapt knowledge and productivity. In general, as countries increase their level of investment they also increase their capacity for R&D; as a result, the level of aggregate productivity of agriculture is higher. The results also show a strong relationship between capacity, investment and productivity growth in countries with temperate climates (Southern Cone and Mexico) leading the way with relatively high levels of investment, capacity and productivity growth.

Figure 14. Relationship among R&D investment, capacity and productivity growth.



Source: Sain and Ardila 2010. Note: Parentheses in each box show the group average of the TFP index.

Other policies and/or programs to support maize production

In 2011, stimulating agricultural production was one of the core aspects of public policy in the countries of the LAC region. For instance, a number of policy measures were adopted to regulate prices in food markets, directly or indirectly, in order to guarantee the public access to food. The creation of information systems on prices and regional production, the broadening and strengthening of social protection networks and increased support for family farming were some of the areas of joint cooperation on which the governments of South America, the Caribbean and Central America reached agreement (FAO 2011).

From a regional perspective, it can be observed that production policies of Caribbean countries in general are focused on replacing food imports with domestic production, while exporting some high quality products. These countries have historically been net importers of food (mostly wheat and maize), even if there is enough domestic production to meet consumption. In Central America, in contrast with the Caribbean, there is greater potential for expanding agriculture and increasing production (IICA 2011). Thus, countries' policies are mainly designed to increase agricultural production in order to progressively reduce the region's dependence on imports. These policies focus mainly on the most important foods in the diet, such as maize, beans and rice, and entail comprehensive plans and development programs.

In the case of South America, the challenges relate mostly to increasing exports of products that maintain high yields, and to promoting the cultivation of products that are mostly imported at present. Consequently, there is a wide variety of measures in the region, depending on the nature and approaches of each country. Policies are aimed primarily at stimulating food production, while consolidated items/products are promoted through protection and assistance policies. Agricultural financing is the main public policy instrument used to promote production, with development finance institutions heavily involved. In addition to such funding measures, countries have also introduced risk management measures, usually executed by crop insurers. Countries like Venezuela, Colombia and Ecuador set prices for foods such as maize, wheat and milk in order to guarantee producers a minimum income, prevent production levels from being affected by possible price variations and encourage an increase in the cultivated area and higher productivity (FAO 2011, Bellú and Pansini 2009).

In the past five years or so, concerns over the impact of GCC have been incorporated into the policy agenda of nearly all LAC countries, in particular in Central America, where the impact on maize production and on the livelihood of maize producers.

4. Maize Output Value Chains and Consumption

4.1 Maize consumption

Even though maize has been around for many centuries, international maize economy has undergone major changes over the past two decades in terms of production, utilization, trade as well as marketing structure. Although this crop was originally considered mainly as a food crop, it has gradually evolved to become a key ingredient in animal feed and biofuel production. These changes have been driven mostly by factors ranging from rapid advancements in seed and production technologies, changes in national policies and international trade, nearly uninterrupted expansion of feed usage across the globe, especially in the emerging economies of Asia and Latin America to more recently the sudden surge in demand for ethanol (Abdolreza, 2006).

In LAC maize is the second crop most produced and consumed, after sugar cane and before cassava, wheat, rice, and potatoes. Rough estimates based on production patterns and international trade flows suggest that in the period 2000-09, LAC countries consume on average 13% of the maize produced globally; concentrating in 2009 most of the domestic consumption in South America (63%) and Central America (34%). Moreover, by the same year the region maize domestic consumption (i.e. feed, food, other uses, processing and seed) overpass its production by 4% which was satisfied with imports. The countries which contributed the most to this deficit were Mexico, Colombia, Venezuela, Peru, Dominican Republic, Chile and Guatemala (Table 23).

Direct human consumption (Food)

Central America and NLA (Mexico) are the regions that have the highest maize consumption as food; consuming in 2009 about 67% of their total maize production. Even though in 2009 more than one quarter of the production in LAC was destined to food consumption (58% of which was consumed in Central America), on average 8% of the population were below minimum level of dietary energy consumption (CEPAL stats, 2010). But, while maize consumption continues to rise in the Latin America region, per capita consumption is leveling off or even declining in several countries, mainly due to the insufficient growth in production. In the period 2000-09 the annual average consumption per person in Central America, South America and the Caribbean was of 68 Kg, 29 Kg and 24 Kg, respectively. Being the Caribbean the region which average food consumption per person has increase the most in the last decade, going from 11 to 24 kg/year. Overall, the countries with the highest consumption per person per year were Mexico (120 Kg), Guatemala (86 Kg), Honduras (79 Kg) and El Salvador (73 Kg) (FAOSTAT, 2012). Being Mexico the country in the world with the highest maize consumption as food, which in 2009 represented 12% of total world maize consumed, denoting 65% of its total maize production. Likewise, Honduras, Panama, Nicaragua and Guatemala as a whole uses on average 85% of their production on food. Also, domestic demands for maize in Argentina, Brazil and Paraguay are satisfied by local production, exporting the surplus.

Indirect human consumption (Feed)

The country in the region that uses maize mostly for feed is Brazil, which consumes 68% of its total production for that purpose. In general, YDM is preferred for livestock feeding in most parts of South America and the Caribbean, because is rich in energy and gives poultry meat, animal fat and egg yolk the yellow color appreciated by consumers in many countries. It is evidently that diets in Latin America are changing as incomes rise; being forecast by 2030, an increase in per capita consumption of livestock products by a further 44% and a rise in demand for maize of 100% by 2050 (Bruinsma, 2003; Shiferaw et al., 2011; Delgado, 2003).

Maize use as biofuel

As shown before there are no relevant amounts of maize used as biofuel in LAC.

Factors behind consumption trends

Previous studies on the possible causes of the explosive growth of cereal demand in particular of maize, identified three determining factors: population growth, income per capita and urbanization growth (Byerlee 1986, Huddleston 1984). As income increases, consumption of animal protein increases more than proportionally and therefore the demand for maize as feed. In addition, there is a substitution effect in human consumption by wheat products (e.g. flour and bread). Other important structural factor affecting the level of maize consumption as food, and that is not explicitly mentioned in the literature, is the cultural factor that is usually embedded in the demand function as *"tastes"*.

4.2 Maize output value chains

Given the nature of the production and markets of maize in the world, the supply chain of maize may vary; but there are common aspects depicted in figure 5. Depending on how strong the economy is and how well set up are the market structures of import/export, the links in the chain would have a varying strength. There are hundreds of products and co-products derived from maize, thus the chain can still be extended further. Given that maize production is so broadly supplied and distribution and trade hinges on different routes; transportation systems and port facilities, are critical in the competition for markets within and outside national boundaries (UNDP, 2010).

Characterization of maize producers varies among regions and countries; but in general it will depend on the importance of maize in peoples' diet and on their access to resources (i.e. market oriented or home-consumption). In countries where maize is a staple food, such as in Central America and in tropical zones of LA, mostly smallholder farmers using rudimentary technologies with limited access to markets and capital, can be found (Secretaría de Economía Mexico, 2012). For instance, in the tropical zones approximately more than a million families harvest white maize, who are mostly small, dispersed and unorganized producers (Saavedra, Viana, Munguia, 2007). Conversely, big and more industrialized producers (i.e. high use of technology and investments) are common in countries where maize is not a staple food; this is the case of Brazil, Chile, and Argentina. For instance, in Chile about 71% of maize producers cultivate between one to 20 hectares and, in Argentina, more than 75% of maize producers harvest more than 30 hectares (Fundación Chile, 2007).

In many cases stages at which maize has been processed and transported to become animal feed, foodstuffs or industrial products are controlled by private firms and in some cases concentrated in only few actors (UNDP, 2010). This is the case of Bunge Group (Argentina) which operates one of the world's largest flour milling operations. In the case of LA in general, commercial and industrial processors dominate the output value chain; mainly in the oil and feed industry (Fundación Chile, 2007). Being Archer Daniels Midland-ADM (U.S.) the largest agro-fuels producer and ZenNoh (Japan) the third largest soybean and oil exporter (UNDP, 2010). In the sub-tropical region of LA commercial and traditional processors coexist, having most of countries in this zone the Mexican structure, i.e. even though small and big producers coexists, the latter has a leading role. For instance in the case of flour production, in Mexico two private processors, MASECA (72%) and MINSA (24%) are the biggest suppliers in the country; having smaller shares HARIMASA (2%) and GARGILL (1%) (Secretaría de Economía, 2012).

The great majority of the world trade in all of the major grains is currently carried out by private operators, having them very large market share especially in the case of the maize sector. For instance, three companies account for 80% of U.S. maize exports and more than half of the world's maize market trade, being them in order of importance Cargill, Archer Daniels Midland (ADM) and ZenNoh. Cargill (U.S) accounts for 20% share of U.S. wheat exports, and a quarter of Argentina's exports of wheat, maize and soybeans. Additionally, besides these companies, four other private companies, Bunge Group, Louis Dreyfus, Nidera and Noble, virtually manage all grains trade in the world (World Bank, 2009). Bunge Group (Argentina) annually trades some 30 million tons of grains and it is responsible for about a fifth of world trade in oilseeds and oils, followed by Louis Dreyfus (France) which accounts for some 15% of world market trade in grains and oilseeds. Finally, Nidera (The Netherlands) which major trading operations takes place in Latin America, trades annually some 18 million tons of soybeans, wheat, maize, rice and other grains (UNDP, 2010).

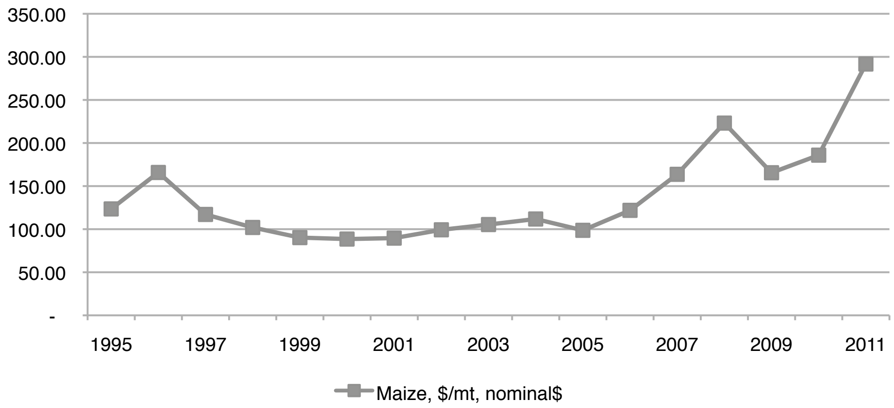
Although LA does not produce significant amounts of bio-alcohol from maize, it does play an important role in the biofuel market through the production of ethanol from sugar cane in Brazil and of biodiesel from soybean oil in Argentina, becoming this country the sixth producer in the world of vegetable oil (IICA 2010). As a matter of fact, Brazil and Argentina play an important role as biofuel producers in the world, taking the former the lead from the U.S. in 2006. While at the present, the issue of the use of food as a renewable source of energy is not a point for maize use in LA, it is an important concern for public policy and research in the near future as oil becomes more and more scarce.

4.3 Maize trade

Main marketing systems/channels and market characteristics

Maize price inflation has been driven because of fundamental changes in global supply and demand, which include: high energy prices, climate change, and recently rising biofuel production and demand (World Bank, 2008d). In terms of short-run studies, the International Monetary Fund (IMF) estimates that biofuel demand has accounted for 70% of the increase in maize prices so far (Lipsky, 2008). Shifting global food supply and demand has had predictable price effects that have been further complicated by the rising cost of non-renewable resources (World Bank. 2008d). Moreover, the unwillingness of U.S. and European Union governments to move away from biofuel subsidies will probably keep agricultural markets significant tighter for years to come. So for the moment at least, biofuels are not substantially lessening the impact that rising oil prices are having on agricultural production and trade (Headey & Fan, 2010). The combination of factors driving food prices up has led to a growing consensus that food price inflation is more a structural phenomenon than a cyclical one.

Figure 15. World. International maize prices (US/MT). 1995-2011



Source: World Bank (citing: US Department of Agriculture; World Bank)

The data presented in the previous section indicate the existence of an expanding maize demand which represents an opportunity for grain-producing countries. The differentiation between white and yellow maize is also reflected in the prices. Taking as reference prices for white and yellow maize (grade 2) in the Kansas market, it is observed that in the last thirty years the price of White maize is superior to the yellow by a variable percentage that has reached maximum levels higher than 40%. However in the last 10 to 12 years the tendency of this difference or prize for quality has been declining, reaching an average of 18% in the period 1990-96 (FAO-CIMMYT 1997)

In LAC, food price inflation has increased across the entire Region, affecting both net food exporters and net food importers. Between 2006 and 2008 the international food price index nearly doubled in nominal terms. Among cereals, wheat and maize prices are the ones that have grown the most in the past year e.g from 2006 to 2008 the international price of maize increased 122%. One implication is that even some countries that are net food exporters may see their food trade balance decline, depending on the composition of their import and export baskets (World Bank. 2008d). Thus, rising food prices are a growing policy challenge for both middle-income and low-income countries in the region, taking a significant number of countries actions to better position their exports.

While the LAC region as a whole is a net food exporter, food price inflation still has a detrimental impact on the income, nutrition, and health of poor consumers**.** There are signs of concern regarding the extent to which the prices of white maize (used in the production of tortillas) are affecting food security in Central America and Mexico. The upswing in white maize prices has continued to propel food inflation indexes in Central America and Mexico. For instance, between June 2010 and June 2011, wholesale prices in Mexico for white maize and tortillas increased 65% and 25% respectively. Similarly, in a mere 12 months, wholesale white maize prices rose 56% in Guatemala and 112% in El Salvador (FAO, 2011). Additionally, the increase in food prices and differences in trade patterns can interact to create negative consequences even for food exporting countries.

Pricing structure

The pricing structure along the MVCS gives rise to a set of indicators related to the efficiency of the markets linking the different sectors along the value chain. Table 22 shows the values for the selected indicators. In the light of the scanty available information it is worth to note the declining trend of the marketing margins in the different regions declining that would be pointing to an increase in the efficiency of the grain marketing system. Regarding the improved seed prices, the evidence supports the hypothesis that the trend of low relative prices will prevail in all the regions. For LAC as a whole it takes approximately between 20 and 30 Kg grain per kg of hybrid seed from the public sector[24], so its adoption (change of landrace, or OPV) is highly profitable and casts doubt on the hypothesis of low profitability as a fundamental cause of its lack of adoption.

The same considerations apply to the price of nitrogen for whose purchase the farmer spends approximately 10 Kg of grain per Kg of nitrogen, when in general; the grain production response to this nutrient is much higher than this level. The case of pesticides is not clear since its impact on maize yield depends on the level of incidence of pests which is a random event. However given the high presence of pests harmful to maize across environments, the likelihood that the expected benefit of the application of optimal levels of pesticides be higher than the expected costs is high. However in this consideration usually the damage to the environment by pollution with pesticides is not considered. Although there is a tendency for the elaboration of pesticides more environmentally friendly (the glyphosate molecule is rapidly degraded), there is also a strong trend supporting the replacement by non-polluting agro-ecological methods for pest control (Good Practices).

Besides the numbers there is the need for in depth social and economic research on the influence of the markets structure in the price formation mechanisms as well as on how the final value is distributed along the chain.

Regional and international trade

The geographical concentration of major grain supplies against the geographical dispersion of demand suggests that trade will continue to be important in fulfilling grain requirements, particularly for wheat and maize (FAO yearbook; 2012). Even though global trade in maize has increased significantly over the past decade, from 82 million tons to around 107 million tons, with the fastest expansion taking place in more recent years; international trade accounts for only 12% of world maize production, which represents over one-third of total cereal

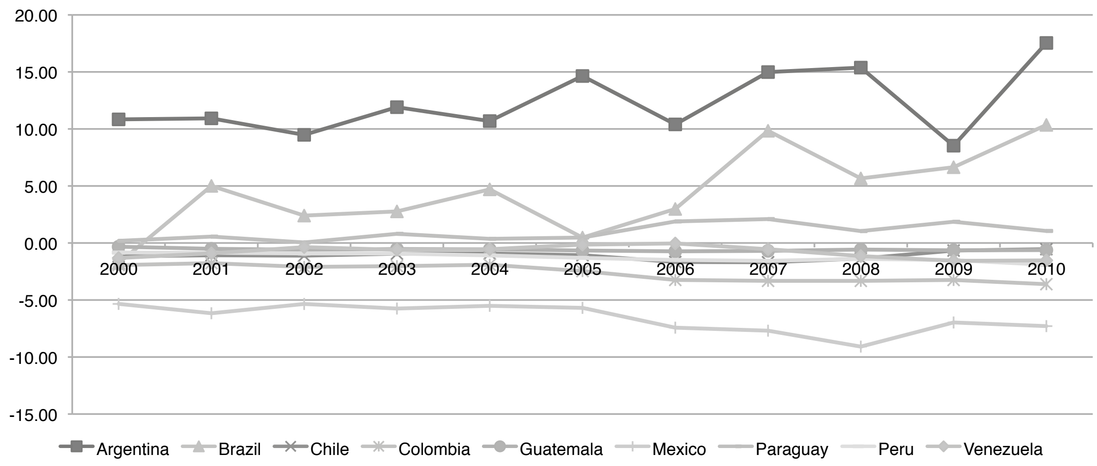
24 El precio de los híbridos privados son considerablemente mas elevados, aun así, el cambio de una OPV a este material resulta rentable desde el punto de vista del aumento en rendimientos

trade (FAO, 2012; FAOSTAT, 2012). Nevertheless, the pattern of the world coarse grains economy, 74% of its aggregate output is maize, has undergone drastic change in the location of consumption, increasingly shifting the major export markets to the developing countries. This is the case of LAC, region that has gone from being a net importer of maize, with a deficit of 1.3 million tons in 2009-2010, to be a net exporter, with a surplus of 3.7 million tons in 2010-2011 (FAO, et al., 2011).

Table 24 shows the main maize trade indicators across LAC MAEZs. In contrast to wheat and soybeans, maize exports are heavily dominated by the U.S. (two-thirds of the global share), making the maize market very sensitive to events in the U.S. (Headey & Fan, 2010). According with the study "Food security panorama in LAC" in 2011 the exports from the US accounted for 52% of the annual maize traded volumes, meanwhile Argentina accounted for 15% and Brazil for 12%. Clearly the U.S. heavily dominates global exports of maize and thus U.S. grain prices are typically quoted as international prices. Given this fact, events/shocks in the U.S. economy or in U.S.-dominated grain markets are some of the factors that contributed to the recent food crisis in LA.

In 2010 only South America was a net exporter with a balance of 21 million of tons (FAOSTAT, 2012). Unsurprisingly, the regions that are most dependent on the U.S. as a source of food imports are Central America and the Caribbean (net imported regions) and some of the more northern countries of South America; exporting in 2010 the U.S. 900 mil tons of white maize (i.e. 90% of its total white maize export) to Mexico, Honduras, Colombia, El Salvador and Costa Rica. Even though a few other countries and regions are fairly dependent on the U.S. for food imports, there are strong mitigating circumstances in most cases. In 2012 among the top 10 U.S. export markets for maize in LA were: Mexico, Venezuela, Cuba, Guatemala and Costa Rica, in that order of importance (USDA, 2012).

Figure 16. LA: Historic trade balance (X-I). 2000-10



Source: FAOSTATS data

During 2010, maize imports in LA were the highest in Mexico, Colombia, Peru and Venezuela, ranging from 1.5 to 7.8 million tons. Among the members of the MERCOSUR, Brazil was the country that imported the most, with more than 460 thousand tons in the same year (FAOSTAT, 2012). Total imports by countries in LAC are forecast to increase slightly to 27 million tons in 2011/12, being most of the anticipated increase from the region's largest buyer, Mexico, where imports are forecast to rebound to the 2009/10 peak of 11.3 million tons, amid a small decline in production and rising domestic maize prices. Higher imports are also forecast for Chile and Colombia, largely to meet increasing domestic feed demand (FAO, 2011).

Brazil, Argentina and Paraguay have become major net maize exporters in the region, given their high yields, large production area and slow domestic expansion demand. During the period 2008-11 according with USDA data, Argentina and Brazil exported on average 14 and 10 million tons of maize respectively, making them the world's second and third largest maize exporters. In 2009 Argentina exported an average of 66% of its annual production; nevertheless this country has seen its share of the international maize market decrease from approximately 13% in 1997 to almost 8% in 2009. Although U.S. exports are expected to lowered for 2011/12, global trade is boosted nearly 2 million tons on strong shipments from South America as exports from the LA region accelerate with high prices, mainly from Argentina (500,000 tons), Brazil (1 million) and Paraguay (400,000) (UNDP, 2010; FAS/USDA 2012). Brazilian exports are on track to achieve a record of 12 million tons during the 2010/11 cycle, thus contributing to an extraordinary maize trade surplus in the region (FAO, 2011).

In general, most of the maize exports are yellow; being the size of white maize international trade limited, since most of it is consumed domestically in producing countries (e.g. Mexico and Guatemala). White maize world trade is estimated to range between 1.5 and 2.0 million tons in normal years, a volume which does not seem to have changed significantly over the past 10-15 years. Over time, developing countries have become the principal importers of white maize, coming mostly from the U.S. which exports of white maize account for only slightly more than 2% of its total maize exports (USDA, 2012). Almost all shipments (90%) of white maize from the U.S. were directed towards Mexico (58%), Honduras (9%), Colombia (9%), El Salvador (8%) and Costa Rica (6%). Representing Honduras and El Salvador white maize imports from the U.S. 26% and 18% of their total quantity of maize imported. Clearly international trade flows are highly regionalized (FAO & CIMMYT, 1997).

Trade agreements and Policies

In general, commodity exporters continue to benefit from very favorable terms of trade, and countries with strong links to financial markets (Brazil, Chile, Colombia, Peru, and Uruguay) will also benefit from easy external financing conditions. Meanwhile, countries with strong trade links to Brazil (Argentina, Bolivia, Paraguay, and Uruguay) will continue to benefit from its robust growth (IMF, 2011). Some of the major grain policies developments in the region in 2010/11 we have (FAO, 2011):

- Argentina (2010): Export quota- Initial export quota of 2011 maize crop set at 5 million tons
- Mexico (2010): Set up strategic reserve i.e. purchase of maize authorized in futures market to alleviate the impact of maize price increases on tortilla
- Peru (2011): Import tariff removed on some food products including maize and rice, in order to stabilize food prices
- Venezuela (2011): State market intervention, i.e. producer support price increased 30% for maize.

Among regional trade agreements[25] in LA we have: Andean Community (CAN), Caribbean Community and Common Market (CARICOM), Central American Common Market (CACM), Latin American Integration Association (LAIA), Southern Common Market (MERCOSUR), CAFTA (Central America Free Trade Agreement), Global System of Trade Preferences among Developing Countries (GSTP), Protocol on Trade Negotiations (PTN) and North American Free Trade Agreement (NAFTA) (WTO, 2012).

25 Regional Trade Agreements (RTA) are reciprocal trade agreements between two or more partners (WTO)

Tables for Part I.

Table 5. Importance of maize in crop production

Region	Countries	Main crops	% of total crops production		Increment (%) in:	
			2000-05	2006-11	Importance	Volume
Southern Cone temperate (3)	Argentina, Chile and Uruguay	Soybeans	33	40	19.3	49.3
		Sugar cane	23	22	-0.3	24.8
		Maize	**12.7**	**12.4**	**-2.1**	**22.4**
		Wheat	12	9	-23.3	-4
		Vegetables Primary	4	3	-21.1	-1.3
		Others	15	13		
Southern cone subtropical (2)	Brazil, Paraguay	Sugar cane	69	75	8.7	67.4
		Soybeans	9	8	-8.8	40.5
		Maize	**7.2**	**6.4**	**-10.7**	**37.5**
		Cassava	5	3	-32.4	4.1
		Oranges	3	2	-33.4	2.6
		Others	7	6		
Andean Subtropical (5)	Bolivia, Colombia, Ecuador, Peru, Venezuela	Sugar cane	56	52	-6.6	6.3
		Bananas	9	9	3.7	10.1
		Potatoes	7	7	10.2	10.8
		Rice, paddy	6	7	7.4	3
		Maize	**4.9**	**5.6**	**13.9**	**5.9**
		Others	17	19		
Central America (7)	Belize, Costa Rica, Guatemala, El Salvador, Honduras, Nicaragua, Panama	Sugar cane	70	67	-4.1	15
		Bananas	8	9	2.8	23.3
		Oil palm fruit	5	8	46.3	75
		Maize	**5.2**	**5.3**	**2.4**	**22.8**
		Vegetables Primary	4	5	12.1	34.5
		Others	6	6		
North America (1)	Mexico	Sugar cane	50	49	-1.3	-31.8
		Maize	**20.7**	**21.1**	**2.2**	**-5.2**
		Vegetables Primary	11	12	2.9	-21.9
		Sorghum	6	6	-4.3	23.6
		Oranges	4	4	-1.7	-6
		Others	8	8		
Caribbean		Sugar cane	73	66	-9.3	0.7
		Rice, paddy	6	8	26	11.9
		Vegetables Primary	7	7	3.9	18.8
		Oil palm fruit	4	7	64.2	15.9
		Bananas	3	3	25	22.8
		Others	8	9		

Source: Estimations based on FAOSTATS

Table 6. Importance of maize production in the economy

Key Indicator	Temperate Southern Cone		Subtropical Southern Cone		Subtropical Andean Region		Tropical Central America		Subtropical Northern ALC		LAC	
	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%
AGDP	7,311	3.1	22,860	3.7	4,689	2.6	6,764	2.5	1,070	3	7,786	3.0
AGDP/GDP	0	0.0	0	0.0	0	0.0	0	0.0	0	0	0	0.0
Maize Production Value (MPV)	613,656	7.8	3,072,738	14.7	373,819	11.2	134,870	11.8	376,915	7	647,848	12.4
MPV/AGDP	6	6.9	**16**	**19.3**	11	6.6	7.6	10.1	**37**	**4**	**11.0**	**8.9**

Source: Estimations based on FAOSTATS

Table 7. Maize production growth anatomy (Average 2000 – 2010)

Key Indicator	Temperate Southern Cone		Subtropical Southern Cone		Subtropical Andean Region		Tropical Central America		Northern ALC		LAC	
	t	Growth rate	Value	Growth rate	Value	Growth rate	Value	Growth rate	Value	Growth rate	Value	Growth rate
Production (t/year)	6,276,252	**2.9**	23,255,605	**5.0**	1,293,439	**4.0**	512,115	**3.4**	21,079,100	**2**	**5,639,971**	**3.8**
Area (Ha)	958,587	0.7	6,647,808	1.8	485,331	1.4	285,209	1.3	7,202,643	-1	1,618,120	0.9
Yield (t/Ha)	7.0	1.9	3.0	3.5	3	2.5	1.8	2.3	3	3	3.1	2.3
Growth anatomy		**3**		**1.9**		**1.8**		**1.8**		**-4**		**2.5**

Source: Estimations based on FAOSTATS

Table 8. Predominant production systems across MAEZ in LAC

Key Indicator	Temperate Southern Cone		Subtropical Southern Cone		Subtropical Andean Region		Tropical Central America		Subtropical Northern ALC		LAC	
	Value	%	Value	%	Value	%	Value	%	Value	%	Value	%
Average production 2000 -2010 (000 t)	6,276	12	23,256	44	1,293	2	512	1	21,079	40	52,417	100
Main producing countries	ARG	92	BRA	97	ALL FIVE	100	GU;HON; ES	83	MXCO	100		
Production share of YDM (%)	>95	-	nd	-	45	-	12	-	8	-	-	-
Production share of WDM/FM (%)	0 5	-	nd	-	55	-	87	-	92	-	-	-
First season production share	Summer	-	80	-	Variable all year	-	75	-	70	-	-	-
Second season production share	Summer	-	20	-	Variable all year	-	25[1/]	-	30	-	-	-

Notes: 1/ In TCA the second season encompasses a small amount sown in a third season (apante)

Source: Estimated with information from FAOSTATs, Representative Country Reports and IICA Proyecto Red Sicta. 2007.

Table 9. Improved maize seed use across LAC

	Hybrid				OPV				Commercial Improved seed			
	1990	1996	1999	2011-12	1990	1996	1999	2011-12	1990	1996	1999	2011-12
TSC	**55**	**85**	**80**		**23**	**2**	**20**		**78**	**87**	**100**	
Argentina	70	84.9	80		30	2.4	20		100	87	100	**100**
Chile	85				10				95			
Uruguay	10				30				40			
STSC	**39**	**42**	**43**		**6**	**4**	**18**		**45**	**46**	**61**	
Brazil	63	49.3	59		7	7.3	10		70	57	69	
Paraguay	15	33.9	27		5	1.7	25		20	36	52	
CAC	**22**	**26**	**16**		**10**	**3**	**18**		**32**	**29**	**34**	
Costa Rica	5	41.4	16.25		10	1.5	17.75		15	43	34	
El Salvador	65	47.6	34		0	0.5	46		65	48	80	
Guatemala	36	15.4	0		24	1.7	1		60	17		**36**
Honduras	5	8.6	29		10	7.2	9		15	16	38	
Nicaragua	9	1.3			8	5.5			17	7		
Panama	14	42.3	2		6	0.7	15		20	43	17	
STAR	**27**	**38**	**45**		**18**	**6**	**26**		**46**	**35**	**71**	
Bolivia	3		37		21		25		24	0	62	
Colombia	8	19.8	36		5	6.6	23		13	26	59	
Ecuador	10	21.8	52		39	5.0	37		49	27	89	
Peru	24	13.0	13		18	11.7	37		42	25	50	**50**
Venezuela	91	99.0	88		9	0.0	7		100	99	95	
SNLA	**15**	**19**	**15**		**11**	**1**	**7**		**26**	**20**	**22**	
México	15	19.2	15	**19**	11	1.1	7	**11**	26	20	22	**30***

Note: (*) There is a significant difference between the southern states which encompasses about 50% of total maize area where only 10% is sown to improved seed and the northern states where approximately 90% uses improved seed mainly hybrid seed.

Source: For years 1990, 96, 99: CIMMYT, Maize Facts and Trends, several issues and Morris and Lopez Pereira 1999; other years from National Reports.

Table 10 . Maize fertilizer intensity and maize nutrients consumption across LAC 1999 - 2000

	Fertilized maize acreage (% of maize area)	Nitrogen applied to maize (kg/ ha)	Phosphorus applied to maize (kg/ ha)	Potassium applied to maize (kg/ ha)	Total NPK applied to maize (Kg/ha)
TSC	**50**	**51**	**37**	**0**	**88**
Argentina	50	51	37	0	
Chile					
Uruguay					
STSC	**48**	**27**	**56**	**19**	**102**
Brazil	61	35	65	37	
Paraguay	35	18	46	0	
CAC	**52**	**92**	**24**	**11**	**127**
El Salvador	80	n.a.	n.a.	n.a.	
Guatemala	53	86	26	7	
Haiti	n.a.	115	0	0	
Honduras	53	105	43	22	
Nicaragua	21	61	27	14	
STAR	**64**	**120**	**44**	**35**	**199**
Bolivia	40	40	40	0	
Colombia	59	105	48	70	
Ecuador	79	81	3	6	
Peru	56	170	60	33	
Venezuela	88	203	68	68	
SNLA	**43**	**157**	**61**	**3**	**221**
México	43	157	61	3	

Source. CIMMYT. Maize Facts and Trends 1999 – 2000

Table 11. Nutrients consumption and trends across LAC 2002 - 2010

Key Indicator	Temperate Southern Cone		Subtropical Southern Cone		Subtropical Andean Region		Tropical Central America		Subtropical Northern ALC		LAC	
	Value	Growth	Value	Growth	Value	Growth	Value	Growth	Value	Growth	Value	Growth
Total nutrients consumption	718,172	4	4,925,876	3	380,962	5.6	105,210	3.1	1,619,890	0.2	953,516	2.6
N consumption	388,780	5	1,281,372	5	217,870	5.4	62,016	3.9	1,076,034	3.6	370,212	4.4
P2O5 Consumption	252,042	2	1,731,431	2	75,676	8.8	19,375	0.1	324,471	-14.3	297,034	1.1
K2O Consumption	77,350	2	1,913,073	2	87,415	3.5	23,818	3.6	219,385	2.9	286,269	1.7
Use Intensity (NPK) (Kg/ha)	216	5	117	3	186	4.4	203	2.5	65	0.2	182	3.8
Total nutrients production (t)	649,325	4	3,208,198	1	479,941	4.4	0	0	438,260	5.4	984,165	2.7
Total nutrients imports	518,625	4	3,591,219	3	288,590	3.2	108,678	3.2	438,260	5.4	721,670	2.8
Total nutrients exports	238,846	5	293,358	2	107,124	23.3	5,203	4.6	157,756	38	127,116	4.4

Table 12. Pesticides consumption and trends across LAC 2002 - 2010

Key Indicator	Temperate Southern Cone		Subtropical Southern Cone		Subtropical Andean Region		Tropical Central America		Subtropical Northern ALC		LAC	
	Value	Growth	Value	Growth	Value	Growth	Value	Growth	Value	Growth	Value	Growth
Use intensity Fung_Bact	2	10	na	na	5	-0.2	3	-3.2	1.3	16.8	3	0.6
Use intensity Herbicides	5	13	na	na	7	0.0	6	-0.8	1.4	16.3	6	2.4
Use intensity insectides	2	30	na	na	3	2.7	2	-6.2	1.0	13.6	2	3.6

Table 13. Irrigated maize acreage 1999 - 2000

	Irrigated maize area (%)
TSC	**3**
Argentina	3
Chile	
Uruguay	
STSC	**10**
Brazil	19
Paraguay	0
CAC	**6**
El Salvador	0
Guatemala	2
Haiti	n.a.
Honduras	15
Nicaragua	<1
STAR	**19**
Bolivia	10
Colombia	22
Ecuador	<1
Peru	**41**
Venezuela	2
SNLA	**20**
México	20
LAC (average)	**10**

Source: CIMMYT Maize Facts and Trends. 1999 - 2000

Table 14. Yield potential relative to current yield (t/ha) in Latin American and the Caribbean (figures in parentheses are current yields)

	Ecology			
Source	Highland / Transitional (NLA;GU;STAR)	Midaltitude / Sub-tropical (NLA; STSC; STAR)	Tropical lowland (NLA CAC)	Temperate (TSC)
Pingali P:L: (Ed) 2001	Potential = 6.0 Actual = (1.1) Yield Gap = 4.9 (445%)	Potential = 10.0 Actual = 4.0 Yield Gap = 6.0 150%)	Potential = 5.0 Actual = 1.5 Yield Gap = 3.5 (233%)	Potential = 12 Actual = 7 Yield Gap = 5 (70%)
Sain et al.			Potential = 4.9 Actual = 1.0 Yield Gap = 3.9 (397%)	

Table 15. Dominant constraints to bridging the yield gap between potential and actual yields in tropical/subtropical environments of Latin America

Type	Constraint	Description/coverage
Abiotic	*Drought/moisture stress*	This constraint applies to all environments. It is very likely that the constraint will aggravate under the impact of the GCC.
	Low Soil Fertility	Most of the maize in LAC is sown in tropical/subtropical soils characterized by low soil fertility particularly low nitrogen,
	High Soil Acidity	Acidic soils cover approximately 43% of the world's tropical land area. About 64% of tropical South America, particularly in Brazil (STSC) and Peru (STAR), are acidic soils.
	Soil Erosión	Hillside maize production systems, in the tropical lowlands and in the mid-altitude tropical and subtropical environments, resulted in high rates of soil erosion in many areas. The constraint will aggravate with the impact of the GCC.
	Lack of Improved Germplasm for the Tropical Highlands	The lack of improved germplasm for tropical Highland Maize can be attributed to many factors but important ones are the significant breeding challenges due to the myriad of highland environments and the resulting germplasm x environment (G x E) interactions, and the social and cultural factors involved in the process.
Biotic - Diseases	*Turcicum blight.*	This disease, is most serious in relatively cool and humid regions, specifically in the tropical and subtropical mid altitude areas where maize is grown as a winter crop.
	Com stunt.	This endemic disease affects maize production in all environments across LAC..
Biotic – Insects	*Stem borers.*	Throughout the world, stem borers have been the most damaging group of insect pests in maize cultivation.
	Postharvest pests.	These pests are particularly damaging in the humid storage conditions often found in tropical and subtropical countries.

Source: Pingali P.L. (ed.) 2001.

Table 16. Costs and profitability indicators of maize production across LAC

Key Indicator	MAEZ					
	TSC (Argentina)	STSC (Brazil)	STAR (Peru)	TCA (Guatemala)	SNLA (Mexico)	LAC
Cost per hectare (us$/ha)	**1152**		**2221**			
Yield (t/ha)	**7.6**		**5.9**			
Unit Cost (us$/t)	**150**		**330**			
Farm price	**200**		**330**			
Unit quasi rent	50		0			

Table 17. Maize inputs market structure across LAC

Market	Key Indicator	Temperate Southern Cone (Argentina)		Subtropical Southern Cone (Brazil)		Subtropical Andean Region (Peru)		Tropical Central America (Guatemala)		Subtropical Northern ALC (Mexico)	
		Value		Value		Value		Value		Value	
Maize seed production	ICR2	**74**				**66**	**-**	**40**	**-**		
	ICR4	**96**					**-**	**54**	**-**		
Maize seed trade	ICR2					**41**		**98**	**MX,**		
	ICR4					**70**		**-**			
Fertilizer production	ICR2							**-**			
	ICR4							**-**			
Fertilizer trade	ICR2					**71**		**62**			
	ICR4										
Pesticides trade	ICR2							**43**			
	ICR4										

Table 18. LAC: Institutional structure of the Agricultural R&D System

Level	**Institutions**	**Products provided**
National/ Local	National Agricultural Research Institutes (NARIs) Agricultural universities and foundations, Non-governmental organizations Producers associations Private companies of inputs (seeds, veterinary products, food, chemicals, machinery)	National Public – semi-public goods Private Goods
Regional	Regional Forum of Agricultural technology (FORAGRO) Regional agricultural cooperation agencies (IICA) Regional cooperative research programs (PROCIs-PROCISUR, PROCI-ANDINO, PROCITROPICOS, SICTA, PROMECAFE) Research networks for specific product/theme, (FLAR, CLAYUCA) Research and training organizations (CATIE; EARTH; CARDI)	Regional Public Goods
International	International research centers (CGIAR) Multinationals private Companies International Research adn Development Centers (IDRC) Universities (USA, Canada, Europeans) Foundations (Ford, Rockefeller, Kellogg, others) International Agencies of Agricultural Cooperation (FAO)	International Public Goods

Fuente: Sain Gustavo y Jorge Ardila .2009.

Table 19. LAC: Basic indicators of the agricultural R&D systems. 2000-06

Key Indicator	Temperate Southern Cone		Subtropical Southern Cone		Subtropical Andean Region		Tropical Central America		Subtropical Northern ALC		LAC	
	Value		Value		Value		Value		Value		Value	
Government Investment (000 int.$)	94	9	757	-15	83	-5	6	8	214	2	118	-23
NGOs Investment (000 int.$)	2	3	40	4	49	0	6	4	0	na	13	-1
Private Investment (000 int.$)	0	na	0	na	0	-	0	na	0	na	-	-
High educ. Investment (000 int.$)	57	5	175	0	29	-2	4	16	250	3	50	-15
Total public Investment (000 int.$)	152	8	926	-15	161	-3	16	8	464	3	177	-17
Total Agric. Investment (000 int.$)	152	8	926	-15	161	-3	16	8	464	3	177	-17
Government Investment (%)	66	2	96	6	51	-2	46	-2	46	0	56	-3
NGOs Investment (%)	3	-3	3	4	31	3	36	-3	0	na	26	1
Private Investment (%)	0	na	0	na	0	-	0	na	0	na	-	-
High educ. Investment (%)	32	-3	15	0	18	1	19	10	54	0	25	2
Total public Investment (%)	100	0	100	0	100	0	100	0	100	0	100	0
Public researchers (FTE)	1,072	-1	1,561	-28	356	30	137	2	3,413	-23	878	-9
Government researchers (FTE)	541	12	1,564	9	376	13	58	8	1,387	15	546	6
Higher researchers (FTE)	654	-1	286	15	180	0	33	15	995	10	312	4
ONG researchers (FTE)	17	3	87	1	246	44	26	-7	2	0	-	11
Private researchers (FTE)	0	na	0	na	0	-	0	na	0	na	-	-
Total researchers (FTE)	2,278	2	3,454	-4	1,157	20	255	4	5,797	-2	1,777	-1
Public researchers (%)	44	-2	45	-7	25	10	51	1	59	-20	47	-1
Government researchers (%)	31	5	39	7	32	-6	26	-2	24	18	30	2
Higher researchers (%)	24	-8	15	3	21	-20	13	10	17	12	17	2
ONG researchers (%)	2	7	2	6	22	24	10	-9	0	2	8	-3
Private researchers (%)	0	na	0	na	0	-	0	na	0	na	-	-

Source: ASTI.

Table 20. LAC countries grouped according to R&D investment intensity.2006

Investment intenstity (%)	Countries		MAEZ
Alto >= 1.20%/año	1.	Uruguay	STC
	2.	Brasil	STSC
	3.	Chile	STSC
	4.	México	NLA
	5.	Argentina	STSC
Medio >= 0.75% y < 1.20%	1.	Costa Rica	TCA
	2.	Belice	TCA
	3.	Nicaragua	TCA
Bajo < 0.75	1.	Panamá	TCA
	2.	Colombia	STAR
	3.	Honduras	TCA
	4.	Rep. Dominicana	TCA
	5.	El Salvador	TCA
	6.	Guatemala	TCA
	7.	Paraguay	STSC

Source: Sain and Ardila 2010 based on Stads y Beintema 2009

Table 21. LAC: Countries grouped according to their capacity to generate and use technology spillovers

Generation capacity	Description	Country
High (4)	Countries that have high capacity of generating technological overflow out, which means that they also have high capability of appropriating the technology overflow coming from outside.	Brasil, Argentina, México, Chile
Medium (9)	Countries that have low ability to generate technological overflow to the outside, but if they have good capacity to take advantage of the technology overflow coming from outside.	Venezuela, Cuba, Colombia, Uruguay, Costa Rica, Perú, Panamá, Jamaica, Ecuador
Low (10)	Countries that have low ability to generate technology overflow and low ability to leverage available overflows inward.	Bolivia, Honduras, Guatemala, El Salvador, Nicaragua, Paraguay, Rep. Dominicana, Haití, Belice, Resto del Caribe

Source: .Sain and Ardila 2009.

Table 22. MVCS Pricing Structure

		TSC		STSC		TCA		STAR		SNLA		LAC	
Eslabón	Indicador	1999-2000	2010-12	1999-2000	2010-12	1999-2000	2010-12	1999-2000	2010-12	1999-2000	2010-12	1999-2000	2010-12
Grano	PfYDM (USS/t)	65		97		149		169		142		124	
	PfWDM (USS/t)	na		315		153		227		158		213	
	PcYDM (USS/t)	90		140		206	313	286	300	173		179	307
	PcWDM (	na		516		208	303	371		214		327	303
	Marketing Margin YDM	38		45		38		69	43	22		42	43
	Marketing Margin WDM	na		64		36				35		45	
Seed	Phib/PYDM	46		59		10		15		19		30	
	Phib/PWDM	na		10		11		12	7	17		13	7
	Popv/PYDM	nd		21		6		7		9		11	
	Popv/PWDM	na		3		6		5	3	8		6	3
Labor	W/PYDM1999-2000 (Kg/day)	308		72		20		18		38		91	
	W/PWDM1999-2000 (Kg/day)	na		20		20		18		34		23	
Nitrogen and pesticidesl	Pn/PYDM	16		8		8		6		4		8	
	Pn/PWDM	na		1		7		5		4		4	
	Pp/PYDM	10		13		10		6		4		9	
	Pp/PWDM	na		nd		9		5		4		6	

Source: CIMMYT Maize facts and Trends. Several issues

Table 23. Maize consumption across LAC MAEZs 2000 – 2010.

Key Indicator	Temperate Southern Cone		Subtropical Southern Cone		Subtropical Andean Region		Tropical Central America		Subtropical Northern ALC		LAC	
	Value	Growth	Value	Growth	Value	Growth	Value	Growth	Value	Growth	Value	Growth
Total consumption (t)	2,614,411	3.7	19,811,540	3.8	2,235,883	6.2	877,625	4.1	27,092,142	3.3	5,339,380	3.9
Total consumption per capita (Kg/hab)	124	3.4	151	2.4	156	4.7	149	2.0	255	2.0	152	2.9
Food consumption (t)	263,762	2.3	2,254,312	5.0	861,783	3.7	419,937	1.7	11,925,159	0.6	1,478,601	1.8
Food Consumption per capita (Kg/hab)	19	1.4	38	1.5	46	2.1	68	0.5	124	-0.7	52	0.6
Feed consumption (t)	1,679,097	5.6	15,039,207	3.6	1,169,066	8.9	276	0.2	8,368,075	5.9	3,078,625	4.8
Food consumption/ maize production (%)	27	-7.5			59	-0.5	67	0.7	63.3	-1.6	67	0.7
Feed consumption/ maize production (%)	90	-2.9	18.4	-7.7	88	4.4	276	0.2	39.8	3.8	276	0.2

Table 24. Maize Trade

Key Indicator	Temperate Southern Cone		Subtropical Southern Cone		Subtropical Andean Region		Tropical Central America		Subtropical Northern ALC		LAC	
	Value	Growth	Value	Growth	Value	Growth	Value	Growth	Value	Growth	Value	Growth
Imports	452,741	1	430,436	3	1,002,570	7	950,282	4.9	**6,096,965**	5	950,282	4.9
Exports	**3,974,408**	2	2,871,861	25	23,523	-4	1,065,209	6.5	202,590	15	1,065,209	6.5
Value of maize exports	547,011	11	405,187	32	3,780	5	1,513	9.7	42,100	30	147,675	15.2
Value of maize imports	77,136	11	58,243	9	175,605	16	66,495	14.1	1,116,287	14	157,718	13.9
Net imports	-3,519,024	0	-2,403,657	0	957,547	7	374,196	4.9	6,578,538	5	111,175.6	0.9
Imports explicit price	1,119	12	908	19	398	17	188	7.2	158	9	494	13.6
Exports explicit price	129	10	173	-3	0	0	0	0.0	0	0	677	-0.1
Main origin of importations	na	-	USA		ARG		USA	USA	USA	-	USA	-
Main type imported	na	-			YDM		YDM	YDM	YDM	-	YDM	-
Main destination of exportations			SK; Iran; SP				na		na	-	-	-
Main type exported	YDM		YDM		FM		na		na	-	YDM	-

Source: FAOSTATs and country reports

PART II.

MAIZE INVESTMENT OPPORTUNITIES IN LAC

1. The future outlook for MVCS in LAC

The empirical evidence presented in the previous sections points to a set of key drivers of maize production and consumption in LAC's different MAEZs. Table 25 lists the tendencies of some of the main economic drivers that will affect maize production in LAC over the next nine to ten years and consequently will affect the demands on the maize RD&D system. These projections, prepared by the United States Department of Agriculture, are based on a series of assumptions about economic growth and the population in both developed and developing countries (USDA 2012).

Table 25. Main maize production/consumption drivers

Driver	Main impact and forecast through 2021
Global economic growth	Global economic growth is assumed to grow at an annual rate of 3.3% with China and India as main growth engines.
Population	The rate of population growth is a key driver of food demand, particularly important in the case of WDM consumption. It is expected to grow at an annual rate of 1% during the period 2011–2021.
Real Latin America GDP growth	A key driver of indirect consumption. It is expected that GDP in LAC countries will increase at annual rate of 4.2% as the global economy starts to recover, pushing up the demand for animal proteins (poultry, swine, cattle).
International maize price	The maize price is an indicator that works on both the demand and supply sides. Maize prices are expected to continue their upward trend as a result of the demand for biofuel, as well as the increase in human consumption.
Meat prices	The high prices of grains and oils will increase the cost of feed rations, which will be reflected in the final prices of meat.
Energy prices	Crude oil prices will bounce up as the world economy recovers (2011 onwards). Preliminarily estimates suggest that the price will be around USD 120 per barrel during the period 2013-2021.
Maize trade	Exports. Argentina and Brazil's exports will continue to grow, with Brazil leading the way. Imports. The trend of rising maize imports will continue, with Mexico leading the way.
RD&D investment	A key indicator on the supply side. Higher productivity and lower production costs are needed. In the past decade, there was an increasing trend that may continue in the years ahead, contingent on economic recovery.
GCC	The effects of GCC on agriculture in general, and on maize production in particular, will worsen over the next ten years, especially in fragile tropical and subtropical environments.

Source: The 2021 forecasts are from USDA–ERS 2012.

Table 26 lists some of the impacts resulting from the expected changes in the drivers on the maize market (supply, demand and prices).

Table 26. Some projections of the main drivers through 2021

Impact on		Projection through 2021
Demand		Food. As a result of economic and population growth, the demand for food in the developing countries increased strongly, particularly for meat, milk and byproducts, fruits, vegetables and processed foods. Meat. The future increase in the demand for meat, milk and byproducts will favor LAC producer countries (Nicaragua, Uruguay, Brazil and, possibly, Argentina). Demand for maize. Increased demand for meat will boost demand for grains, especially maize, for the production of concentrates. Biofuels. The demand for biofuels will increase significantly in the European Union and the United States. As a result, biofuel production will grow significantly in Brazil and Argentina, increasing the pressure to use maize as biofuel.
Supply	Production	**YDM and WDM production** will continue to increase at rates above that of population growth in all the MAEZs. Growth will not keep pace with consumption, however. The shortfall will have to be met with imports. **Acreage**. The empirical evidence collected for this report points to a positive correlation between maize acreage and price incentives. Another important factor is the amount of suitable land available. There is a great potential in the STAR and STSC if acid soils can be incorporated into maize production. For example, it is estimated that if the Brazilian *cerrados*[2] were to be developed, another 60 million hectares could be brought into production using currently available technologies *(*Meng and Ekboir 2001*)*.
	Net imports	**Imports** will increase for all LAC countries, particularly Mexico (5.1%), Central America & the Caribbean (1.5%), Brazil (3.6%) and other South American countries (1.8%). **Exports** will increase in the two main exporting countries - 2.1% in Argentina and 4.3% in Brazil.
Prices		**Maize price**. Demand forces will predominate over those regulating the supply side, pushing up international maize prices during the period 2013-2021. Winners: Argentina, Brazil. Losers: Mexico (major importer) and other importing countries **Crude oil prices** will bounce up as the economy recovers. Preliminary estimates suggest that the price will be around USD 120/barrel between 2013 and 2021.

Source: Based on USDA 2012

In summary, it is expected that between 2013 and 2021 maize consumption will grow faster than domestic production. Since consumption of YDM will drive the increase in consumption, imports of this type of maize are expected to continue to rise. Direct human consumption of WDM will also increase, but to a lesser degree.

These trends have to be adjusted to the situation of each of the MAEZs.

2. Maize Research Investment Opportunities

2.1 Main constraints and opportunities

Biotic and abiotic production constraints Biotic and abiotic production constraints

LAC has a substantial opportunity to raise maize production by increasing maize acreage and yield. The empirical evidence presented in previous sections shows that there is a large yield gap in tropical and subtropical LAC regions (Pingali ed. 2001, Sain *et al*. 2001) that could be closed if appropriate measures were put in place. Biotic and abiotic constraints (factors limiting maize acreage and yield) are specific to the cropping environment and the production structure. Table 27 lists the main constraints identified in the different environments across LAC, as well as the main technology options available for overcoming them.

Table 27. Dominant biotic and abiotic constraints to bridging the yield gap

Environment/ MAEZ	Constraint Type	Name/explanation	Technology
Highland/transitional (NLA; STAR; Guatemala)	Abiotic	Drought/moisture stress	• *Early maturing germplasm for drought avoidance* • *Cultivars with drought tolerance.* • *Farm level drought management*
		Limited technology options *Lack of Improved Germplasm for the Tropical Highlands*	• *Native FM improved with selected traits appropriate to cultural and social circumstances of maize producers* • *Appropriate crop management practices for soil conservation and water efficiency*
	Biotic	Ear rot	• *Biotech* • *IPM*
		Rust	• *Biotech* • *IPM*
Mid-altitude/subtropical (STAR; STSC)	Abiotic	Soil erosion	• *Appropriate crop management practices for soil conservation and water efficiency*
		Drought/moisture stress	• *Early maturing germplasm for drought avoidance* • *Cultivars with drought tolerance.* • *Farm level drought management*
	Biotic	Turcicum blight	• *Biotech* • *IPM*
		Borers (S.W. corn borer)	• *Biotech* • *IPM*

Tropical lowland/ (TCA; STSC)	Abiotic	Low soil fertility/soil erosion	• *Fertilizer efficiency* • *Appropriate crop management practices for soil conservation and water efficiency.*
		Soil acidity	• *About 64% of tropical South America, mainly Brazil and Peru, has acidic soils. Germplasm tolerant to acidic soils* • *Appropriate crop farming to counter the negative effect of acidic soils*
		Drought/moisture stress	• *Early maturing germplasm for drought avoidance* • *Cultivars with drought tolerance.* • *Farm level drought management*
	Biotic	Fall armyworm	• *Biotech* • *IPM*
		Stunt	• *Biotech* • *IPM*

Source: Based on Pingali 2001

SWOT Analysis of the MVCS across LAC

Table 28 summarizes the SWOT analysis carried out in each of the four country case studies. The concerns highlighted are consistent with the main biotic and abiotic constraints to increased maize productivity and production identified in the previous section. Six elements of the MVCS in LAC are worth noting:

i) *Increasing maize demand* is perceived as a positive force that favors maize production;

ii) *Government economic policy* is perceived as not favoring maize production/productivity. There are many facets to this issue, for example: low investment in RD&D; economic policies distorting farm prices; and road and storage infrastructure investments.

iii) *Maize productive structure*. The atomized, disperse and disjointed structure of the subsistence sector is perceived as an important disadvantage in the MVCS.

iv) *Input and service market failures*. Input markets, including the improved seed market, have concentrated production and distribution structures.

v) Higher productivity is perceived as the main way to increase production. The possibility of increasing acreage is mainly restricted to areas in the STAR and the STSC. In both cases, appropriate technology has to be in place.

vi) The impact of GCC is a major concern for many maize-producing areas of LAC, particularly in the TCA, STAR and southern Mexico.

Table 28. SWOT Analysis of the MVCS in LAC

<table>
<tr><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>The most important strengths identified in each case study include:

TSC (Argentina). Biophysical (climate, radiation) technological innovation throughout the MVCS, and a strong and developed inputs and services market (particularly machinery services).

STAR (Peru). Biophysical (climate) allowing year-round production, investment in irrigation infrastructure, large FM genetic variability

TCA (Guatemala). Maize is culturally rooted in the farming population. Importance of maize in the population's diet. Consumed in diverse forms. A growing and developing seed industry. Large genetic diversity of WDM and FM.

NLA (Mexico). Maize is culturally rooted in the farming population. Importance of maize in the population's diet. Consumed in diverse forms. Strong, developed seed and inputs and services markets. Policies and programs supporting maize production.</td><td>The most important weaknesses identified in each case study include:

TSC (Argentina). Economic policies are a disincentive to maize production. Insurance and financial market failures. Production technology requires high per hectare investment. Low price information at farming level.

STAR (Peru). Atomized and disperse production structure. Improved seed market failures (availability and low stability). Inefficient marketing structure (high transaction costs).

TCA (Guatemala). Atomized and disperse production structure. Inefficient marketing structure (high transaction costs). Low technological level (low yield). Poor road and storage infrastructure. Improved seed market failures (lack of availability in many areas). Low investment in RD&D.

NLA (Mexico). Atomized and disperse production structure. Inefficient marketing structure (high transaction costs). Low technological level (low yield). Poor road and storage infrastructure. Improved seed market failures (lack of availability in many areas). Low investment in RD&D.</td></tr>
<tr><th>Opportunities</th><th>Threats</th></tr>
<tr><td>The following are some of the most important opportunities identified in each case study:

TSC (Argentina). International and domestic demand in expansion. Availability of second generation technology. Strong links with developed complementary value chains.

STAR (Peru). Possibility of increasing maize acreage. Domestic demand in expansion. Possibility of increased demand for FM in special markets.

TCA (Guatemala). Domestic demand in expansion. Important production of WDM. Large maize yield gap. Maize production all year around.

NLA (Mexico). Domestic demand in expansion. . Large maize yield gap. Maize production all year around. Sizable production of WDM.</td><td>The following are some of the most important opportunities identified in each case study:

TSC (Argentina). Policies that are a disincentive to production may continue or worsen. Risk of further seed market concentration.

STAR (Peru). Failure to reach quantity and quality market standards. Policy on GMO may worsen seed market shortages. Rising inputs and services prices.

TCA (Guatemala). Negative impact of global climate change. Lack of technology. RD&D policies.

NLA (Mexico). Negative impact of Global climate change. Lack of technology. End of government programs.</td></tr>
</table>

2.2 R&D investment opportunities

Maize R&D activities are not carried out in an institutional vacuum; rather, they are immersed in the national R&D system. As such, many of the challenges for maize research are the same as those faced by the wider research system. The main challenges that the maize research system must tackle in the medium term are:

i. Demand for multiple products

Perhaps one of the most pressing challenges that the LAC research system must confront is an environment characterized by limited resources, and diverse demands from society resulting from economic, social, cultural, health and environmental concerns.

Environmental sustainability

The maize R&D system is required to increase productivity while at the same time conserving natural resources (soil and water) and preserving the quality of the environment.

Increasing demand for maize will put pressure on the agricultural frontier and lead to deforestation. In this context, economic and institutional policy can do more than technology to change future land use decisions. Increased productivity and competitiveness of land already under cultivation slows down the expansion of the agricultural frontier.

Soil quality

Soil erosion is more of a technology-related problem for maize cropping in LAC, particularly in CA and the STAR, where maize is mostly sown on fragile hillside soils. The maize R&D system has been successful in developing soil/water-conserving technologies, many of which have been successfully adopted by farmers. These include tillage, use of straw mulch, the inclusion of legumes in the rotation, contour planting systems and terraces of different types. Unfortunately, their large-scale dissemination is often limited by the economic conditions that characterize agricultural systems where degraded soils exist. The maize research system should concentrate its efforts on the search for "win-win" technological alternatives designed to increase productivity in the short term and preserve/restore the soil in the long term. The policy should facilitate access to this type of technology for small maize producers.

ii. Social and cultural sustainability

Though LAC is considered, with some exceptions, a mainly urban region, it is also true that most extreme poverty is rural. Although agricultural technology may not be the best way out of poverty at the rural level, it is well recognized that the generation and diffusion of technologies appropriate to the conditions of poor farmers can contribute significantly to poverty reduction (Thirtle *et al.* 2003). In this sense, perhaps the greatest challenge for the maize research system is to prevent technology from contributing to the widening of the gap between rich and poor that already exists (Pardey *et al.* 2006). It is important, then, that new technology reach groups of small maize farmers.

Another great challenge for the maize R&D system in LAC is to encompass the indigenous population. In this case, the challenge lies in incorporating different worldviews into the system, otherwise technologies may not always be considered appropriate by indigenous maize producers. This is more important in those countries with the largest number of ethnic groups. Almost 80% of the indigenous population of the Americas is concentrated in five countries. Mexico and Peru account for more than 50% and Bolivia, Guatemala and Ecuador for 30%; the remaining 20% is distributed among the other countries of the region (Sain and Calvo 2009).

iii. Trade liberalization and new technological developments

The greater insertion of the LAC economies in the world market will put pressure on the generation of innovations that promote competitiveness. This demand is related to the development and adaptation of new technologies:

- i) Precision agriculture
- ii) Information and communications technologies with application level of farm and farmer
- iii) Traceability systems
- iv) Technology application of the "ecological footprint" concept and its implications in international trade
- v) Development of biotechnology, which will favorably impact current production levels, reduce production costs and improve nutrition and health, particularly within family agriculture, in many countries of the region. This calls for a parallel development of regional capacities, to ensure the presence of biotechnological events in LAC, with a parallel development of the processing industry
- vi) New management and business management technologies
- vii) Development of institutional and policy innovations.

iv. Uncertainty

LAC agricultural research systems must prepare themselves for several important uncertainties that are very likely to develop in the medium term with the impact of global climate change on maize production. According to the projections of the Intergovernmental Panel on Climate Change (IPCC), temperatures will rise significantly in relative as well as absolute values. Both the intensity and frequency of precipitation will also be affected. It is expected that tropical and subtropical countries will be more affected by the negative effects of climate change than those with temperate climates, though this does not mean that there will be no negative impact on agriculture in the latter countries. The impact of GCC on maize production and productivity and, therefore, on the well-being (vulnerability) of maize producers will be felt particularly strongly in Central America, while temperate countries such as Argentina and Chile may actually be able to expand farming activities all the way to their southern extremities due to rising average temperatures. In addition, climate change will make a higher proportion of the technology in use obsolescent, increasing the pressure for greater investment in research and the training of new researchers, without neglecting other ongoing activities (Sain and Ardila 2009).

3. Conclusions and Recommendations

One general conclusion of the diagnosis is that although maize producers in LA face common threats, they also have different circumstances that makes that solutions must be tailored to the different maize environments. The MAEZs analyzed in this work is a possible useful disaggregation. More research is needed but a refinement recognizing the altitude parameter seems necessary.

In the grain production sector it is necessary to recognize both the traditional / subsistence sector and the commercial one. In many case the close association between maize and small poor peasants makes that conclusions or strategies to facilitate the uptake of project outputs go beyond the specific of maize. For instance given the cultural importance of maize in all MAEZs but the Southern Cone, R&D must integrate the cultural values and believes of the native population and descendant. It is recommended that in countries with significant number of indigenous population (maize producers), the NARI incorporates a department or program with a multidisciplinary team specifically focused on that segment of (maize) producers. Members must be enough open minded to allow the blending of both types of knowledge with a common agreed objective that it is not necessarily improving yield as a unique target. This is particularly true for maize breeding programs, it seems that commercial maize producers have no problem in using last generation hybrids, but this is not the case of traditional producers who are not using commercial seed even when substantial effort has been allocated by the public sector.

The main threat to maize producers in LA is the impact of the Global Climate Change (GCC). Although the consequences of GCC will reach all countries in the region, maize producers in the hillsides of CA and other regions of LA will be strongly affected. It is necessary to intensify research and extension program to reduce the vulnerability level of small maize producers in these marginal and sensitive areas.

One of the impacts of the GCC that it is already feeling in many regions of LA is the increase in the intensity of occurrences of biotic and abiotic stresses. For example soil losses by erosion and other climatic sources are common in many maize production areas across LA, and it is expected to worsening as the precipitation intensity increases. The incidence of some pests has also been reported as increasing in parts of Central America.

Price distorting policies are also limiting maize production growth across all MAEZs. More research is necessary in this area to measure the policy impacts and to identify and elaborate alternative less distorting policy instruments.

The atomization and spatially spread of a large amount of small grain producers makes difficult and costly to collect and transport the grain increasing the total marketing cost and reducing the competitively at the processing industry level. More research is needed to explore different alternatives to promote storage at the field or local level in order to concentrate production, aggregate some value by drying it and cleaning it and have enough volume to better negotiate the price.

More competitive and transparent markets at all levels in the MVC are necessary to improve not only the efficiency of the marketing system but also its equity among participants' agents particularly the small producer.

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PART III.

MAIZE VALUE CHAIN ACROSS AGRO-ECOLOGICAL ZONES AND REPRESENTATIVE COUNTRIES

The information presented in this third part strongly rests on that presented in the national reports which in turn rest on different reference sources. In this part no citation of third parties is done and the reader is referred to the corresponding national report for further details and original information sources.

1. MVCS in Temperate Southern Cone (TSC) - Representative Country: Argentina

(This section strongly based on: MAIZAR. 2013)

1.1 Importance of maize production in TSC

According with FAOstat (2012) during the period 2005-11 four crops encompassed 83% of total crop production in the TSC region with maize seizing a third place (12%) after soybeans (40%) and sugar cane (22%) and before wheat (9%). Although maize production increases its maize volume by 22%, it could not keep it up with that of soybeans (49%) and sugar cane (25%), losing consequently importance in the crop production portfolio of the TSC. Even though maize production growth rate from 2000 to 2010 was of 2.9%, it is value grew at a rate of 7.8%, which shows the impact of higher and increasing maize market prices. Moreover, maize production only represented 6% of the Agricultural Gross Domestic Product (AGDP) in the region, which indicates the growing importance of high value products like soybeans in Argentina and fruits and vegetables in Chile. Nevertheless, the Temperate Southern Cone is a net exporting region of maize and as such domestic availability results from subtracting net exports, which can be interpreted as part of the consumption sector, from the domestic production. In 2012 the MVCS as a whole generated in Argentina approximately 450,496 jobs, 6% from which corresponded to both direct jobs (i.e. production, processing and conditioning sector including, transportation and distribution) and indirect jobs (i.e. companies that provide inputs and services to the value chain). This amount represents 2.6% of the Economically Active Population (EPA) in agriculture. Finally, it is worth noting that countries in the TSC region have the lowest rate of indigenous population in all LAC (Annex 1), and as such maize has not the same cultural roots that characterize other countries in the region.

1.2 Domestic Availability in TSC

Maize production and trade

Within the TSC Argentina is the dominant country, since it accounts for about 94% of the total area cultivated with maize and about 92% of the total production. Hence, main producing regions in this country are the main producing regions in the TSC. Even though in Chile maize is not an important part of its population diet; this country has the highest maize yield in the Southern Cone and in LA, with an average productivity close to 11 tons/ha during the period 2006-2011 (FAOstat, 2012) due to a combination of high technology, irrigation and a small size effect[26]. In the last decade more than 80% of Chile's maize production went to the animal feed industry. Chile and Uruguay supplement their domestic demand with maize imports, which are led mainly by Chile, with a share of 37% of the total maize regional imports in 2009. Meanwhile, Uruguay had a share of 5% (FAOstat, 2012).

In Argentina, production concentrates primarily in the provinces of Buenos Aires, Cordoba and Santa Fe, which together constitute the "Central or Nucleus Zone". This area concentrates 70% of the total area cultivated with maize in the country, and it contributes with 77% of the national production. The importance of this zone is the result of a mix of biophysical characteristics (climate and soils) with economics factors related to the proximity to export ports. Buenos Aires, the main producing province, contributes with a third of the Argentina maize production. Although maize production grew at an annual rate of 14% during the period 2001-11 other crops grew at a higher rate, this is the case of barley brewing (31%), sorghum (19%) and soybean (18%) which grew at an annual average rate of 31%, 19% and 18%, respectively. The rest of the provinces where maize is produced are known as "The Marginal Zone", recently with a very interesting dynamic in the area sown with maize due to a combination of high maize prices and new technology.

By far the most common maize grown in TSC is yellow dent maize (YDM) followed by yellow flint maize (YFM) and popcorn maize, which in the last decade has shown an important development, especially in Argentina, and has position the TSC region as the 1st world exporter of this kind of maize. Note that most, if not all, of the dent maize grown in the region is red colored. Finally there is some floury or starchy maize (FM) in the highlands of Chile and Argentina, that presents different colors including white and is preferred by the native population due to its cooking and taste characteristics; and it is mostly consumed fresh as "choclo".

26 This effect refers to the fact that no low yield marginal land pushing down national average is used.

During the period 2000-10 in the TSC region maize productivity as well as its acreage grew at an annual rate of 1.9% and 0.7% respectively, both of which contributed to a yearly increase in production of 2.9%. This situation led to a Growth Anatomy Index[27] of 2.6, which means that for each 1% increase in maize acreage, maize yield increases by 2.6%. Although the TSC region ranks third in area cultivated and volume produced after Brazil and Mexico, it shows the highest maize yield level in all LA which on average ranges from 11 t/ha in Chile to 7 t/ha in Argentina. According with MAIZAR[28] in 2012 Argentina produced maize in an area of 5 million hectares, 74% of which produced approximately 26.9 million tons of maize that was used for commercial purposes; while the production generated in the rest of the area did not enter the trade circuit. Most of the maize traded corresponds to commercial maize (78%), followed by forage (17%) and maize carry (3%). This production volume positions Argentina as the 5th maize producer in the world, but since 60% of it is exported, given the low domestic consumption, this country ranks as the 3rd maize exporter worldwide. Also, it is worth to remark that Argentina export potential can increase since maize directed to forage can be easily substituted by the sorghum and other products.

On average during the period 2000-12 maize net exports from the region was around 3.5 million tons, volume that has been stagnated during that time. This happened since both exports and imports grew almost at the same rate, even though the latter represents 10% of the former. All the maize that this regions exports is yellow given its high international prices that on average are 129 US$/t.

Maize producers in TSC

In 2011 around 26,600 farmers traded maize in Argentina[29]; 30% of which commercialized less than 100 tons and are considered small-scale farmers; 60% traded between 100 and 2000 tons and are considered small producers; and only 10% of them are large farmers who sell more than 10,000 tons of maize. Although small farmers account for 90% of total farms, they only account for about half of total maize production, since they produce in less than 300 hectares and reach an average productivity of 7t/ha[30]. In Argentina most of the available land area for maize production has good deep soils with good content of organic matter and nutrients. The nutrients that limit maize productivity include nitrogen, phosphorus, and recently sulfur.

Maize technology use in TSC

One outstanding characteristic of the TSC region is the intense use of up to date technology in maize production. It is estimated that around 90% of the maize in the region is produced using modern technology, situation that is reflected in the high productivity levels. Being improved maize seed, one of the most used technology in the region. The adoption of this technology has been very dynamic and fast, going from the use of a single hybrid, *Bt Maize*, from 1998 to 2003 to the adoption of the hybrids *TH maize* and *BtxTH* in 2004 and 2007, respectively. It is worth noting that *BT maize* in Argentina grew at an average annual rate greater than 300%; which however dropped to only 1% during the period 2004 to 2012. During the cropping cycle of 2011-12 approximately 84% of the 5.01 million of hectares cultivated with maize was sown using transgenic seed (GMO), 57% of which (i.e. 2.4. millions of ha) was seed with accumulated features of insect resistance and herbicide tolerance (BtxTH); and the remaining 33% and 10% corresponded to insect-resistant Bt maize and herbicide-tolerant TH maize, respectively.

Nonspecific inputs and services in TSC

In 2012 83% of the total number of hectares sown to the crop did under 0 –till or Direct Sowing while the remaining 17% are sown with conventional mechanical tillage. One event that boosted the diffusion of No Tillage Agriculture or Direct Seeding in Argentina during the 90's was the development and subsequent massive

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27 Growth anatomy = yield growth / area growth. Estimated with information form FAOSTATS

28 MAIZAR is the name of the Argentine Asociation of of Maize and Sorghum

29 This is likely an underestimate of the true number of maize producers since it does not take into account some 850,000 hectares of maize for self-consumption that do not enter the commercial circuit.

30 Estimated by assuming a constant maize yield of 7 t/ha for all size stratus, to approximate the importance in term of area/production from the importance of volume traded.

diffusion of Glyphosate and the advent of glyphosate-resistant crops, and among them *maize RR*. The use of the technology *No till-glyphosate–maize RR* allows producing maize in environments, and even in ecosystems, previously unthinkable and also intensifies land use by allowing the rotation of wheat, maize and soybean in a same agricultural cycle. By 2012 around 83% of the total area cultivated with maize used No Tillage Agriculture and the rest of the area was sown with conventional mechanical tillage. Furthermore, the adoption of No Tillage Agriculture drove the consumption of fertilizers in maize production, which took off during the 1990's.

During the 2011-12 cropping cycle around 3.09 tons of fertilizer was used in cereal production, most of which was used for soybean (31%), maize (30%) and wheat (25%); and the rest for sunflower, sorghum and barley production. Also, the TSC is among the LAC regions that applies the highest doses of fertilizer for maize production. It is estimated that 88% of the maize planted area applies 200 kg of fertilizer per hectare; hence this input demand lays around 931,212 tons; 87% of which is distributed among the main producing provinces of Argentina i.e. Buenos Aires (31%), Santa Fe (21%), La Pampa (19%) and Córdoba (16%). On the other hand, in terms of nutrients around 60% of the total fertilizer consumed corresponds to nitrogenous, 31% to phosphorus and 9% to sulfur. Regarding plagues and weed control from 2002 to 2010 it is estimated that the annual consumption of Fung_Bact, herbicides and insecticides were on average of 1.6, 4.8 and 2 kg/ha, respectively. Also, in Argentina only three insecticides are applied in almost 75% of the total area cultivated with cereal, being *Cypermethrin* undoubtedly the most widely used. This is reflected in the high growth rates of herbicides and insecticides during the analyzed period, which were of 12.9 and 29.5%, respectively.

Almost all of the maize produced in Argentina and Uruguay, is rain fed, however in Chile irrigation of coastal valleys has increased in the past decades pushing up land productivity. Nevertheless, a practice that has started recently in Argentina is the use of supplementary irrigation. Another characteristic of maize production in TSC, particularly in Argentina, is the development and intense use of agricultural machinery. One remarkable characteristic in this country is the development of a national industry of agricultural machinery and equipment (e.g. tractors, seeders, sprayers and harvesters). It is estimated that more than 55% of the machinery used in the agricultural sector are made in Argentina. Another characteristic of the sector is the development of an extended and well-articulated machinery service market.

Another important effect of No Tillage Agriculture in Argentina was the reduction of tractors usage at the farming level, and thus their increasing efficiency. It is estimated that the current use of the agricultural tractor in Argentina in the rotation wheat/soybean/maize is not more than 2 hours/ha per year. For example, Brazil produces 130 million tons of maize using 25,000 tractors per year (i.e. 5,200 ton of maize for each tractor); while Argentina produces 96 million tons of grain using 8,400 tractors (i.e. 1,428 ton of maize for each tractor). Clearly Argentina presents a better average efficiency in the use of tractors than Brazil. Argentina has a rich history of high degree of innovations, developments and manufacturing of combine harvesters, thereby generating a revolution of efficiency in maize production, for instance Precision Agriculture. Also, another important innovation in the past 10 years is the massive and definitive adoption of modern seeders with automatic maize seed distributors, variable seeding and satellite positioning systems, which are 100% of national production.

Factors associated with maize technology use

Even though there are some areas in the TSC with intercropped maize, the predominant system is sowing maize as a single crop during the summer time. In Argentina and Uruguay maize is sown in an annual rotation with a winter crop, usually wheat, until the introduction of the No till - glyphosate – maize RR technology that allows the rotation wheat – maize -soybean. Although with certain variability, across main producing regions maize is cultivated with high technology. This is the case of Argentina and Chile, where yield differences between both can be attributed to the proportion of total production which is irrigated and also to the size effect. Several studies in Argentina identified five main factors that limit the quantity and quality of maize production in the country, which include: water stress, MRCV (Mal de Río Cuarto virus), insect borers, foliar diseases (rust) and stem diseases (rots), and contamination with mycotoxins. On the other side, the following five factors were identified as responsible for increasing maize productivity: 1) Advances in genetics and crop management technologies; 2) Market availability and use of transgenic seeds of new hybrids of higher yield potential and better resistance to pests and diseases; 3) Increase in the fertilized area; 4) Increase use of direct seeding system; and 5) Incorporation of the practice of supplementary irrigation.

Economics of maize production

Considering Argentina main maize producing areas, the highest yields and gross margins can be observed in the northern area of Buenos Aires and South of Santa Fe, where both direct seeding and conventional technologies are used (Table 29). It should also be noted that in all the areas studied the benefit/cost ratio is greater than 1.

Figure 29. Argentina: Cost structure and gross margins by type of technology used. 2012

Detail	Units	Córdoba Centro-Sur	Buenos Aires Norte & Sur de Santa Fe		Buenos Aires	
					Southeast	West
		Direct	Direct	Conventional	Conventional	Minimum Till
Production costs	**US$/ha**	**435**	**611**	**625**	**588**	**507**
Inputs & services	US$/ha	290	432	363	350	306
Total tillage	US$/ha	44	48	131	129	100
Harvesting	7,7 % I.B.	101	131	131	109	101
Gross benefits	**US$/ha**	**1,300**	**1,700**	**1,700**	**1,400**	**1,500**
Expected price	US$/qq	20	20	20	20	20
Yield	qq/ha	65	85	85	70	75
Gross margin	**US$/ha**	**865**	**1,089**	**1,075**	**812**	**993**
Marketing costs	US$/ha	482	434	434	344	515
Other indirect costs	US$/ha	115	209	209	112	140
Net margin	**US$/ha**	**268**	**446**	**432**	**356**	**338**
Indiference yield	qq/ha	40	51	52	43	46
Gross margin – Low yield	US$/ha	140	439	425	234	158
	qq/ha	40	65	65	50	45
Gross margin – High yield	US$/ha	555	1,217	1,202	662	660
	qq/ha	75	120	120	80	85

Source MAIZAR 2013.

1.3 Maize Inputs, Service Markets

Maize seed supply

During the period 1998-2012 in Argentina 20 events of maize were generated and authorized for seeding, consumption and marketing. These events were realized by four dominant companies, two of which encompasses 74% of the market and the other two the remaining 26%. Most of them are maize seed resistant to insects and herbicides (55%), insect-resistant (30%) and herbicide-tolerant (15%). It is worth clarifying that all maize seed that are used in Argentina are produced locally i.e. there are no seed imports.

Non-specific inputs in TSC region

There are no detail statistics about the use of other inputs other than seed (i.e. nonspecific inputs) to maize production, for that reason aggregated statistics should be interpreted with caution.

- ***Fertilizers and pesticides***

In the case of nutrients consumed in TSC from 2002 to 2010 on average 518,626 tons of them were imported, 49% of which are P2O5, 46% N and only 5% K2O; nutrients that grew at an annual rate of 4.7%. On the other hand, also exports of P2O5 and K2O have been observed, which in the studied period were of 7,570 and 144, 472 tons per year, respectively. The grow rate of these exports were on average 8.6%. Regarding pesticides use in the TSC region, it is remarkable that even though herbicides use intensity during the period 2000-10 was higher than the use of insecticides with 4.8 and 2 kg/ha per year, the latter shows higher growth rate (29.5%) than the former (12.9%).

- ***Machinery and agricultural equipment***

Another characteristic of maize production in TSC and in Argentina in particular is the development and intensification of the use of agricultural machinery. One remarkable characteristic is the development of a national industry of machinery development in the country. It is estimated that more than 55% of total machinery used in the agricultural sector are made in the country.

Another characteristic of the sector is the development of an extended and well-articulated machinery service market.

Tractors: Another impact of direct seeding was to reduce the use of tractors at the farming level. It is estimated that the current use of the agricultural tractor in Argentina in the rotation wheat/soybean/maize is not used more than 2 hours/ha/year. This has the final effect of increasing the tractor use efficiency in Argentina. For example, Brazil produces 130 million tons of grain with a market of 25,000 tractors per year for an average production of 5,200 ton of maize for each tractor; instead Argentina produced 96 million tons in 2008 with a 8,400 tractor market for an average efficiency of 1,428 ton of maize for each tractor, clearly Argentina presents a better average efciicency in the use of tractors than Brazil.

Seeders: One of the biggest innovations during the past 10 years is the massive and definitive adoption of modern seeders with automatic maize seed distributors, variable seeding and satellite positioning systems. These are 100% domestically produced.

Sprayers: It is estimated that spraying in maize production is carried out in 80% of the cases with self-propelled machines.

Harvesters: The Argentina has rich in history with high degree of innovation, development and manufacturing of combine harvesters, thereby generating a revolution of efficiency in maize production (eg. Precision Agriculture).

- ***Irrigation***

Almost all of the maize produced in TSC and in Argentina and Uruguay in particular is rain fed maize, however in Chile irrigation of coastal valleys has increased in the past decades pushing up the land productivity. A practice that started recently in Argentina is the use of supplementary irrigation if necessary and available.

1.4 Maize Research and Development System in TSC

National institutions

The three NARIs: INTA in Argentina, INIA in Uruguay and INIA in Chile, are considered institutions that have successfully reengineered in the past 10 to 20 years. They have been innovative in looking for alternative funding sources, particularly in association with the private sector (Sain and Ardila 2001).

1.5 Maize Processing Agroindustry and Consumption in TSC

Stylized structure of the marketing system in Argentina

The maize value chain in Argentina comprises the following five links: science and technology; provision of inputs; agricultural production; industry and marketing. The chain also relates with indirect actors which include institutions from the public and private sector that provide services and infrastructure, as well as the society. In general maize producers sell their produce following two channels, one of them is a direct sale at the farm level to the industry or to an exporter, normally conducted by large scale farmers. The second channel is commonly used by small and medium maize producers, who basically sell their grain to a collector or to a cooperative that determines the sale's conditions and has to find a final buyer. Overall farmers who sell directly may have substantial costs reductions with respect to the second method, since they can generate savings in freight, conditioning and commissions costs. In general, maize grain is a main and very important raw material for various industries in the TSC region. For some sectors the widespread availability of low-cost maize represents a great unique opportunity for growth. The production of animal feed is from the quantitative point of view, the most important maize processing industry; followed by the wet and dry milling industry.

In Argentina the wet milling industry is concentrated in seven plants which belong to four companies that produce gluten (feed and meal), glucose, starch, maize oil, solid dextrose, maltose, syrup mix, caramel coloring, maltodextrin, and modified starches, among others. Unlike the dry milling industry, these establishments have larger scale processing capacity that ranges on average from 300 to 800 tons/day; but three of these plants can processed approximately 1,300 tons of maize per day. Usually, the products of this industry do not reach destinations outside the region (with the exception of maize oil), given their low market value (200-300 USD/ton) and high freight costs. These plants activities are mostly automated and thus, they do not demand that much labor, being estimated that they employ directly up to 2,000 people.

On the other hand the maize dry milling industry can be divided by the type of industrialization and thus the products they make. Thus, on one side there are plants that produce flour, grouts and meal for polenta (first industrialization), and on the other we find snacks and breakfast cereals (second industrialization from grains, rolled, flaked, pearled, sliced, kibbled). Also, other products derived from this industry include germ oil, gluten feed, gluten meal for animal feed, and brewer grits used in the manufacture of beverages. In Argentina the dry milling industry comprises over 70 mills which are geographically distributed in eight provinces of this country, and that process a total of 400 thousand tons of maize a year. The vast majority of these mills are small and medium enterprises, mostly family oriented, that have an installed capacity that varies from 30 to 150 tons/day on average. Certain mills in this industry demands red coloured Flint maize, which has its own production and marketing circuit with certification and traceability, and therefore receives higher prices than that the common yellow dent maize. In 2009 the Argentinian dry milling industry exported approximately 30% of its production i.e. 60 thousand ton, 38% of which was regular maize flour and 42% maize flour with vitamins. Even though, Argentinian market share of this kind of products in the international market is not significant, it has grown significantly going from 0.39% in 2002 to 1.42% in 2009.

Finally, regarding bioethanol production in Argentina, until 2011 sugar cane was the main input used by this industry and most of its production was concentrated in the Northwest region of the country, which supplies the domestic market. However, by August 2012 ethanol made from maize and sorghum was introduced to the market. Currently, in Argentina there are two plants that deliver ethanol to the Bio-ethanol National Plan and three other under construction, which are expected to start operating in 2013. Furthermore, already six companies have assigned their quotas to enter the domestic market, but still did not begin to build their plants.

Domestic consumption in TSC

Overall, in the TSC region there are no consumption habits of maize, since the annual consumption per capita is less than 20 kg, which is mostly in the form of dry milling products e.g. polenta and snacks. On average from 2002 to 2010 maize consumption was around 1.94 million tons, 86% of which was destined to the feed industry and the rest to the food industry; presenting an annual growth rate of 5.6 and 2.3%, respectively. As mentioned before, TSC is a net exporting region, which is reflected in the volume and annual growth rate of maize exports and the declining rates of the proportion of total production that goes to the domestic consumption (food and feed). As expected, the figures do not change much when Argentina in particular is considered. Of the 16 million tons consumed in 2012, 42% was demanded by the cattle feed industry, 28% by the poultry, 16% by the dairy industry, and 4% by the pig farming industry. The remaining 10% was distributed between wet (7%) and dry milling (3%). Clearly, most of the maize production in Argentina (90%) goes to the domestic consumption of the animal feeding industry, while the rest goes to the milling sector.

During the period 1990-2010 Argentina commercial maize production (not including the forage maize), domestic consumption as well as exports grew steadily at an annual rate of 9, 8 and 13%, respectively. Clearly, exports grow at a faster rate than domestic consumption; for example, in 1990 the latter represented 50% of total production while in 2010 this figure reduced to 30%. Historically Argentine MVCS has been oriented to external markets however selling a product with low added value (commodity). Hence, one aspect that has hindered chronically production systems growth are the barriers that limit access to developed countries markets, this is the case of subsidized products. This is the case of several Argentinian agricultural products such as meat, dairy, grains (maize and sorghum), industrial by-products of the wet and dry milling, ethanol, etc. During the period 1990-2012 the Argentinian maize price FOB was on average approximately 137 US$/t, which grew at an annual rate of 5%. In the last five years Argentina exported an average of 14.4 million tons of maize to about 100 different destinations. In 2011 the exports were around 15.81 million tons of maize, most of which went to Colombia (14%), Algeria (12%), Peru (10%), Indonesia (9%), Malaysia (9%) and Egypt (7%). In February 2012 Argentina exported for the first time to China, thanks to the Phytosanitary agreement signed by these two countries.

1.6 Outlook of the MVCS in Temperate Southern Cone

SWOT Analysis of the MVCS in Argentina

Table 30. Argentina: SWOT Analysis of the MVCS.

Strengths	Weakness
• High structural and technological competitiveness • Important level of research, development and adoption of technology • Possibility to continue increasing maize yields. • Great ability to generate genuine employment, with national coverage and high impact on the communities in the interior. • Importance of maize for sustainable rotation in agriculture. • High participation in international markets with many destinations, in grains and other products. • Diversified, little concentrated and growing domestic market. • Argentine maize with nutritional quality and industrial advantages. • Existence of an Association (MAIZAR) that integrates all members of the MVCS based on trust and ongoing dialogue among its members.	• Government interventionism (discontinuous export markets, ROE, and other commercial and customs regulations). • High fiscal pressure and use of distortionary taxes for grains and derivatives (rights of export, etc.). • High investment per hectare which limit the expansion to other favorable environments • Inefficient transport infrastructure (road, rail and river) • Insufficient credit lines with rates and terms appropriate to the different links of the chain. • Insufficient storage infrastructure for the chain's requirements. • Little use, dissemination and access to market and agricultural insurance coverage tools. • Low levels of adoption of good agricultural practices, especially in relation to soil conservation. • No product differentiation by quality. • Insufficient diffusion of domestic prices at the producer and consumer level

Opportunities	Threats
• Increasing world demand for maize and derivatives. • High availability of biotechnological tools applied to the cultivation and the processing industries. • New uses of maize. High value/changes in traditional consumption habits (new materials, nutraceuticals), which would boost the development of new transformation industries. • Increased use of renewable energy local and internationally (biofuels) • Deepen linkages with other value chains to generate synergies among them.	• Tariff, barriers (technical, sanitary and phytosanitary standards) and subsidies. • More efficient approval system of genetic events. • Risk of the seed market to evolve towards a non-competitive structure. Currently, only three companies develop new events and one of them does not grant licenses on the events it generates. • Development on a commercial scale of 2nd generation biofuels.

2. MVCS in Subtropical Andean Region (STAR) - Representative Country: Peru

(Section strongly based on Huamanchuno Cecilia. 2013. The Maize Value Chain in Peru. IICA. Forthcoming)

2.1 Maize Domestic Supply in STAR

The STAR is a net importing region and as such domestic supply of maize results from the sum of domestic production plus net imports[31]. The following sections describe both components.

Maize production

As in the case of Central America, in the Subtropical Andean Region (STAR) no country is a dominant maize producer. If we just consider the total area cultivated with maize in this region Colombia covers 27%, Venezuela 22%, Ecuador 19%, Peru 19% and Bolivia 13%. On the other hand, taking into account the total maize output of this region, Venezuela, Colombia and Peru are the countries that contributes the most with 30, 25% and 21%, respectively; while Bolivia and Ecuador share is 12% each. Although diverse in several aspects, these countries share some common characteristics like agro-ecological zones where maize is cultivated and the type of maize grown in each of them. In the STAR maize is cultivated in three different natural regions: the Coast, the Forest and the Andean highlands. In all of them two predominant types of maize are grown approximately in equal proportions: yellow dent maize (YDM) and Floury Maize (FM), being the latter usually white but it can also have different colours. Although in general both types of maize were grown in approximately equal proportions, in the past decade the demand for YDM has increased at a highest pace than that of FM. In other words, YDM increased its relative importance in terms of acreage and production to approximately 60%. Geographically, YDM is mainly grown in the Coast; while fresh FM (choclo) is mostly grown in the Inter Andean Valleys and in Lowland Forest, and as dry grain it prevails in the Andean highlands. In the case of Peru, most of the maize is produced in the central and north area of both the coast and highland zone, concentrating 67% of YDM production in the latter and 71% of FM in the former.

During the period 2005-10 five crops concentrated 81% of the total agricultural production in the Andean Region, which are sugar cane (52%), bananas (9%), potatoes (7%), rice paddy (7%) and maize (5.6%). While, bananas and potatoes show an increase in their volume produced of 10%, maize's is of 5.9%. The importance of maize in the region is also reflected in the dynamic of its production value, which from 2000 to 2010 grew in absolute terms at an annual rate of 11%. Furthermore, Maize Production Value (MPV) represents 11% of the Agricultural GDP and presents an annual growth rate of 6.6% during the studied period. In economic terms maize ranks third in importance in Peru, with YDM accounting for almost 60% of the value of annual sales and FM the remaining 43%. Moreover, if the MVCS in this country is analyzed as a whole, particularly that of the YDM, its economic importance is intertwined with the poultry industry which generates 1.3 billion dollars annually in sales i.e. 50% of the gross value of the livestock production. Likewise, FM traditionally restricted to the domestic market, has started to conquer some niches in the international market, exports considered as non-traditional products, generating 2012 about US$ 21 million.

Maize has been and still is, together with potatoes, one of the most important components of the STAR population diet. On average from 2000 to 2010 total maize consumption in the region was around 2.24 million tons, 52% of which went to the feed industry, 39% to the food sector and the rest to other industries. Per capita maize consumption is estimated to be around 156 kg/year, which during the analyzed period grew at an annual rate of 6% resulting from the accelerated growth of the feed industry consumption that grew at a rate of 9% as a response of the increase in the consumption of animal proteins. Also, it is worth noting STAR is a net importing region, since for each ton of maize produced 0.88 goes to the feed consumption and 0.59 to food.

The social importance of maize for the STAR can be observed by the number of rural families whose subsistence depends on this crop. In the case of Peru, it is estimated that by 2011 52% of maize farmers produced

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31 Domestic supply is defined as: Production (Q) + Net Imports (Imports – Exports) + Initial Inventory if available. Because it must be exhausted in a given period of time, it must be identical to Consumption in its different forms including as food, as feed, as seed and as addition to the Inventory.

this crop in approximately 518,863 hectares; generating this activity 144 thousand permanents jobs, which is equivalent to 52 million of temporary jobs and 60% of the total jobs that the entire MVCS requires. The importance of maize in this region, goes beyond to the economic aspects, but it should also being analyzed from a cultural point of view, especially for the rural population of the Andes. The cultural attributes of those who engaged in maize cultivation, are expressed by the pride they have when conserving and managing ancient cultivars and practices. This gives them a high sense of identity with themselves that can be seen in various expressions of cultural heritage, such as textiles, ceramics, dance, songs and myths. In the case of Peru, by 2010 the National Institute of Culture of this country declared the "*knowledge, traditions and traditional technologies associated with maize cultivation as National Cultural Heritage*". According to that Declaration "*in the Empire of the Incas or Tahuantinsuyo maize was related to the cult to the Sun*" and from its grains was elaborated a sacred beverage (i.e. chicha) with nutritional and psychoactive benefits that has a central place in this country rituals.

Growth anatomy of maize production in STAR

During the period studied domestic maize production in the STAR was on average 1.3 million tons, which grew at the healthy annual rate of 4% mainly driven by productivity enhancing technological change but also pushed by gains in maize acreage resulting in a growth anatomy index of 1.8. However the dynamic is quite different for both types of maize grown in the region. In the case of the YDM the national production in Peru grew at an average annual rate of 5.5%, largely because of the expansion of the area cultivated rather than from technological change. In the case of the FM in the last two decades, production grew as a balance between increments in the area cultivated and low land productivity increments. Specifically in the case of the southern highland area of Peru, the significant increment of this type of maize can be attributed to the technological development of the White Giant Maize from Cuzco (*Blanco Gigante del Cuzco*). Since this is a very specific event, it cannot be extrapolated to the rest of the STAR; however the production from the center and north of the highlands can, since most of the maize produced is intended for family self-consumption or for local / regional markets.

It is worth to remark that lowland forest in Peru has a great potential and it is estimated that agricultural land can increase by incorporating more than 1.5 million hectares of "restinga[32]" soils. Part of this land can be cultivated with YDM or following the past trend with FM for its fresh consumption. In the case of dry FM its harvested area remained virtually stagnant during the last 10 years, while fresh FM (i.e. choclo) grew more than double during the same period (120%). This difference can be explained by the destiny of the production, since dry FM is mostly commercialized and demanded by rural Andean families because of its nutritional aspects; fresh FM is used for family self-consumption and has a strong link with domestic demand coming from the cities.

Besides biophysical characteristics, the differences in maize productivity levels between countries within the STAR can be primarily attributed to technology used. However, other factors that affected this crop productivity include:

i. Inappropriate use of water, soils, and indiscriminate use of agrochemicals and synthetic fertilizers associated with monoculture that affects the soils physical and chemical stability conditions

ii. Presence of rain with erratic distribution (mostly rain-fed agriculture) and the recurrence of adverse weather events (e.g. Frost, hail and drought) in the Andean region

iii. Increase in the presence of pests and diseases due to uninterrupted cycle of maize

iv. Limited progress in R&D and limited technical assistance and/or transfer of technology services

v. Weak infrastructure supporting productive services and

vi. Scanty articulation between the public and the agricultural sectors.

Maize net imports

The STAR is a net import area that shares the dilemma of all importing countries reflected in the high growth rate of the value of imports due to the impact of the high growth rate of the international maize prices. In the case of maize, from 2000 to 2012 the volume of net imports was on average 957,547 tons, which grew at

32 Sandy, acid and poor in nutrients soils covered by vegetation of characteristic herbaceous plants

an annual rate of 6.5%. Most of the maize that the region imports is yellow which represents 60% of total consumption and has an implicit price of 398 US$/t. In the specific case of Peru, for instance, in 2012 maize CIF value represented 41% of the total cereal imported value cereals; 35% of total agricultural imports and 15% of total imports. Furthermore, given that the foreign currency used for maize imports increased by six-fold during the analyzed period, the import value of YDM in Peru contributed the most (13.2%) to the value of agricultural imports, followed by soybean cakes (11.5%), wheat (10.7%) and soybean oil (9.6%). The main origin of the Peru YDM imports is Argentina, followed by the U.S, Paraguay, Brazil and Bolivia. Also, we should remark that the import industry has an oligopolistic structure since four import companies capture 67% of the market.

Although for the region maize exports have a declining trend, in the past 5 to 10 years a promising tendency has come out with increasing exports of floury or starchy maize which also have a high international price. Peru exported around 12,000 tons of this kind of maize, generating 21.7 billion dollars in foreign exchange. Half of the volume exported was Cuzco Giant White Maize, which is protected by property right mechanisms such as denomination of origin. Among the main importing countries of this type of maize are Spain (66%), Japan (17%) and the U.S. (14%). Finally, STAR countries have made significant progress in signing trade agreements and hence opening their economies to foreign markets. This is the case of MERCOSUR and the Pacific Basin Trade Agreement in addition to individual bilateral agreements. This is the case of Peru which in the past decade signed important agreements with the US, China, Canada and Singapore.

Maize producers

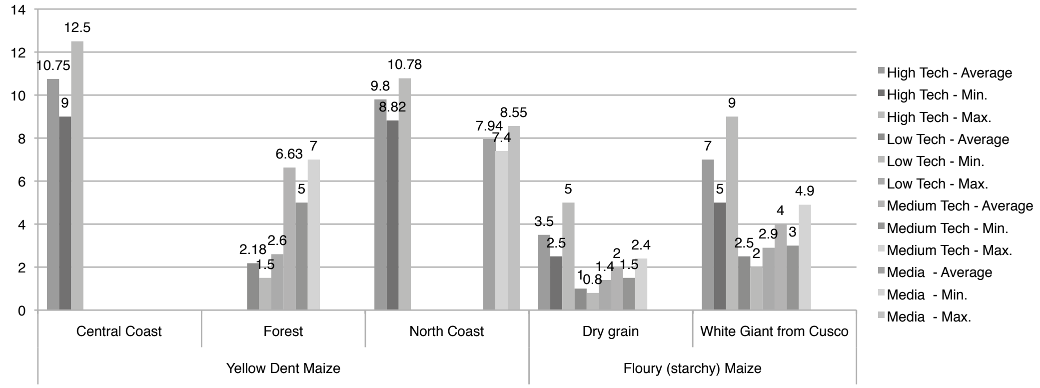
Most of the maize production that takes place in the STAR is conducted by small farming business. This situation is illustrated by the farm structure in Peru where almost 66% of maize is produced by farmers who own less than 5 hectares and about 25%, who are considered medium sized farmers, have between 5 and 20 has. Around 33% of this latter group of farmers produce YDM and 16% of them FM. Note that in this country commercial intensive farming predominates in the Coast, who represents less than 9% of the total farms. Also, farm size determines the type of maize to be produced, for example in Peru 81% of FM and 51% of YDM producers own less than 5 hectares. One important characteristic of the agricultural producer in Peru is their low levels of education, 33% of who have not even completed their primary education and 13% do not have any studies. The situation however is different across regions and type of maize produced. For instance, in the north and south Peruvian coast, where most YDM is grown, more than half of maize producers have at least secondary education and in some cases higher education; while farmers located in the Andean Highland, where FM is grown, farmers have even lower education levels. Nevertheless, another factor to consider when interpreting this situation is related with cultural differences between regions.

In the case of Peru, small maize producers are characterized by their low levels of integration to markets, limited sources of income, insufficient capital endowment (land, livestock, tools, agricultural equipment, machinery, and credit), intensive use of family labor, virtually no access inputs, services and markets. On the other hand, medium-sized maize farmer's main features include a greater degree of market articulation; better access to technology, technical assistance, resources and services. Finally, large commercial farms are fully articulated to the markets and employed high level of technologies.

Maize production systems and technology use

In Peru YDM can be produced all year long, although September is the month that most of this kind of maize is sown, covering 16% of the area with it. However FM is particularly sown in October when about 31% of the area is planted with this type of maize. Consequently, YDM production is available in the markets all the year, with a small peak in November (13%); while FM production reaches its peaks in May (29%) and June (35%). Regarding the production systems used in this country, three levels of technological development can be found, high, medium and low; this is the case specifically for YDM producers in the coast. In the case of FM, two main producing systems dominate, a traditional system, used by most of the farmers; and a high yield modern system used by farmers who produce the Cuzco Giant White Maize. These technology differences are reflected in maize yield as illustrated in Figure 17.

Figure 17. Peru: Average yields of maize, by region, type and technology used. 2011



Source:Huamanchuno 2013.

The production system used in Peru by most farmers are low in technology, which means that they do not use used improved seed; apply low levels of fertilization which consists of adding small quantities of nitrogen to the soil; they also use cheap and sometimes forbidden agrochemicals to combat pests; and usually they just use family labor and animal power for land preparation (Table 31.). On the other hand, medium-technology producers use national hybrids due to its low unitary costs as well their low retail prices, since a bag that contains 75,000 seed produced locally costs 135 US$, while an imported bag costs 215 US$. This kind of farmers use urea as the main and only source of nutrients and their usage of agricultural machinery is limited due to the service high costs (200 US$ /hour/machinery/ha for seeding and fertilization). Finally those farmers who use high technology regularly buy large quantities of imported hybrid seed, apply high levels of fertilization with doses of macro-elements and micro-nutrients in response to the results of soil and/or foliar analysis; and they also make preventative applications of agrochemical. In this type of commercial agriculture, most activities (e.g. land preparation, sowing, hilling and harvesting) are mechanized reducing substantially the quantity of labor used by hectare.

Figure 31. Peru: Maize production structure by technological level in the STAR

Input	Low technology		Medium (transition)		Modern (high) Technology	
	Type	Amount	Type	Amount	Type	Amount
Seed	Local	25-30 Kg	Certified National	75,000 seeds	Imported hybrid	60,000 seeds
Fertilizer	Urea	4 bags	Urea	12 bags	Urea Ammonium sulfate Sulfomag (k)	12 bags 4 bags 4 bags
Agro-chemical	unknown	Up to 5 applications	Insecticides & herbicides	Up to 7 applications	Insecticides herbicides & adherents	Up to 3 applications
Machinery	Land prep. & Planting	25 hrs animal traction	Limited access due to high costs	4-6 hrs	Land prep.& Planting	5-7 hrs machinery

Labor	Family	135 men days	Familiy & hired	120 men days	Hired	90-110 men days
Irrgation	Gravity	Little if any availability	Gravity	7,200 m^3/year/ha	Technical irrigation	4,400 m3/year/ha
Yield	**< 4; Average 2.2 t/ha**		**Min 4, Av. 6, Max 8 t/ha**		**> 8; Average: 9.5 t/ha**	

Source:Huamanchuno 2013.

Factors associated with maize technology use

The main factors that affect farmer's decision to adopt a new technology, in both the STAR and CA regions, include farmer's lack or limited access to information about technology, markets and prices; high costs of adopting new technologies, limited access to resources (e.g. land, water, services); type of farming system; quality of resources; as well as training, motivation and involvement level of the different social actors. Low working capital available to farmers at the beginning of each agricultural cycle hampers their access to inputs and services which can contribute to a better technical and efficient crop management. Clearly, most of these factors point out the current symptomatic dissociation that exists in the process of generating and transferring technologies, which in most of the cases are not adjusted to the farmers' circumstances and thus have limited access. The other factors are particularly important to determine the adoption of soil and other natural resources conservation practices.

Moreover, socio-cultural factors in the STAR, especially in the Andes, play an important role in determining the adoption level of any technology. In this context, the assessment of ancestral practices of maize cultivation in many cases weight more than external technical recommendations. Hence, cultural aspects may explain small farmer's low predisposition to adopt new technologies generated and diffused with a completely different vision of the world (Sain and Calvo 2012). Among the main institutional factors that affect maize productivity the insufficient progress in the R&D sector is a vital one. In this sense, a greater involvement of the private sector to transfer technology linked mainly to the use of hybrid seeds is necessary. Another important institutional factor is the low levels of development of agricultural support markets, such as machinery services, credit and specialized technical assistance. This situation increases these services prices significantly and makes them therefore, inaccessible for a large part of the maize farming population.

Economics of maize production

The economics of maize production in the coast of Peru (Table 32) indicates that only the use of modern high technology makes maize production profitable according to the benefit cost ratio. It must be taking into account, however, that in the case of small farming most of the labor cost incurred in maize production is family labor.

Table 32. Peru: Cost structure and benefit of YDM production in the Coast region. 2012.

Item	Cost by technological level		
	Low	Medium	Modern (high)
Seed	50	161	140
Fertilizer	136	408	585
Agro-chemical	110	200	120
Machinery	80	320	260
Labor	1,298	1,154	1,057
Irrigation	35	55	30

Transport	90	190	120
Indirect cost (Technical assistance)	0	0	65
Total costs US$/ha	**1,799**	**2,488**	**2,377**
Average yield (t/ha)	2.2	6	9.5
Farm price (US$/t)		327	327
Gross benefit ($/ha)		**1,962**	**3,106.50**
Net benefit ($/ha)		-526	729.5
B/C ratio		**-21**	**30.7**

Source:Huamanchuno 2013.

2.2. Maize Inputs, Service Markets in STAR

Maize seed supply

The use of improved seed varieties (IMV) is not widespread in the case of Peru, especially in the case of FM where 95% of farmers use their own seed they produced using traditional methods carried out by themselves, and in most cases also trade seed with their neighbors or sold in local markets. There is however little information in how this market works. In the case of YDM production, its seed demand is estimated to be around 7,570 tons per year, 60% of which is covered with non-certified seeds, 31% with imported seeds and the remaining 9% with national certified (INIA, 2013). By 2012 the quantity of imported seed as well as domestic certified seed, compared to from the analyzed period, increase by 36 and 4% respectively. Even though in Peru there are 23 companies that produced seed, this industry shows an oligopolistic structure given that only two dominant firms control almost 66% of the total seed production i.e. Agrhicol SAC and Pro-Semillas SAC (12%). The national certified seed production capacity is however still incipient, since in the last five years the national production covered only 8.5% of the total seed demand. In general, seed production in Peru is oriented to the production of Open Pollinated Varieties (OPV) rather to hybrid materials, concentrating the former 81% of the production and the latter 19%.

The countries from which Peru buys most of the hybrid seed include Brazil, Argentina, Chile and Colombia. Around 41% of these imports are made by four private companies: which have a Concentration Ratio of ICR2 of 41 and ICR4 of 70. While hybrid seed is used in the Coast of Peru, in the Highland and in the Forest prevail the use of OPVs, although the substantial grow of the poultry industry in the Forest has pushed up the demand for hybrid seed at the farmer level. The most commonly used seeds in this country are Cargill C-408, C-606, C-701, AGROCERES, PM-212, PM -104, Dekalb - 821-834, 3041 PIONEER, Master NK, Semeali XB7011 and AG-612. Regarding genetically modified seeds, by December 2011 the Peruvian government approved the law 29811, which prohibits the production and introduction in the national territory of live modified organisms (LMOS) for a period of ten years either for farming or breeding purposes. The law may have implications in the seed importing market given that this law implies a zero tolerance regime. Although the producers recognize the importance of the use of a good seed to achieve higher levels of productivity, the use of new varieties are determined by the mistrust farmers have towards commercial seed; high prices of imported seeds, predominance of smallholdings, lack of organization of small producers; absence of technical assistance programs; characteristic of the Peruvian Amazon soils (i.e. Low tolerance to acidity); and in the case of FM is important to consider cultural and culinary aspects.

Non-specific inputs

There are no detail statistics about the use of other inputs other than seed (i.e. nonspecific inputs) to maize production, for that reason aggregated statistics should be interpreted with caution. Overall the STAR region is a fertilizer net exporter region although during the analyzed period (2002-10) nutrient consumption grew at a higher rate (5.6%) than its production (4.4%). In other words, for each ton of nutrient, mostly N, that the region exports 0.27 tons is imported. Nitrogenous is the fertilizer that is mostly produced and consumed, given that 86% of the total production corresponds to it and 57% of the total consumption (FAOstat, 2012). However, Phosphorous (P2O5) is the fertilizers that its production has increased significantly in the past decade, growing at an annual rate of 22%. As a whole the region uses annually about 186 kg of nutrient per hectare, consumption that positions it right after TSC region.

The case of Peru is different to the regional trend, since it is a net fertilizer importer given that 98% of the fertilizers available in this country come mainly from Russia and the U.S. Approximately 71% of the total imported volume in 2012 were concentrated in two companies, i.e. the structure of the fertilizer import market is oligopolistic. Prices of these fertilizers have shown an upward trend since the beginning of the last decade until 2009, when they dropped due to the international crisis, to gradually reverses from 2010 to the present. Increasing these prices on average by 238% from 2000 to 2012, reaching during the latter an average price of 572.7 US$/kg. It is worth noting that Peru marketing channels have a wide coverage, being thus very efficient in their national distribution. Specifically in the case of maize production, most of the fertilizer demand comes from YDM producers, who also use improved seed. Fertilizer application also depends on the maize production region, i.e. farmers in the coast an average apply of 2 bags of urea, while 81% of farmers in the forest and 31% in the Highland do not apply any fertilizer to maize production.

During the studied period it can be observed that in the STAR as a whole the annual use of pesticides has been stagnated at 4.9 and 7.4 kg/ha in the case of Fungicides and Bactericides and herbicides, respectively. However, the intensity of insecticide use (i.e. 3.3 kg/ha) has increased at an annual rate close to 3%. These trends however have differences at the country level, reflecting technical levels. For instance, in the case of Peru, on average 60% of maize producers do not spend any money on pesticides or insecticides. Regarding machinery and agricultural equipment usage, all the tillage work is carried out by most of maize producers manually or with animal traction, particularly in the Andes Highland. In Peru is estimated that half of maize farmers tend to rent machinery services, mostly in the Cost region of the country. Although there is not specific information on maize irrigation in the STAR, given the crop low productivity levels, it can be stated that access to water is a problem. In the case of Peru about 70% of the agricultural area is produced under rain fed conditions, 27% under gravity irrigation, and 3% under technical irrigation[33]. Consequently, much of the cultivated maize is done under rain fed conditions, system that predominates in the forest (96.1%) and Highland (85.1%); given that the Coast is the region that has better irrigation infrastructure.

Supply of other services and production factors

The provision of financial services to agricultural activities in Peru is quite inefficient. It is estimated that in this country only 3% of the total direct loans made by the national financial system goes to the agricultural sector. Additionally, small farmers are not used to rely on the financial system and given the difficulty to access to it, they recur to different sources of credit e.g. relatives, wholesalers. Regarding labor in small scale agriculture such that predominant in the STAR, this is a key production factor. According to the production structure in Peru about 90% of the total labour used to grow maize is family labour and the rest is hired[34]. Lastly, according to infrastructure services, in accordance with the Global Competitive Report (2011), the quality of roads, ports, airports, and railways infrastructure in Peru are deficient, ranking below other Latin America countries such as Brazil, Argentina, Chile and Uruguay. With respect with information and communications technologies, in LAC a general trend to adopt it is observed. For example, the num ber of telephone lines in Peru grew from a low 3 per 100 inhabitants in 1992 to 118 in 2011. Cell phones also have an impressive dynamic, given that in 2004 around 2% of the households owned at least one, in 2012 this participation was at 54%. Also, by mid-2012, almost all of the 1,833 districts nationwide had access to internet and 9.9% of rural families reported having access to the internet, using it at least once a week.

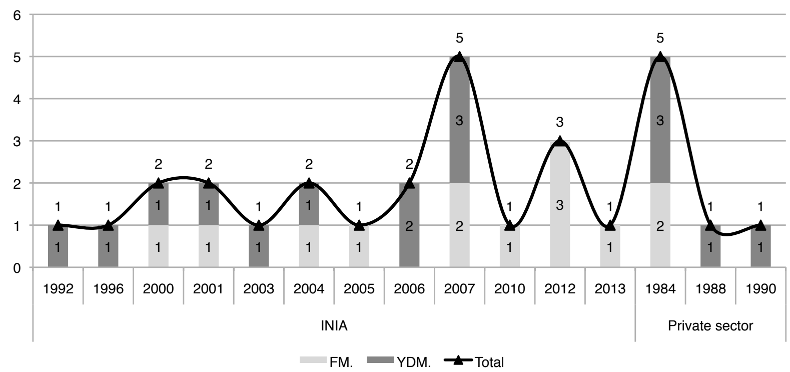
33 Technical irrigation encompasses all irrigation techniques but flooding.

34 In Peru farmers uses a labor exchange system among neighbor farmers called “minga”

Maize Research and Development System in STAR

Up to the mid 80's maize technological supply in Peru consisted of 29 cultivars that were released by the National Agricultural Research Institute (NARI), and since 1983 the private sector realized and registered around 61 cultivars. The main feature of these cultivars is their resistance to pests and diseases (e.g. fusarium), high productivity potential and tolerance to acidity, a common characteristic of the Peruvian Amazon soils. The private sector began to play an important role in the introduction of cultivars in this country since the mid-1980 until today. For instance since 1986 this sector registered 59 cultivars while the public sector registered only 13. Given the large diversity of micro-climates that characterize countries in the STAR region, particularly in Peru, it is no surprise the existence of a wide range of cultivars; since the yield potential, adaptability and agronomic quality can vary significantly from one place to another. It should be noted that agricultural technical assistance in Peru has traditionally been provided by the public sector and by projects led by NGOs. However in the case of the production of YDM on the coast and forest, commercial houses play an important role of providing not only inputs, such as fertilizers, agrochemicals and seeds, but also technical assistance. From 1984 to 2013 in total 29 cultivars were released, 15 of them corresponded to FM and 14 to YDM, although the use of the former is more extended than the latter. The public sector released 76% of these cultivars, which on average are more productive on the fields than the ones generated by the private sector. For instance the highest yield generated by FM public varieties in 2012 were on average 8.8 t/ha, while the most productive private varieties reached only 1.81 t/ha .

Figure 18. Peru: Number of improved maize varieties released. 1984 -2013



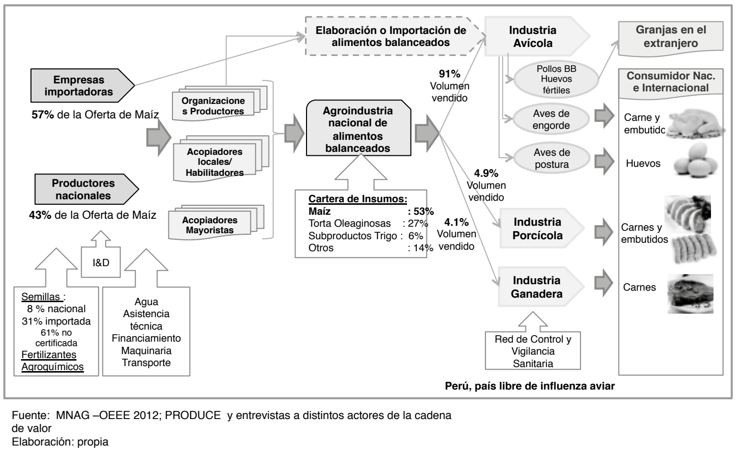
Source:Huamanchuno 2013.

2.3. Maize Processing Agroindustry and Consumption in STAR

Stylized structure of maize marketing system

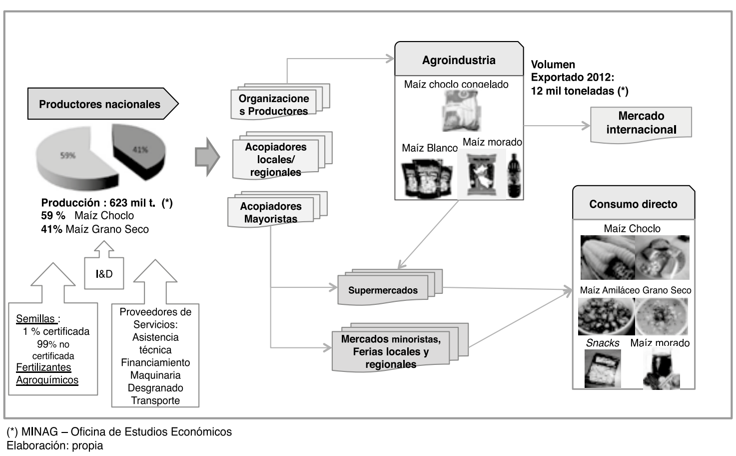
One of the features that the maize value chain system in Peru has is the informality of its agents, which translates in distorted prices. These actors are usually, collectors/transporters and companies that buy maize at the farm gate and sell it to manufacturers companies that produce animal feed in the case of the YDM and to regional local fairs and supermarkets in the case of FM. Other important characteristics of the marketing system include the high level of concentration in some stages of the chain, farmer's low bargaining power, informal entrance barriers at critical marketing points (e.g. wholesale markets) and the poor marketing infrastructure. Figure 19 and Figure 20 illustrate in a stylized way the marketing system for both the YDM and FM in Peru.

Figure 19. Stylized scheme of the MVCS of yellow dent maize in Peru



Source:Huamanchuno 2013.

Figure 20. Stylized scheme of the MVCS of floury (starchy) maize in Peru



Source:Huamanchuno 2013.

Main Participating agents in the MVCS in STAR

Maize producers

In general maize producers, of both floury and yellow dent maize, are small subsistence farmers living in rural areas especially in the Andean highlands and who consume most of their production for self-consumption. These farmers are characterized by the poor living conditions they have, low levels of education, poor business capacity and limited bargaining power within the MVCS. An interesting feature of FM producers is that most of them belong to an indigenous ethnic group and continue cultivating this type of maize using traditional practices inherited from their ancestors. As a result, maize productivity is highly variable with average yield ranging from 1.25 to 6 t/ha as well as quality which dos not satisfy standards that the market demands. In Peru, YDM producers are better organized than the FM producers since they form part of the “National Association of Maize and Sorghum” which is the most representative association at the national level. This Association brings together 16 committees and/or regional associations of producers of maize and sorghum (i.e. 73% of the country’s departments).

However, it is worth mentioning that the structure of the FM production, formed by dry and fresh grain (choclo), has changed in the last 20 years. In the past, there was more production of dry grain (59%) since it was mostly used for self-consumption by Andean producers; however, nowadays, this participation is exactly the opposite. This dynamic is consistent with the decrease of FM dry grain consumption; which dropped from 18 kg/person in the '50s to 8.7 kg/ person in 2009. Clearly the demand growth of FM for choclo pressured the market supply to provide more and better inputs and services, which translates into a greater seed production of for this type of maize.

Marketing and consumers

The distribution channels for maize in Peru depends on the type of grain we are referring to. In the case of FM retailers sell the product through basically two marketing channels, either directly in regional markets and/or to wholesale markets that generally are close to the production areas. On the other side, YDM is marketed mainly by collectors, distributors and wholesalers that come to the production areas to buy directly to the maize producer volumes that are attractive for marketing in regional markets as well as for different industries (e.g. food, animal feed). These agents are usually located in areas close to their main consumers, such us the poultry and pork industries, and big cities.

The agro-industry which uses floury maize as input has experienced remarkable growth in recent years in both domestic and international markets. Regarding the YDM the feed industry is the one that demands the most of type of maize, using in 2012 around 3.22 million 57% of which were imported and the rest is satisfied with domestic production. Even though, the poultry industry prefers feed elaborated with local YDM given its high protein and good concentration of carotene, most of the feed used are made with imported grain because of low levels of domestic production and the expanding demand of this industry. The poultry sector in Peru is composed by approximately of 180 agro-industrial enterprises and the pork meat industry by 65 companies.

The main forms of FM consumption in this country are either fresh as "choclo" and/or processed. Per capita consumption may differ according to the geographical area, hence it is estimated that the annual consumption in rural areas is on average 12.6 kg/person, while in the urban areas it reaches only 2.9 kg/person. Moreover annual per capita consumption of FM is greater in the Highland areas with 10.5 kg, which is five times higher than in that in the forest (2.5 kg) and in the coast (2.3 kg). Regarding YDM human consumption, this is indirect made through the consumption of animal protein either from poultry or pig meat.

Maize consumption

The average maize consumption in the STAR from 2000 to 2012 was around 2.24 million tons, quantity that grew at an annual rate of 6.2%, which is higher than the rate at which the population grew. This is the result of the indirect consumption of maize as input by the feed industry that is the result of an increasing consumption of animal proteins mainly from poultry meat. More than 50% of this consumption was demanded by the feed industry. On average per capita maize consumption in the region is approximately 156.4 kg/year and specifically in the case of feed consumption it is around 46 kg/year.

Floury or starchy maize along with potato and rice, are central components of the diet of an important part of the STAR, particularly in the Highlands. This is the case in Peru, where 91% of FM production is self-consumed by producers, marketing the rest. Additionally, with the revaluation of this traditional crop, per capita consumption of FM went from 8.6 kg/ year in 2007 to 9.7 in 2011. On the other hand, the importance of YDM lies on the increasing national demand of poultry and eggs; given this it is the main input to produced animal feed used by this industry i.e. 68% of the feed diet is composed by this type of maize[35]. Additionally some percentage, still small, of YDM is used for human consumption in the form of flour and flakes, among others. By 2013 it is estimated that the consumption of YDM in 2013 will be around 3.5 million tons.

35 Chicken meat is a basic component in the diet of Peruvians, consuming about 34 kg of poultry meat per person per year; which means a demand for 44 million chickens a month

Maize pricing structure

One important indicator of the marketing system is the pricing structure of the system and in particular the marketing margins[36] defined as the relationship between the margins that wholesalers get with respect to the price farmers receive; the larger the relative increase the more expensive is the marketing system. Based on the marketing margins estimated for the main types of maize produced in Peru, it can be observed that YDM is the lowest with a value of 64.2%, which means that for each US$ that a farmer receives a wholesaler gets 0.642 US$. On the other hand, in both cases dry and fresh FM their margins have a value of 137.9 and 206.9%, respectively. These values do not reflect only marketing costs related to the difficult of collecting grain in the prevalent production structures, but also maize producers bargaining power. In general, since YDM producers have higher education, some degree of associativity and some economic power, they have larger bargaining power than FM grain producers.

2.4. Outlook of the MVCS in STAR

Limiting factors to the growth of productivity and efficiency in STAR

The STAR region shares most if not all of the 8 limiting factors listed for the CA region: Low level of technological innovation and technology adoption; deficient infrastructure sector support; low value-added production, uncertain land tenure; restrictions to access rural finance services; increasing vulnerability to the effects of GCC; and increasing degradation of natural resources, land and water.

Research and development priorities in the maize sector

Some of the main areas that need to be address in the maize production sector include maize breeding, crop management, technology transfer, better policies and strong public programs that support local maize production and industry with and active participation or regional and national governments. Specifically, depending on the region the maize varieties needed may vary, for instance, in the Coast region hybrids and QPM varieties with high yields are needed, in the Forest synthetic varieties adapted to *restingas soil* and in the Highlands synthetic, open pollinated and freeze tolerant varieties are required. Regarding crop management it is vital to generate technologies to produce in *restinga soils*, develop modern fertilization techniques in order to apply optimum doses, as well as improve soil conservation technologies. Additionally, it is vital to generate massive technology transfer mechanisms that increase small and medium-sized agriculture access to them, while understanding and using ancient farmer's production knowledge as well as the genetic diversity in the area.

36 (Wholesale price – Farm price)/Farm price

Constraints and opportunities in the maize sector

Table 33. Peru: SWOT analysis for the MVCS.

Strengths	Weakness
- Climate, biodiversity and capability to produce all year long - Coastal valleys have permanent access to irrigation water - Modern technology and infrastructure for irrigation accompanied by public-private investments - Public programs incentivizing technology adoption - Existence of large genetic variability and types of FM. - Increasing use of improved seed in the case of YDM due to a greater seed availability - Official recognition of the denomination of origin for the "Cuzco White Giant Maize" (2005).	- Excessive smallholding, a feature of national agriculture. - Inefficient marketing structure: #farmers > # small buyers - High transaction costs and constraints to productive investment - Limited access to public and private supporting services - Insufficient supply of improved seeds and low levels of adoption. - Low productive stability of hybrid seeds with respect the broad existing microclimates - Often maize production does not comply with the phytosanitary and zoosanitary requirements from the final markets - Maize producers have low levels of education, organization and managerial abilities. - Low added value given to maize production
Opportunities	**Threats**
- Possibility of incorporating large tracts of land for cultivation in the Coast, Forest and Highland - Sustained demand for YDM from the growing poultry industry, as well as for FM fresh as choclo. - Opening of new markets e.g. biofuels - Government interest to strengthen the agricultural innovation system, as well as the institutional support to national, regional and local levels - Promote the consumption of Andean grains, and cereals such as FM - Growth in demand for FM in different forms.	- New markets are demanding quality, timely deliveries and economies of scale - Imminent shortage in the supply of imported hybrids due to regulations that limit the entry of transgenic seeds with a scheme of zero tolerance - Rising prices of agricultural commodities and the increase use of biofuels brings problems of shortage of domestic food supply, and thus affecting overall national food security.

Source:Huamanchuno 2013.

3. MVCS in Tropical Central America (TCA) - Representative Country: Guatemala

(Seccion strongly based on Reyes Hernández M. 2013., and Sain et.al., 2002)

3.1 Maize Domestic Supply

Central America is a net importing region and as such domestic supply of maize results from the sum of domestic production plus net imports. The following sections describe both components.

Maize production and net imports

In Central America maize ranks fourth in importance, after sugar cane, bananas and oil palm fruit. These four crops together with vegetables encompass 94% of the crop volume produced by the region. Although the value of maize production relative to the Agricultural GDP is only 7%, its economic importance should not be underestimated, given that during the period 2000-10 it grew at annual rate of 6.5%, and that this crop is harvested by a large number of farms in Guatemala, Honduras, El Salvador and Nicaragua, accounting for almost half of the area assigned to annual crops in CA. Furthermore the social and cultural importance of maize production in Central America is very significant, given that this crop is a vital component of peoples' diet especially in the three main producing countries, Guatemala, El Salvador and Honduras, dating back to pre-Columbian times. Currently maize jointly with beans continues to be an essential food for the CA population particularly in the diet of the poor. It is estimated that the current average consumption per capita is 149[37] kg per year, however there are important differences across countries. As moving south, the importance of maize in human consumption diminishes and that of rice increases. Hence, in Panama and Costa Rica maize is not an important component of their diets while in Guatemala it is estimated that it provides almost 40% of total calories; similar percent can be observed in Honduras, El Salvador and Nicaragua. Finally, culturally maize relevance goes back many centuries before the Spanish conquered America. The relationship of indigenous people with maize is based on respect, so according to their mythology, without it, human beings would not exist (Popol Vuh, 1960).

Three countries in Central America produce about 93% of this region total maize production, Guatemala is the leading producer with 45% of the regional offer, while El Salvador and Honduras contribute each with approximately 20%, and Nicaragua with 8%. Given that Costa Rica, Panama and Belize differ in important productive, economic and social characteristics, the Central America MVCS characterization made based on Guatemala maize production applies specifically to the main maize producers in the region. Maize production in Guatemala takes places in all 22 Departments (i.e. districts) that comprise this country, covering at least two agro ecological regions: Low tropical (<1,500 masl) and Highland (> 1,500 masl). Approximately 70% of the maize producing area can be found in the low tropical area, mostly where humidity is favorable. The Highland zone is usually divided into two: one transitional between 1500 and 1800 meters above sea level (masl) and other above 1,800 masl, where the production of Floury or starchy maize of different colors predominates and are mostly cultivated by the indigenous population using traditional cultivation techniques.

The production of white maize in Guatemala concentrates in the Low tropical zone, especially where humidity is favorable, and covers the Departments of Peten, Alta Verapaz and Jutiapa. In the case of yellow maize production it predominates in the Low tropical zone where humidity is limited and covers the Departments of Huehuetenango and Quiche. Petén is the Department where maize production area is growing significantly given that the agricultural frontier advances over the forest and the savanna; producing on average 187,103 tons. Together with Petén, maize production area in Alta Verapaz, Jutiapa and Quiche grew at an annual rate of 53% during the period 2000 -2010. The remaining Departments follow a stagnant or declining trend in the area cropped with maize, mainly due to high prices of land and competition with other crops.

Given that there are no specific figures on the level of employment in maize production for Central America, they were indirectly estimated assuming fixed coefficients by multiplying average use of labor per hectare for the average area planted per year. This calculation showed that maize cultivation occupies around 44

37 Consumption defined as Production plus net imports (IICA RedSICTA 2007)

million of temporary jobs per year or approximately 245,000 permanent jobs per year. Although, these figures are not necessarily reflected in the labor market statistics since much of this labor requirement is fulfilled with family labor; its magnitude sheds light on the importance of maize cultivation in agricultural employment in the region. By 2012 approximately 4.1 million[38] people were economically active in agriculture.

During the period 2000–10 maize production grew in Central America at an annual rate of 3.4%, which is much higher than that of the population (1.8%). Dissecting the production growth rate by its area and yield components reveals that production growth was driven by both, mostly by maize yield, even though there has been some increase in the cultivated area. However, this growth pattern is not the same for all countries in the region. For example in Guatemala, maize yield remains almost stagnant in the mentioned period but the area sown with maize grew at a rate of almost 4% as a response to high maize prices and agricultural frontier expansion, mostly in the Department of Petén.

The other main component of the domestic supply is the amount of net imports. Although exports in the last 12 years have been steadily growing at an annual rate of 8.7%, which is greater than the rate at which imports grew (5.1%); they are not important in CA (exports represent just 4% of maize imports). Imports steady growth is consistent with the differential in the increment in maize consumption over domestic production. Almost all the imports are composed by yellow dent maize (YDM) imported form the USA. The problem that CA faces, as many developing regions, is that importing prices are growing at an annual pace of 7% putting a growing burden on the already weak countries finances.

Maize producers

There is scanty information about the structure of maize producers in Central America due to the lack of censuses data. At the beginning of the 90's, approximately 78% from the 1.7 million of farmers were involved in the production of four basic grains: maize, beans, rice, and sorghum (CEPAL, 1994). Of the total area dedicated to these basic grains 60% was cultivated with maize and the rest was roughly in equal parts among the other three grains. Given that in Central America is a mountainous region, where more than 75% of the total area has slops and predominance of poor degraded soils; farming land is a scared resource. It is estimated that 63% of farmers who produce maize, beans, rice, and sorghum are categorized as "micro-farms" given that they produce in less than 1 hectare, and the rest of the farmer who produce in less than 3 hectares are considered "sub-family farmers". For this report both categories are encompassed in one called "small farms". Based on this figures, we conclude that almost 80% of all maize producers in CA own on average less than 3 has (Deve, 1990). The importance of small-scale maize farming is exposed when considering that is conducted in 60% of total maize acreage providing with almost 60% of total maize production in CA.

Maize production systems and technology use

Most of maize in CA is cultivated as a single crop, although is estimated that one third of the acreage is sown in association with beans or sorghum. By far the type of maize that is commonly produced in the region is White Dent Maize (WDM), followed by Yellow Dent Maize (YDM) that covers one fourth of the area cultivated, and in some areas, like Guatemala Highland, Floury Maize (FM) is also cultivated (Reyes, 2013). In response to topography and climate factors, which determine consequently access to technology, there are two maize production systems used in Central America (Sanders and Lopez-Pereira 1996). One of them is the traditional system, where small-scale farmers produce basic grains in sloped areas, using very few purchased inputs and crop management practices. The other production system is used by medium and large scale farmers generally in valleys and other areas of high potential, usually as part of a diversified operation. These farmers normally purchase improved seed and fertilizers.

It is estimated that in CA around 60% of maize production comes from the traditional system. However, this figure hides large variability of how maize is produced; which according to Sain et al. (2002) it can be done using three technological levels: traditional, transitional and modern. The traditional subsistence sector that provides about 50% of total production coexisting with a modern commercial and a transitional sector of small farming migrating or adopting modern technology; that provide 42 and 8% of the total maize produced, respectively. Another variable that also differentiates these

38 IICA RedSICTA 2007 based on a total maize acreage of 1.8 millions hectares per year.

production systems is the final destination of the maize produced. It is estimated that on the average small farms consume 52% of their annual production and sell the rest. This share varies across countries and farm size; for instance there is an inverse relationship between farm size and quantity of maize that produces keep for self-consumption. It conclusion, two predominant technological levels among maize producers in CA can be found. On one side there is a traditional system that co-existing with a commercial system and with a migrating sector in the middle of them. In the following table the technology structure used by each of the three maize production systems in CA are presented.

Figure 34. Technological levels in maize production in Central America

Actividad	**Technological level**		
	Traditional	**Transition**	**Modern**
Land preparation	Slash and burning	Slash plus 1 herbicide application	Mechanized
Planting			
Spatial arrangement	Square 1x1	In rows	In row2
Plant density (miles de pl/ha)	40	50	60
Type of seed	Recycled OPV	Commercial OPV	HYB
Fertilization			
Applications (Number)	1	2	3
Doses N (Kg./ha)	30	60	100
Doses P (Kg./ha)	0	20	40
Weed control			
Type	Manual	Chemical	Chemical
Number	2	3	3
Soil insect control (No)	0	23	3
Foliage insect control (No)	0	2	3
Harvest type	Manual (field bending)		Manual (storage)
Average yield (t/ha) [3]	**1.3**	**2.3**	**3.6**

Source: Sain et al. 2002

Factors associated with maize technology use

Almost all of maize produced in Central America is grown in a tropical or subtropical atmosphere at altitudes ranging from 500 meters above sea level to 1800 (Dowswell et to the. 1996). Some of the features that give CA its unique conditions for the development of biotic and abiotic factors that limit maize productivity include short duration of solar radiation, and high levels of temperatures (25 to 28 ^{o}C), relative humidity and precipitation. Among the most important biotic factors in the region that affect maize production are the presence of insects (e.g. blind man, screwworm) and fast and aggressive growth of weeds, fungi (e.g. *Perenosclerospora spp.*), rot stem and cob, Helmynthosporium maydis, maize stunt, and others; that require preventive controls as well as maize that are genetically tolerant to these diseases. Regarding abiotic factors the most important include limited amount of solar radiation and drought or lack of water availability.

Several factors have been mentioned in the literature to explain the predominance of a relatively low use of modern technology for maize production in Central America in general including Guatemala. Many studies explain that the low use of improved seed in Central America, particularly Guatemala, is associated to its availability, producer's lack of knowledge of its benefits as well as its tasting and marketing characteristics; and in the case of hybrids the fact that the seed must be bought each planting season. Fertilizers are applied by almost all maize producers in different dosages, particularly nitrogen and phosphorous. The main factors that influence the low use of pesticides include high prices and availability; as well as limited knowledge about its use (e.g. appropriate doses). Regarding use of herbicide use, this is quite low given that the relative high endowment of family labor allows for manually weed control.

Furthermore, among the main factors that affect farmer's decision to adopt a new technology Central America include farmer's lack or limited access to information about technology, markets and prices; high costs of adopting new technologies, limited access to resources (e.g. land, water, services); type of farming system; quality of resources; as well as training, motivation and involvement level of the different social actors. Low working capital available to farmers at the beginning of each agricultural cycle hampers their access to inputs and services which can contribute to a better technical and efficient crop management (Sain 2011). Clearly, most of these factors point out the current symptomatic dissociation that exists in the process of generating and transferring technologies, which in most of the cases are not adjusted to the farmers' circumstances and thus have limited access. The other factors are particularly important to determine the adoption of soil and other natural resources conservation practices.

Also government policy with respect to basic grain (including maize) production affects farmer's technology adoption. During the 90's, characterized with low international prices and the policy reforms in place, maize domestic production in the region was discouraged by severely reducing the budget of public institutions responsible for agricultural research, development and transfer of new technology. For instance, in Guatemala the national agricultural extension service was closed until 2010. In the last decade, however, high international price and food security concerns pushed government policies in the opposite direction. One example of this change can be observed in the implementation of the Guatemalan National Fertilizer Program started in 2000, which aimed to boost productivity by providing small farming a quintal (45.36 kg) of fertilizer formulas such us: 20-20-0 or 15-15 - 15 and a quintal of urea (46-0-0). On average, during the period 2001-2012 this Program distributed an average 86,782 tons of fertilizer per year, representing 14% of the apparent national fertilizer consumption in 2012. It is estimated that 94.6% of the total beneficiaries apply the fertilizer to maize (Reyes Hernandez 2013).

Economics of maize production

During the production cycle 2002-03 maize production cost in Central America ranged from 108 to 275 US$/t. In the case of Guatemala, maize production cost for the year 2011-12 was around 223 US$/t, 35% of which comes from inputs purchasing (fertilizers, herbicides and pesticides), 29% from labor used for input application and manual harvest; and 26% from mechanical land preparation.

Average unit costs of maize production in Central America are strongly correlated with the level of technology, which in turn is correlated with the structure of domestic supply and the level of agricultural wages. The larger the share of the traditional peasant sector in the composition of domestic supply, the higher unitary cost of production will be; lowering this way the probability of being competitive in a given market. In the following table the estimated cost structure for each of the three identified technological systems can be observed, as well as the weighted[39] average for the CA region (Sain et al. 2002). It is worth to remark that although the modern system has the higher production cost, it has the highest yields and consequently the lower average cost.

39 Corresponds to the relative importance of each technology in terms of the number of firms using them.

Figure 35. Cost structure of maize production at three technological level in CA

Activity	Cost in us$ by technological level 2000 – 02			Weighted average
	Traditional	Transition	Modern	
Land preparation	31	55.4	83.5	
Planting	17	34.1	49.2	
Fertilization	22.2	78.2	139.9	
Weed control	25.8	58.3	79.6	
Insects control	24	78.5	78.5	
Working capital	29.4	37.4	52.8	
Harvest	38.7	51.6	51.6	
Total production cost in US$	**188**	**393.5**	**535.1**	**350.22**
Rendimiento (Kg/ha)	**1.07**	**2.2**	**3.5**	**2.18**
Costo unitario ($/Tm.)	**175.7**	**178.8**	**152.9**	**160.7**

Source Sain et al. 2002.

3.2 Maize Inputs, Service Markets in TCA

Use of improved seed

One of the most important factors that determine productivity is the genetic potential imbued in the maize seed. When it comes to a country, the level of average productivity will be largely determined by the proportion of the acreage that is being produced using modern varieties of high yield potential. For example, worldwide data show there is a significant correlation between these two variables (r = 0.47). In general, an increase of 10% in acreage with improved maize varieties (IMV) is associated with an increase in the average yield of 131 kg/ha (Sain et al., 2001).

In Central America, with the exception of El Salvador, there is no time series data available about the proportion of maize area sown with improved varieties. Thus, any analysis must look for information from previous studies in selected years. At the end of the 90's Central America usage of improved maize varieties was not very high compared to other 7 tropical regions that produce white dent maize, such as China (CIMMYT, 1999). Hence, if maize producers in CA want to reduce the unitary production cost, it requires using more improved seed.

TCA requires improving the use of Commercial Improved Maize Varieties (CIMV)[40] in order to increase productivity and lower their production cost. It is estimated that from 1985 to 1996 there was an average increase of 27% of the maize acreage with CIMV in the region. Specifically in the case of Guatemala this rate was of 17%, but if we considered data from 2011-12 this rate is around 36%. During the last 20 years a clear path of use of CIMV can be observed, reaching in the three main maize producers in the region the highest level of adoption in the mid 80's. This patter coincides with the hypothesis that when breeding programs are under responsibility of the public sector, the use of CIMV is tied to the public sector budgetary conditions[41].

The temporal pattern of VMC use of in the different countries of CA indicates the existence of structural factors that have an impact on the maximum percentage of use, as well as factors that regulate the dynamics of adoption in the short and medium term. At the aggregate level two obstacles, often mentioned in the literature, are related to structural problems in the seed industry which are: availability, quality and adaptability of the seed

40 Commercial improved maize varieties include bought OPV and bought hybrids. As farmers use to keep seed for next season planting, there is a large proportion of small farmers that use recycled OPV also called "Acriollados" in the literature. There is not recycled hybrids.

41 During the 80's the three main producing countries completed a set of policy reforms that include a severe reduction of the public sector as a supplier of agricultural services.

when used by farmers (López-Pereira and Garcia 1994, Sain and Martinez, 1997, Kosarek, Garcia and Morris 2001). At the farm level, there is no doubt that the profitability of the improved seed adoption is a necessary condition for the farmers to adopt it; which in turn depends on the relative seed price, expected productivity, capital cost (including transaction costs) and farmer's risk aversion and perception on main traits of the new variety. Relative seed prices and productivity gains are very favorable in the case of CA, which are among the lowest in the world (CIMMYT, 1988). In other words, at the beginning of the 90's in order to buy one kilogram of OPV or hybrid (usually it's double or triple hybrids), 4 and 6 kg of grain were needed. These prices have increased in the past 10 15 years but they are still among the cheapest in the world. For instance, in 2012 7 kg grain was needed to buy 1 kg of public hybrid. The available information indicates a clear association between the use of CIMV and credit availability and available policy programs which reduce the relative seed price to the unit i.e. through the program a farmer can exchange 1 kg of grain for 1 kg of improved maize seed.

Improved seed production

Guatemala is not only the main maize producing country in Central America, but also the most important seed producer, including in its production improved seed of open-pollinated (OPV) and hybrid materials (HYB) materials[42]. Currently in Guatemala production of genetically modified varieties (VGM) are prohibited by law. In 2012 Guatemala seed industry produced around 2.1 thousand t/year, which was not enough to satisfy the domestic demand. This industry comprises 27 producers four of which dominate the market, but one in particularly controls 28% of the total annual production, showing relatively high concentration ratios. In general, improved seed production occurs in the whole country. Among the materials developed and produced by the public sector are the famous hybrid HB-83, hybrid and OPV ICTA Maya and ICTA B-7. These materials are also produced by other institutions, this is the case of HB-13 and ICTA B-7 being former produced by 18 different companies and the latter by a cooperative and five producer associations. The absolute and relative prices of ICTA OPVs and hybrid materials for the year 2011-12 were at 1.26 and 3.27 US$/kg, respectively. Prices of imported seeds, on the other hand, are much higher, reaching $us 13/kg in the case of hybrid seed.

The other component of national seed provision is the balance between seed imports and exports. From 2000 to 2012 Guatemala imported on average 615.9 thousand tons of improved seed, volume that grew at annual average rate of 21%. Imports, particularly of YDM, come mostly from Mexico and the U.S., have a huge annual growth rate of 66% a year during the studied period, while that of maize for popmaize grew at an annual rate of only 12%. These increases are related with the rise of per capita income. It is estimated that the availability of domestic seed in Guatemala was around 3,621 tons, 59% of which was produced in the country. This quantity is enough to potentially plant around 227,000 has or 35% of total maize cropped area with improved seed; situation is similar in the other countries in the region. Clearly if demand for improved seed increases in the short run, the only way to satisfied is through imports.

In summary, the seed industry in Guatemala is highly concentrated in one Company that controls 53% of the seed market; however, with a lower market share one national private company ranks fourth in terms of market share. Concentration indexes point to a seed importing industry highly concentrated, i.e. encompassing the leading company almost 90% of total seed imports. It should also be noted that in Guatemala there are no antimonopoly laws. On the other hand, Trans-National Companies (TNCs) and their local operators have enough resources to develop germplasm and to differentiate their products in the market; gaining in that way enough power to dominate the improved seeds market in Guatemala and possibly in the other countries in the CA region. (Reyes Hernandez 2013)

Nonspecific inputs

Fertilization is a widely used practice in maize production in all countries of CA. In the case of Guatemala, it is estimated that 66% of maize producers fertilize this crop, covering them 62% of the area sown with it. This high usage shows a well-developed national marketing system, which coverage facilitates producer's access. In general terms, the fertilizer market is older than that of the improved seeds. Different fertilizers are domesti-

42 Statistics in Guatemala do not distinguish between OPV and Hybrids materials so this separation must be estimated indirectly.

cally elaborated from inputs imported from abroad, which are then subject to a simple process of formulation or packaging and distributed through a network of wholesale dealers in the central cities and retailers in the areas of production. In that way fertilizer prices are closely related to international prices, that on average were at 657 US$/t by 2013.

Following the general trend in LAC total nutrient consumption as well as use intensity grew during the period 2002–10 at an annual rate close to 3 and 2.5%, respectively. It is estimated that in the region 203 kg of nutrient is used by hectare. During this period the region consumed on average 105,210 tons of nutrients per year, 59% of which correspond to nitrogenous, 23% to N2O and 18% to phosphate (P2O5). All the fertilizer consumed is imported since there is no production in the region, however there is some minor amounts exported (5,200 t) as a result of firms that elaborate and package mixed formulas from imported raw materials (FAOstat, 2012). The most important providers of this input are the U.S and Mexico, which together in 2012 contributed with 51 and 97% of the nitrogenous and phosphate used, respectively. Regarding imports of potash fertilizers, they come mostly from Canada (38%), Russia (32%) and the U.S. (19%). The fertilizer import industry is composed by 54 companies 2 of which dominate the market.

In general the intensity use of pesticides from 2002 to 10 has followed a decreasing trend in Central America with the major drop rate registered in the case of insecticides (-6.2%). In the same way as chemical fertilizers, pesticides are imported and also have high nationwide marketing systems after a simple process of formulation or packaging. According to the Guatemala Ministry of Agriculture the main imported pesticides used in maize production include a short list of herbicides composed of 2-4 D, Paraquat, Glyphosate and Atrazine. In 2013 on average pesticides prices in localities 160 km away from Guatemala city cost 5.8 US$/liters in the case of Paraquat, 2-4D and Gylphosate; and 7.9 US$ on kg of Atrazine. The biggest pesticide suppliers are the U.S. with a market share of 27% and China with 26%. The following eight supply countries include India, Mexico, Colombia, Germany, Costa Rica, Belgium, England and Israel, which provide with 42.4% of total imports. Total pesticide imports were made by 96 companies, which, in 2012, imported in total 36,279 tons of pesticides. The sector has a more competitive structure than the one from the fertilizers (i.e. ICR2 = 32, and ICR4 = 47).

The only existing statistics on the stock of machines and tools used in agricultural activities in the region are those related to the park of tractors. However, the structure of size of maize farmers revealed in previous sections indicates that very few of them own a tractor for soil preparation, and it is most likely that most of them rent services of machinery for their productive activities. Although there are not any official figures about the use of small machinery and tools (e.g. sellers, backpack-pumps) the evidence points to a large majority of producers possessing them. Hence, it is rather better to know machinery renting prices and their availability, than the number of machinery owned.

Due to the nature of the financial services we focused on information from the representative country, Guatemala. Regarding financial services in this country is estimated that in the last five years (2007-12) the loans destined to maize production grew on average at an annual rate of 62%, while the loans designed to the agriculture sector grew at 7.24%. In 2007 the agriculture sector received approximately 164.3 million of dollars in loans, 1.7% of which went to the maize sector; rate that by 2012 was of 13.2%. This evolution is influenced at some degree by changes in the country policies due to the high international food prices that push up the importance of food security in the political agenda. Although the amount of money designed to maize production has increase. Although this growth is significant is still quite low, since only 4% of the 5,618 millions of dollars of loans distributed in the country went to the agriculture sector in 2012 (Reyes Hernández , 2013).

Finally, the use on Information and Communication Technologies in rural areas in the region has increased significantly in the last 10 years. In the case of Guatemala, for instance, the use of cell phone services and internet has widely extended in the rural areas in the last 5 years. Currently is estimated that there are 131 cellular phones for every 100 inhabitants and 2.28 million of internet users. Another important fact is the number of internet servers, which went from 20,000 to 347,000 from 2007 to 2009. Furthermore, in remotes areas access to internet is not limited to owning a computer given that a high numbers of small internet providers known as “internet cafes” can be found almost everywhere in the country.

3.3 Maize Research and Development (R&D) System in TCA

National Agricultural Research Institutions (NARIs) in CA

The research and development of agricultural technologies in this region is done by relatively young institutions. The first NRIs were created at the end of the 60's beginning of the 70' in El Salvador and Guatemala, process that continued until 2001 when the Institute of Innovation and Transfer of Agricultural Technology (INTA[43]) was created in Costa Rica. The development and diffusion of innovations for maize is immersed in the wider agricultural innovation system of Guatemala, which has four major components: public sector, private sector (formed basically by inputs and seed companies), non-governmental organizations and international institutions (e.g. CIMMYT, CIAT, IICA, FAO, and others) and higher education institutions (public and private universities).

Public sector

The public sector in Guatemala comprises two main institutions: Institute of Agricultural Science and Technology (ICTA[44]), and the Ministry of Agriculture, Livestock and the Environment (MAGA). This sector plays an important role in research as well as dissemination (extension) of agricultural technologies in general and also for maize in particular. Specifically ICTA, created in 1973, focuses on agricultural research and thus is in charge of developing and promoting technologies for the agricultural sector.

A common feature among NRI in the region is the evolution patter on their budgets (public investment). For instance in the case of ICTA from Guatemala and CENTA from El Salvador, their total expenditures follow a similar pattern in both institutions, they both declined at rates close to 10% per year during 1980- 1998. This situation is the result of profound changes in the processes of structural adjustment in their economies that started at the beginning of the 80's and during the 90's, when the third phase of the structural adjustment programs starts in most of the Central American countries. As a result, public investment in R&D decreased dramatically and many of the agricultural public services provided by the Government, such as the extension services, become responsibility of the private sector[45]. Available empirical evidence indicates that Central American countries have greatly diminished their public investment, both in absolute and in relative terms (Stads et al., 20089).

Even though the crisis of the public sector in which maize R&D is immerse, the latter has four special features worth noting:

- Historical tradition: agricultural scientific research in Central America originated with maize research as part of an international effort to obtain improved varieties by the Roquefeller Foundation in the 1950s.
- Rapid decrease of national public budget: For example in Guatemala, the budget allocated to maize declined from 1979 to 1990 at an annual rate of 12.8%, which indicates the bias towards basic grains when allocating public resources. However it seems that this trend has change since 2011 when ICTA budget went from 234 thousand quetzals (1975 constants) to 517 and 719.millions in 2012 and 2013, respectively. Although these positive changes, it is difficult to guarantee they will continue in the future, nor translate in better technologies and thus higher productivity. According with Reyes (2013) is necessary to modify the methodology for technology generation and increase farmer's participation in the process (Reyes Hernández, 2013).
- Regional collaboration***:*** At the end of the '70s formally started a collaborative research program between CIMMYT and different NRI's from Central American and Caribbean. The program, later known as the Maize Regional Program (MRP), ended in 2000. It had three research components: maize breeding, agronomy and economy. Following this program a new regional collaborative program, called RedSICTA started. It is coordinated by IICA and encompasses several public and private actors from CA. RedSICTA focuses in develop and transfer technologies rather than in research.

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43 Instituto de Innovación y Transferencia de Tecnología Agropecuaria

44 Instituto de Ciencia y Tecnología Agrícolas

45 Several mixed forms of public-private partnerships to provide extension services were also tried in various CA countries.

- Strong maize breeding component***:*** During the ’90 a common features of NRIs in the region, as well as the MRP, was to assign around 65% their financial resources to maize breeding and the remaining to crop management and -economic research.
- In Guatemala from the mid-70 to 2000 ICTA liberated a total of 22 improved maize varieties, 16[46] of which were OPV and 6[47] hybrids materials including the famous HB-83. This highly productive period was possible thanks to the collaboration with CIMMYT and the Maize Regional Program (MRP). An economic analysis of the impact of these varieties shows a high profitability of agricultural research for the CA region. In the particular case of Guatemala, an economic assessment of the public funds invested showed benefit/cost ranging 7.16 to 14.32, and internal rates of return from 106.80 to 148.14% (Reyes Hernández, 2001). It is worth nothing that in the last 12 years only 3[48] hybrids were released by ICTA, due to a budget reduction. This implied, for instance, a decrease the number of researches from 250 in 1973 to 62 in 2013, 5 of which are maize researchers.

Private and international agricultural R&D

In Guatemala, private research in maize is mainly driven by some large seeds producers, which develop OPV and hybrids materials that sell locally and internationally. In addition, some companies in the nixtamalized maize flour industry do some research in response to specific problems affecting the quality of the product. For example, one company conducted evaluated products for the control of *mancha del afalto* (disease affecting leaf area of maize) in northern Alta Verapaz and southern Petén, areas where the company acquires 65% of their domestic purchases of white maize. Another source of innovation is carried out by transnational corporations that produce and market agrochemicals. To register their product they are forced by law, to experimentally evaluate them in production areas and prove that they are efficient to control the pest that originates its entry into the market. These companies also have some programs to promote their products in the producing areas. In fact the retail distributors of agrochemicals are considered the main source of this type of innovations in the field (Reyes Hernández, 1982). While there is no data on the number of these dealers, it can be inferred that their participation is significant if it is considered that there are more than one in each municipality, i.e. in all 334 municipalities that Guatemala has. Furthermore, other important distributors include cooperatives, which mostly are individually owned.

Other initiatives that promote the use of technology and good management practices among small farmers of maize and beans, are international organizations such as United Nation, World Bank, IDB, IICA, and others that provide technical and financial support. One example of this type of initiative is the project “*Purchase for Progress*”(P4P) from the United Nations Food Program (WFP). This initiative that lasts 5 years (2008-13) seeks to connect farmers with food processing companies in order to provide market opportunities for small farmers. Finally, International Research Organizations such as CIMMYT, CIAT and CIP and universities, also contributes to maize technology innovation, making research knowledge available to national research institutions and providing basic germoplasm for their national breeding system.

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46 OPVs: La Máquina 7422, La Máquina 7843, B-1, B-5, A-4, Bárcena 71, V-301, V-302, V-304, V-305, Chanín, Don Marshal, Guate--IAN-Xela, Toto Amarillo, San Marceño, y Nutricta.

47 Hybrids: T-101, HB-11, HB-19, HA-28, HA-44 y HB-83

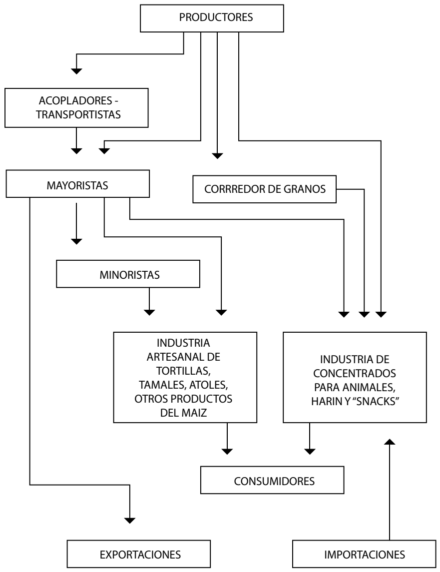
48 ICTA HA-48 e ICTA Maya

3.4 Maize Processing Agroindustry and Consumption in TCA

Stylized structure of maize marketing system

The structure of maize marketing in Guatemala and Central America in general has a sand clock shape with a large number of small producers and consumers in one extreme and on the other a small number of trading and processing agents, and in the middle the agents who use their marketing power to influence different policies (e.g. imports). The marketing structure is quite typical, with small collectors known as "*coyotes"* and big collectors known as "*corredores de granos*" usually associated to a wholesaler. These actors buy directly from small farmers; although in this first link also participate in lesser extent wholesalers and the processing industry. At the wholesale level the grain collected is cleaned, classified and distributed to the different industries (artisanal processing and feed), retailers and exporting companies. Imports compete with domestic production at the feed industry stage (Figure 21).

Figure 21. Guatemala: Maize marketing channels



Source:Reyes Hernadez 2013.

One important indicator of the efficiency of a marketing system is the transmission of value through prices along the value chain, i.e. how the value is distributes along the actors in the chain. This does not only show the gross efficiency of the system but also its distributive properties. Analyzing how the price margins along the MVCS are distributed in the main producing department in Guatemala, we found out that the wholesaler pays 23% more than the price the collector paid to farmers; and that the processing industry must pay for its raw material a price 56% above what the grain producer is paid. Although there is some variation among different producing departments, this margin distribution is consistent with a wider study in Guatemala that found a gross margin at the wholesale level of about 30% and conclude that the problem of maize lies not only in the production sector but also in the high marketing cost, which is the result of an atomized and spatially extended production structure.

During the period 200-12 Guatemala maize domestic production faces an unfair competition with imports, given that yellow dent maize domestic prices are approximately 100% higher that maize international prices and this value is 55% higher in the case of white maize. Although both prices are not directly comparable, since internationalization costs have not been take into account, they indicate the need to gain efficiency in both at the production and the marketing level to be able to compete with the imported maize. During the period analyzed international maize prices growth at an annual rate of 144% while domestic prices grew at the rate of 7%.

Maize consumption in CA region

Following LA trends, total consumption in Central America during the period 2000–10 grew at an annual rate of 4%, which is the result of greater consumption of animal feed (7%), demanded especially by the poultry industry (FAOstat, 2012). This increase is the result of both population and income growth; which however did not mean in increase in consumption of maize as food, which during the mentioned period grew only at the rate of 1.7% that is below the rate at which population grew. These differences reflect an increment in income per capita as well as difference in income elasticity of the demand of both products that boost consumption for animal proteins (mainly from poultry).

In the case of the representative country Guatemala but extending to the rest of the CA region, the type of maize that is mainly consumed by the population is white dent, which is processed to the final edible product through a process called "nixtamalizacion"[49] that is carried over an artisan or industrial form. The most common form that white dent maize is consumed is in the form of tortillas, although it is also consumed as tamales, tamalitos, atoles. bread, pinol, popmaize[50], and others. It is estimated that in Guatemala tortillas consumption is equivalent to consuming 1.3 Kg of grain/person/day. It is interesting to note that in Guatemala, families living in urban areas consume more tortillas than those who live in rural areas. Finally, the kind of maize that the feed industry uses as main input is the yellow dent, which is mostly imported from the U.S., given that this country offers lower prices. The main clients of this product include the poultry, pigs, cattle and horses industries.

3.5 Outlook of the MVCS in Central America

One of the most notable trends in Central America is the growing gap observed between production and consumption. During the period 1990–2012 maize consumption grew at an annual rate of 3.5% while production grew by only 1.8%. This gap has been filling out with imports, mainly of yellow maize from the US. The stagnation of maize production in the region is also reflected by maize productivity trend which grew at a pace not enough to boost production. In the following table a SWOT (strengths, weaknesses, opportunities and threats) analysis for the different sectors in the MVCS in Guatemala is presented. These results are compatible with the results of a SWOT analysis made at the regional level by RedSICTA-IICA (2007).

49 The Nixtamalization, from the náhualt *nextli* (lime ashes) and *tamalli* (cooked maize dough), is the pre-Columbian Mesoamerican process of preparation of the maize dough making bioavailable to the human the grain-essential amino acids and their micronutrients.

50 In local jargon, they are known as poporopos, a word derived from the American "pop maize".

Table 36. SWOT analysis of the MVCS in CA

Strengths	Weakness
• Involves a large number of producers and consumers (i.e. competitive market) • Many products derived from maize • There is a large number of marketing agents throughout the country • A well-equipped National Institute of research • Researchers trained in various agricultural disciplines • Network of grassroots organizations from the village up to the departmental capital (development councils) • There is a national seed industry and implemented seed laws • There is an established group of companies that produce and market maize • Retail distribution network is very efficient	• Most producers are small-scale, have limited access to resources, education, technology and information • Production atomized, disperse and with low levels of productivity • Producers are not organized, which implies high marketing costs • No value added to maize production • Low technological level and limited post-harvest knowledge • Poor road infrastructure, storage capacity and access to financial services for small scale farmers • Week agro-industry sector • NRIs is weak in terms of financial and human resources • Extension is not tied to research and extension agents not well trained • Ministry of agriculture does not guarantee permanence extension activities • No new improved maize varieties in the market • Atomized production structure
Opportunities	**Threats**
• Market in permanent expansion • Growing demand of maize for both human and feed consumption • Positive correlation between local production of improved seeds, and adoption • Global climate change • Positive correlation between local production of improved seeds, and adoption • Global climate change will allow expand production to areas previously not available	• Import prices are lower than domestic prices • Climate change • Wheat imports • Transnational corporations that introduce improve seeds and fertilizers • Ministry of Agriculture activities against agricultural research • Changes in government priorities

Source:Reyes Hernadez 2013.

Despite the fact that maize production in Guatemala will continue growing in the next 10 years, its pace will not be large enough to reach self-sufficiency by 2022. It is forecasted that in order to satisfy maize demand of the population, which will grow at an annual rate of 2.44%, during the period 2013–22 it is necessary that maize production grows at a yearly rate of 8.01%. This production level required might be difficult to achieve in a scenario with a low investment in agricultural research. If there are no changes in the government policies, it is estimated that actually maize production will just grow at annual rate of 2.62%, which will traduce in a higher dependence of this grain imports. Based on Reyes (2013) it can be expected that in the next 10 years maize production will increase by 2,300 t/year thanks to an yield of 2.62 t/ha. However maize consumption is expected to increase at 3,300 tons per year.

Limiting factors to the growth of productivity and efficiency in CA

Global demand and supply are favorable conditions for the competitive development of the production of white dent maize (WDM) in Central America. In general, world maize demand is in constant expansion; Central America jointly with Mexico have a significant share in the world production of WDM, and maize production growth in this region rates relatively higher than other regions. However, a deeper analysis of the components of production growth is required to analyze particularly in maize productivity stagnation. In Latin America cereal production growth during the last three decades is mainly due to technological changes that have produced higher yields (71% of the total growth), rather than the expansion of the cultivated area (29%). According Sain (2011) and MAGFOR (2003) low levels of technological innovation and adoption are the main factors that determine production growth as well as gain in productive efficiency in terms of costs.

A unique feature of the Central American agricultural innovation system is its low level of investment from the public sector that is substituted by external investment from donors, which dependence is growing. This situation is reflected in the variability of founding sources and in the efficiency of the sector expenditures. Central America has a low ability to generate, exploit and capture knowledge and technology spillovers form outside the country and adapt it to the internal conditions of the country through adaptive research (Sain and Ardila 2009).

The adoption of technologies is a complex process, which involves factors on the demand side, as well as on the supply, due to factors that substantially reduce the rates of return on investment in research and dissemination. These factors may go from the inappropriate nature of the technologies to the needs of the producer, to high level of investment required, own technology risk, lack of inputs (seeds, improved, for example), high territorial dispersion and lack of associativity of producers that hampers the work of extension workers and significantly raises its cost, and inadequacy of the transfer and dissemination methods used. Another important factor is the poor extension services coverage, which in Guatemala was almost non-existent for at least 10 years and in the case of Nicaragua the coverage does not cover more than 25% of the objective universe of producers.

Transparency in land tenure is a key factor for the development of a modern agriculture, particularly for the adoption of new technologies, conservation of natural resources and investment in productive improvements. In Central America three main types of land tenure predominate: own, borrowed and rented. However, even in the case of farmers with their own land, it is estimated that a substantial amount of them have not completed the legal process of ownership. This insecurity of property rights on land is a factor that negatively affects productivity, as a result of low incentives for investment (Sain, 2005). Central America has a wealth of natural and physical capital among the best in the world. However, degradation of soils and pastures and the decrease in the area of natural forests constitute a phenomenon prevalent in the region, resulting from disorderly expansion of the agricultural and cattle frontier and the abuse of water during agricultural production.

4. MVCS in Northern Latin America (NLA) - Representative Country: Mexico

(Section based heavily on Saravia and Amaya 2013)

4.1 Domestic supply of maize in NLA (Mexico)

Since NLA (Mexico) is a net-importing region (in this case, a country), the domestic availability of maize is the sum of domestic production plus net imports. The following two sections describe the main characteristics of the two subsectors.

Maize production

Maize is deeply rooted in the Mexican culture and is definitely the most important cereal crop in the country. Its social, cultural and economic importance for the Mexican population and economy has been extensively documented in the literature. The following sections briefly describe some important indicators of maize's importance in different areas.

In terms of production, maize is the main cereal grown in Mexico, followed by sorghum, wheat, barley, rice and oatmeal. It accounts for approximately 60% of the area planted and harvested to grains and oilseeds. During the period 2000-2012, maize's share of total cereal production averaged 66% (FAOSTAT 2013). In terms of total crop production, maize ranks second in importance after sugarcane. It accounts for almost 40% of AGDP, a share that grew at an annual rate of close to four percent during the period 2000-2010 (estimate based on FAOSTAT data). This growth rate is due to the rising value of maize production, which topped seven percent annually during the period 2000-2010, driven by the increases in international maize prices recorded in recent years.

In terms of consumption, maize is the most important staple food and primary source of calories for the majority of Mexico's population, particularly the poor and marginalized segments. On average, maize contributes 70% of the calories consumed in rural areas of Mexico, and 40% in urban areas.

The social importance of maize stems from the fact that its cultivation generates more employment than any other agricultural activity and that it is the main supplier of staple foods in the country. Maize processing and industrialization are also very important generators of employment, accounting for 31% of all jobs in the food industry. Within the maize industry, 88% of the workforce is involved in the preparation of maize tortillas and maize grinding (nixtamal).

Moreover, around 12.5 million people depend on maize production for their livelihoods, which is equivalent to 55.2% of the rural population and 12.7% of Mexico's total population. In 2012, Mexico was the world's fifth largest producer and fifth biggest consumer of maize.

The role of maize in Mexico, however, transcends production and consumption aspects to become a fundamental component of the cultural heritage and identity of Mexicans. The connection between maize and the rural community is evident in indigenous art and archaeology. The cultural significance can also be seen in the different types of maize cultivated, as well as in the rituals, traditions and beliefs associated with this crop and the many ways in which it is processed and prepared in Mexico.

Growth anatomy of maize production

Domestic maize production grew at an annual rate of 2.2% during the period 2000-2010 as a result of a substantial increase in average yield, which grew at an annual rate of 3%, although there is evidence to suggest that the rate of increase has been even more rapid in the last two to three years. For example, maize yield in Sinaloa increased from 3.8 t/ha in 2011 to 6.5 t/ha in 2012 (an increment of 71.1 %), even reaching 9.6 t/ha under irrigated conditions.

The rate of growth of maize yields more than compensated for the fall in maize acreage, which declined at an annual rate of close to one percent. Because of these two trends, NLA is the only MAEZ with a negative Growth Anatomy Index, put at -3.6.

Maize Trade

a) Imports

Despite the fact that Mexico is among the world's major producers of maize, production is insufficient to meet domestic demand. The reasons for this include the many problems that exist in the Mexican economy and the fact that a large proportion of small, subsistence maize producers do not take part in the domestic market. As a result, the country has to satisfy domestic demand with imported maize.

During the period 2000-2010, Mexico imported an average of six million tons of maize annually, with the amount increasing at a rate of five percent per year (based on FAOSTAT data). In 2012, Mexico consumed approximately 28.1 million tons of maize, 78% of which were produced domestically and 22% were imported. Most (80%) of the imported maize is yellow maize # 2 (whole grain), and 15% is broken grain from the US. Before NAFTA, imports of yellow maize and broken maize were growing steadily and significantly; following implementation of the trade agreement, however, imports of broken maize started to grow more quickly because no tariff is attached.

The trend of growing imports is expected to continue in the future, due to the differential in productivity and average cost that makes imported maize much more attractive to the processing industry than the domestically produced variety. For example, it is estimated that the US can produce maize for 40% of the cost of producing it in Mexico and obtain yields of up to 13.2 t/ha (USDA-FAS 2013).

b) Exports

During the period 2000-2010, Mexico exported small and fluctuating volumes of (primarily) white maize. It is estimated that during that period the volume of exported maize grew at an annual average rate of 266% and its value at a rate of 117%. In general, white maize prices are slightly higher than those paid for the yellow variety, although the margins vary according to the overall situation of supply and demand. Despite the fact that Mexico is one of the world's leading producers of white maize, its exportable supply is not significant due to the high level of domestic consumption. Most exports have traditionally been to Central American countries; however, in 2006 Mexico exported white maize to Mozambique and Kenya.

c) Trade treaties and agreements

Mexico has negotiated numerous bilateral and regional agreements in the past two decades. The most important as far as maize production and trade is concerned is the North America Free Trade Agreement (NAFTA) involving Canada, the US and Mexico, which entered into force in 1994.

d) Production geography

Five agricultural production areas can be identified in Mexico—the Central, Central-West, Northwest, Northeast and South regions—, with the amount of maize grown in each one varying considerably. During the period 2001-2012, around 72% of total production came from eight states (Sinaloa, Jalisco, Mexico, Chiapas, Michoacán, Guerrero, Guanajuato and Veracruz), 23% from 10 others and 5% from the remainder.

Two states highlight the duality that predominates in the production of maize for the grain sector: Sinaloa in the Northwest region, the chief maize-producing state, has one of the most developed agricultural sectors in the country, while Chiapas, in the South region, is characterized by low productivity and traditional farmers who mainly grow white maize. In 2012, Sinaloa accounted for more than the 29% of the irrigated area, while Chiapas is the largest producer of maize under rainfed conditions (nearly 11.3% of the total). The Central-West, South and Northeast regions have the largest livestock inventory in the country and, therefore, are also leading producers of yellow maize. More than half of the maize produced under rainfed conditions comes from six states (Chiapas, Veracruz, Jalisco, Oaxaca, Puebla and the State of Mexico) that have large indigenous populations; five of them are the poorest in the country.

Maize producers

More than two thirds of all the country's producers, mostly small-scale subsistence farmers, are engaged in maize production. They produce under rainfed conditions, primarily for self-consumption, and sell the surplus in the local market. As in other regions of LAC, maize production in Mexico has a dual structure. Large producers account for most of the maize harvest, achieving high yields and obtaining the best prices. Small producers, on the other hand, farm small plots, in many cases exclusively for self-consumption and using traditional methods. A small proportion of farms (5%) operated by large producers harvest 42% of the total maize acreage, while a large number (70%) of properties owned by small-scale farmers account for 23%. In between are medium-sized farmers, who harvest a little more than one third of the total (35%).

Maize technology use

Although a wide range of cropping systems exists, the two main ones used are the so-called traditional and modern production systems.

The traditional production system is based on many elements of pre-Hispanic technology and native varieties. Farmers are relatively proficient in producing one or two types of maize. Maize is often grown in association with beans, squash, peppers and other crops for home consumption, under a system known as the interleaved milpa system. It is characterized by little or no use of improved seeds or machinery, and limited or almost no use of fertilizers and chemical pesticides. That translates into yields of below one t/ha. These farmers do not hire labor or accumulate capital and have low levels of social organization. Approximately 40% of maize farmers contribute 10% of national production and 80% of that amount is consumed locally. Traditional maize production has the advantage of being inexpensive but is often considered inefficient.

The commercial operations of large and medium-sized farmers produce white or yellow maize for the market, using advanced technology and improved commercial varieties (mainly hybrids). This type of agriculture uses large tracts of land that usually include irrigation systems and provide yields of close to 7 t/ha. It is carried out in areas with good irrigation and communication infrastructures, as well as good access to transportation, storage units, warehouses and markets.

Irrigation

During the period 2004-2012, maize was cultivated under rainfed conditions on an average of 82% of the total area planted with the crop. Irrigation is used to produce maize in all of Mexico's states except the Federal District, but it is concentrated in only a few of them. Sinaloa alone accounts for almost 40% of the country's irrigated maize production, followed by Chihuahua (11%), Guanajuato (10%), Michoacán (8%), Tamaulipas (5%), Hidalgo (5%), the State of Mexico (4%) and Jalisco (3%). In other words, eight states account for 85% of all irrigated maize production. More than 55% of the cultivated area in the northwest region is irrigated, equivalent to 28% of the region's total arable land and 30% of the land under irrigation in Mexico as a whole.

Irrigation makes a big difference to maize yield, with increments of up to 200% compared to crops grown under rainfed conditions. The use of irrigation systems makes it possible to produce an average of 6.5 t/ha.

Improved Seed

Despite the fact that improved seeds have been available in Mexico for over 40 years and repeated government programs have promoted their use, adoption has been limited, especially among the majority of small producers. Up to 2009, only 30% of the country's total maize acreage was sown with improved varieties, including approximately 19% of hybrid varieties. The situation seems to have begun to change in recent years, however, as it is estimated that in 2011 about 51% of the 7.8 million hectares planted with maize were sown with improved varieties (OPV and Hybrids), 19% under irrigated conditions and 31% under rainfed conditions. (Table 3.14). Sinaloa led the way with 53%, followed by Jalisco with 21%.

Figure 37. Maize acreage in 2011 according to seed and irrigation technology

Region	Total acreage		Acreage sown with non-improved seed Irrigated		Acreage sown with improved seed			
					rainfed			
	Ha	%	Ha	%	Ha	%	Ha	%
Central	1,479,355	19%	1,096,785	29%	99,838	7%	282,732	12%
Central-West	2,083,586	27%	661,635	17%	310,084	21%	1,111,868	46%
Northeast	484,895	6%	189,428	5%	205,116	14%	90,351	4%
Northwest	878,161	11%	6,396	0%	838,770	56%	32,995	1%
South	2,824,304	36%	1,849,781	49%	53,683	4%	920,840	38%
Total	**7,750,301**	**100%**	**3,804,025**	**100%**	**1,507,490**	**100%**	**2,438,787**	**100%**
%	**100%**		**49%**		**19%**		**31%**	

Source: Saravia 2013

The main feature of the current use of improved maize seeds in Mexico is its great heterogeneity. Use varies by type of farmer and region, in line with the inequalities highlighted by the main economic and social indicators. For example, in the South region (Oaxaca, Chiapas, Puebla, State of Mexico and Veracruz), which includes the poorest states whose population is mostly indigenous, traditional maize seed is used on around 92% of plots, estimated to total around 1.9 million hectares in 2011.

However, in the states in the Northern region, which have higher per capita GDP and large-scale production systems and industrial production, farmers use improved seeds. For example, improved seeds were used on 1.1 million of the 1.4 million hectares of land planted to maize in the region in 2011, 89.0% of them under irrigation. The types of seeds used in this region are often hybrid varieties produced by multinationals, with the exception of the highlands where the materials used are hybrids from INIFAP.

Non-seed inputs

Fertilizers. As many as 7.8 million of the 8.3 million hectares sown with maize in 2011 (about 85% of the total) were cropped without chemical fertilizer application. Around one third of that acreage was in the South states. Another 5.7 million hectares were fertilized in 2011, most of which (72%) were farmed under rainfed conditions and, to a lesser extent (28%) with irrigation. The fertilizers most commonly applied in maize production are of the nitrogenous variety (urea, diamonium phosphate, ammonia nitrate and ammonium sulphate) and, to a lesser degree, phosphorous and potassium fertilizers.

Figure 38. Nutrient consumption in Mexico

Indicator	Units	Average 2002 -2010	Growth Rate (%)
Total nutrient consumption	t/year	718,172	3.6
N consumption	t/year	388,780	4.8
P2O5 Consumption	t/year	252,042	2.2
K2O Consumption	t/year	77,350	1.6

Indicator	Units	Average 2002 -2010	Growth Rate (%)
Use Intensity	**Kg/ha/year**	**216**	**4.6**
Total nutrients production	t/year	649,325	3.6
N production	t/year	353,378	0.0
P2O5 production	t/year	5,498	-0.9
K2O production	t/year	197,288	8.1
Total nutrient imports	t/year	518,625	4.3
N imports	t/year	239,999	6.2
P2O5 imports	t/year	254,114	2.4
K2O imports	t/year	24512.5	**5.4**
Total nutrient exports	t/year	238846.4	**4.9**
N exports	t/year	86804.2	**-5.8**
P2O5 exports	t/year	7570.1	**7.7**
K2O exports	t/year	144472.1	**10.2**

Pesticides. The most common herbicides applied to maize include Paraquat, 2,4-D, Amina, glyphosate and Flex; while Lambdacialotrina, Cipermitrina, Exal+Lanate, Lorsban and lambda cyhalothrin are among the most common products used for the control of pests.

Figure 39. Pesticide use intensity in Mexico

Indicator	Units	Average 2002-10	Growth Rate (%)
Use intensity fungicides and bactericides	Kg/ha/year	1.6	**9.9**
Use intensity herbicides	Kg/ha/year	4.8	**12.9**
Use intensity insecticides	Kg/ha/year	2.0	**29.5**

Mechanization (land preparation and processing)

In 2011, around one third of the area planted with crops nationwide (including maize) was cultivated using traditional tools and no mechanical technology of any kind. The majority (65%) of the maize acreage sown without mechanization was located in the South region, where land preparation, weed control and even harvesting are done manually (usually with family labor). However, in recent years maize harvesting has slowly begun to be mechanized through the services provided by third parties.

Mechanized technology of some kind was used on 3.8 million hectares sown with maize under rainfed conditions and 1.7 million hectares under irrigation, almost half of them in the State of Sinaloa.

Summary of maize technology and yield

Table 40 summarizes the state of the art of maize production technology in different regions of Mexico. It is worth noting the highly diverse nature of production systems, which makes the work of researchers and extension agents difficult.

Figure 40. Production technology in Mexico

Technology	Water use / system	Breakdown by region (in %)					Million of ha planted	
		Central	Central-West	Northeast	North west	South	Subtotal	Total
Fertilizers chemicals	Not used	21%	21%	7%	1%	50%	2.05	7
	Irrigation	22%	33%	3%	1%	42%	1.62	
	Rainfall	10%	20%	13%	52%	5%	4.08	
Mechanization	None	23%	10%	2%	0%	64%	2.33	7
	Irrigation	11%	20%	14%	50%	5%	1.67	
	Rainfall	20%	40%	5%	1%	33%	3.76	
Type of seed	Creole	29%	17%	5%	0.2%	49%	3.80	7
	Improved with irrigation	7%	21%	14%	56%	4%	1.51	
	Improved with rainfall	12%	46%	4%	1%	38%	2.44	
Phytosanitary controls	None	22%	32%	6%	0.2%	39%	5.63	7
	Irrigation	3%	6%	7%	82%	2%	1.03	
	Rainfed	18%	20%	5%	3%	55%	1.09	
Technical assistance	None	21%	30%	5%	1%	42%	6.05	7
	Received- Irrigation	4%	6%	12%	78%	1%	0.99	
	Received – Rainfed	21%	29%	7%	4%	39%	0.71	
Total production (Tons x 000)		**1,943**	**5,682**	**1,548**	**3,032**	**5,403**		**17,60**
Yield (Ton/Ha)		**2.13**	**3.90**	**2.61**	**4.33**	**2.47**		**3.0**

Gender differentiated roles

In the case of small producers, all agricultural activities are carried out by members of the family, who are organized for planting, weeding and harvesting the crop; work that is usually unremunerated. It is normal for both men and women to take part, with the tasks of each being very well defined. On the other hand, large and medium-sized maize producers always hire workers. Women are often in charge of agricultural activities, either working themselves or supervising contracted work. Thus, women's activities now extend beyond household chores to include support for the production of maize, which is used for family consumption.

Factors associated with maize technology use

Seed cost and availability are two seemingly important factors with regard to the decision to adopt improved commercial seed by small farmers who grow maize for subsistence with minimal investment in commercial inputs. This applies not only to hybrid seeds but also to other costly inputs, like irrigation and fertilizers.

Other important factors underlying low crop productivity and high per ton production costs include the following:

i. High financial costs,

ii. Agro-climatic features, hydrologic regime;

iii. Lack of technology transfer,

iv. Lack of knowledge of new and operating markets,

v. Lack of knowledge of alternative uses of maize,

vi. Lack of business-oriented producer organizations,

vii. Lack of public policies and federal/state programs to support the short, medium and long-term development of the MVCS.

In the last case, the formulation of policies of this kind is clearly essential, to increase productivity and production efficiency throughout the chain and thereby improve the competitiveness of maize and prevent the slow but steady disappearance of traditional producers of this grain.

Economics of maize production

The cost structure reflects the production technology level. Large producers (60-100 hectares) located in the Northwest (93%) and Bajío (36%) regions, using high technology, usually invest about 12,000 pesos per hectare and obtain yields of 10-12 t/ha. On the other hand, small producers with low levels of technology invest about 10% of that amount. It is worth noting that these costs also vary according to the type of maize produced, i.e., white or yellow. In Mexico, the expected cost of yellow maize production is usually greater than that of white maize, due to the higher quantities of inputs required. However, yellow maize yield is usually higher yield than that of white, resulting in a lower average cost.

In terms of the cost structure of maize production, seeds account for 25-30% of the total cost, followed by fertilizers (10%) and agrochemicals (10%).

Activities related to transportation, storage and marketing continue to be sources of high unnecessary costs and bottlenecks in Mexico's maize sector. The long distances from rural production areas to consumption centers, dependence on expensive trucks, inadequate road infrastructure and the lack of direct rail links to key transport centers (especially ports and markets) have all thwarted efforts to create an integrated market, from farmers to consumers. Similarly, the relatively high cost of fuel (such as diesel) is another element affecting the price of maize. The competitiveness of Mexican producers is also hindered by imports from the US, which are made via rail or boat at much lower cost.

Figure 41. Maize production costs and average maize yield by region and technology level. 2007-08 Pesos/t.

Technology	Central-West		Central		Northeast		Northwest		South		Average	
	$/t	t/ha	$/t	t/ha	$/t	t/ha	$/t	t/ha	$/t	t/ha	$/t	t/ha
BCF			2,072	3.5							**2,072**	**3.5**
BMF	2,182	5.8	2,072	4.0	1,539	8.3	2,575	5.5	2,490	4.0	**1,968**	**6.0**
GCF									2,479	2.9	**2,479**	**2.9**
GCS									1,980	2.0	**1,980**	**2.0**
GMF	1,831	5.4			1,343	6.1	1,257	7.2	1,648	5.0	**1,474**	**6.1**
GMS					2,318	1.5					**2,318**	**1.5**
TCF			3,756	2.4	3,086	1.5			4,432	2.1	**4,077**	**2.1**
TCS									3,641	1.9	**3,641**	**1.9**
TMF	2,364	2.5	2,366	2.7	3,557	1.5			3,659	3.4	**3,146**	**2.7**
TMS	3,208	1.5							3,876	1.5	**3,542**	**1.5**
Average	**2,189**	**3.8**	**2,456**	**3.2**	**1,821**	**3.8**	**1,828**	**6.3**	**2,798**	**2.9**	**2,382**	**3.0**

Source: Saravia 2013

In Mexico, the average profit per ton varies from 60 to 400 pesos. However, it is important to note that there is considerable heterogeneity in terms of the types of producers. In order to improve farmers' income, Mexico's government has granted economic support of different kinds under various programs (Polanco and Flores 2008).

Table 42. Maize production costs and average gross margin by type of technology. 2007-08

Technology	Average production cost	Average yield	Average gross yield	
	$/ton	t/ha	$/ton*	$/ha
BCF	2,072	3.5	-260	-910
BMF	1,968	6.0	60	358
GCF	2,479	2.9	-170	-493
GCS	1,980	2.0	400	800
GMF	1,474	6.1	300	1,820
GMS	2,318	1.5	60	90
TCF	4,077	2.1	-740	-1,520
TCS	3,641	1.9	-860	-1,647
TMF	3,146	2.7	-570	-1,528
TMS	3,542	1.5	-910	-1,365
Average	**2,382**	**3.0**	**-269**	**-809**

Source: Saravia 2013.

4.2 Maize Inputs and Service Markets

Maize seed supply

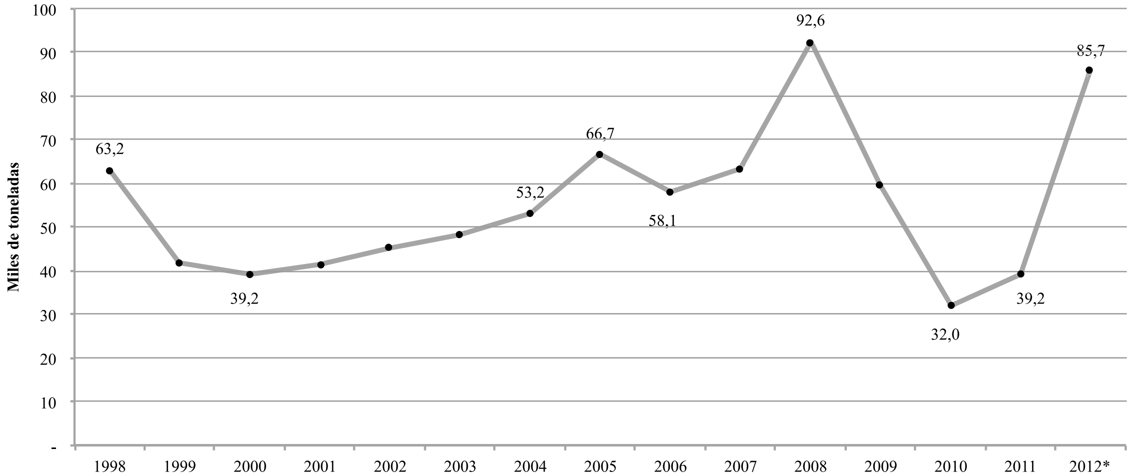
Main types of seed supplied and principal suppliers

The distribution of maize seed in Mexico includes two types of systems, an informal one where local varieties are exchanged between producers, and a formal one that includes the sale of certified seed by large multinational corporations and national private companies and public research institutions. The majority of small-scale farmers use recycled seed, either saving their own from the previous crop or obtaining it from other farmers. Basically, most of the seeds are obtained within the communities in which they live.

In 2011, the 7.8 million hectares planted to maize 3.8 were sown with local varieties, 2.4 million with improved seed for rainfed conditions and 1.5 million with improved seeds for use with irrigation, most of which were imported hybrids. Then, if one takes into account the area sown with hybrid seeds as well as an average density of planting of 30 kg/ha, it is estimated that approximately 45,000 tons of certified maize seed were used that year. More than 90% was marketed by transnational corporations (mainly Monsanto and Pioneer) and the rest by the public sector and around 20 small companies with a capacity of approximately 3000 tons each. Monsanto estimates that from 1990 to 2007, the annual genetic gain was around the 3.8% in the irrigated maize and high-tech areas located in the Bajío and the Northwest of Mexico. The corresponding figure for non-irrigated areas was 1.7% per year.

Public institutions comprise the INIFAP, colleges and agricultural schools, including the University of Chapingo (UACH), the School of Graduate Studies (ColPos) and the Universidad Autónoma Agraria Antonio Narro (UAAAN). The formal system of distribution of improved seeds in Mexico is clearly dominated by the private sector, which controls more than 95% of the market, while the rest is in the hands of the public sector.

Figure 22. Evolution of the maize certified seed production in Mexico 1998-2012*



Source: Saravia 2013

** January-June*

The types of improved seed most commonly used in all regions range from Monsanto hybrids, on the one hand, to OPVs developed by INIFAP, on the other. In the developed markets of the Bajío, the North Pacific and Northern regions, hybrids of large companies like Monsanto and Pioneer predominate, while in the remaining regions INIFAP OPVs and hybrids are the most widely used.

Table 43. Main varieties of seeds used according to applicant/supply and main areas of use. 2012

Applicant	Variety	Market/zone
ASPRO	AS-948, AS-722	Central North
Asgrow	Garañon	Bajío, Northern Pacific and Lowland Tropical
Colegio de Postgraduados	CP Promesa, CP-562	Humid Tropical
Dow Agrosciences de México, S. A. de C. V.	DAS2301	
INIFAP	H-519C, H-318, H-507, H-515, VS-536	Lowland Tropical
	VS-536	Humid Tropical
	VS-536 (OPV), H-443-A (yellow)	Northern Gulf
	Cafime y VS-201	Intermediate Scale
	V-537, Cafime, VS-20, VS-536	Central North
	H-48, H-50, H-515, H-517	High Valleys
	Costeño Mejorado	
Pioneer / Phi México, S. A. de C. V.	P2946W, P3254W	Northern Pacific
	3031, 3028W, 30F53, 30P49, P3837	
Monsanto	Caimán, A-7573, DK-2030	Lowland Tropical
	Bisonte	Northern Gulf and central North
	DK-357	Central Valleys
	DK-2020, DK-2030	Bajío
	Bisonte, DK-2020, DK-2030, MF-8461	Northern Pacific
	A-Tigre Y, CEBU, Cimarron, Gorila, HS-15, HS-5G, Jabali, Ocelote, Z-60, DK-1030, DK-2022, DK-2027, DK-2034, DK-2038, DK-2042, DK-2045, DK-380, DK-777	

Source: Saravia 2013.

Maize seed production and distribution is a highly concentrated market. In 1992, eight of the largest companies met 90% of the needs of the market. In 1996, three companies, Pioneer, DeKalb and Asgrow (Monsanto) were accounted for 68% of sales. The degree of concentration is even higher if we take into account the fact that Monsanto has owned DeKalb since 1998. According to the volume of sales, the company with the biggest share of the national market in 2005 was Monsanto (51%), followed by Pioneer (28%), while the remainder was divided among NK/Zimmerman (6%), CERES (3%) and 26 small businesses (7%). Market share changed slightly in 2012, with Monsanto increasing its share by seven percentage points to reach 58%. This was following its acquisition in 2007 of the transnational companies Delta and Pineland, making Monsanto the current global leader. As a result, the share of Pioneer, NK/Zimmerman and CERES declined that year. However, it is important to highlight the appearance on the market of DowAgrosciences (Brazil), Novasem (former member of Syngenta) and Conlee (Mexico), which mainly sell seeds for tropical conditions.

The regulatory framework governing improved seed in Mexico has very defined phases, from a state regulation on the rights to the generation, reproduction and commercialization of improved materials research to a more mild regulation, where the participation of the seed, both national and foreign companies, determine the characteristics of the market and the distribution of the seeds. The federal law on the protection and use of improved seeds is has been making, leaving farmers select the most suitable to their conditions of production or the market materials which intend to supply. The 2007 law, on the other hand, gives companies total freedom to introduce any material in any region, but without sufficient basic information producers risk selecting a grain not suitable to their area.

Non-specific inputs

Fertilizers and agrochemicals in general are purchased from local distributors, especially those marketed by multinational companies) that constitute oligopolies (Polanco and Flores 2008). There are two major problems with regard to the use of these inputs; their high prices, because most are imported, and small farmers' lack of knowledge about their correct application.

Machinery and agricultural equipment

The market of machinery and equipment for agricultural activities is dominated by a handful of transnational corporations. It is difficult for producers, especially small farmers, to gain access to such equipment because of the high cost involved and the lack of appropriate financing instruments. In general, government supports are channeled towards farmers with more capital, while regions with potential for maize production, such as the southeast of the country, are neglected. A case in point is the Federal Government's Agricultural Diesel Program, which subsidizes such input but only helps large maize producers who own machinery and have control of irrigation water (Polanco and Flores 2008).

Supply of other services and production factors

In Mexico, access to financial services is limited. This situation affects the profitability and competitiveness of maize growing, since farmers who have access to credit have to pay high interest rates, which affect their level of competitiveness. Loans in the country are mainly aimed at medium and large producers; therefore, most small farmers have access to them through different (formal and informal) sources, including family loans (remittances), suppliers and government programs that provide some type of subsidy.

However, the subsidies granted to maize production in industrialized countries generate competition and unfair trade in international markets. For example, Polanco and Flores (2008) estimate that the average annual subsidy to producers in Mexico is USD 700, while in the US it is USD 21,000.

4.3 Maize Research and Development System in NLA

National institutions

Mexico has an extended and complex set of national institutions involved in agricultural R&D. Table 44 lists some of the most important institutions (public, research centers and higher education) involved in maize R&D at the national level. Besides these institutions, the R&D system includes the private sector (represented by seed, fertilizer and pesticide producers and distributors) and a raft of NGO organizations.

Table 44. Public Institutions, Research Centers and Higher Education Institutions involved in Maize R&D in Mexico.

Institution	Name	Acronym
Public	Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias	INIFAP
	Instituto de Investigación y Capacitación Agropecuaria, Acuícola y Forestal del Estado de México	ICAMEX
	Dirección General Tecnológica Agropecuaria	DGETA
	Comisión Nacional del Agua	CONAGUA
	Secretaría de Medio Ambiente y Recursos Naturales	SEMARNAT
Research Center	Centro Internacional de Mejoramiento de Maíz y Trigo	CIMMYT
	Instituto Politécnico Nacional	IPN
	Centro de Investigación y Estudios Avanzados -IPN	CINVESTAV
Higher Education	Universidad Autónoma de Chapingo	UACh
	Colegio de Posgraduados	ColPos
	Universidad Autónoma Agraria Antonio Narro	UAAAN
	Autónoma de Nuevo León	UANL
	Universidad de Guadalajara	UdeG
	Universidad Nacional Autónoma de México	UNAM
	Universidad Autónoma del Estado de Morelos	UAEM
	Instituto Tecnológico de Estudios Superiores de Monterrey (private)	ITESM

Source: Saravia 2013

As for the genetic improvement of maize, this is carried out mainly by public institutions; however, in recent years their role has decreased, while the participation of private companies such as Pioneer and Monsanto is growing.

4.4 Maize processing agroindustry and consumption

The maize market system in Mexico has five large groups of buyers of maize:

i. Large flour companies: MASECA and MINSA function as an oligopoly and acquire the volume of grain required in their plants at harvest price. These companies dominate the domestic maize market in Mexico;

ii. Marketing companies: led by transnational firms that buy grain in producing areas at harvest price, and move it to urban areas for deferred sale, mainly to the maize nixtamal industry;

iii. Regional collecting and storing enterprises: they store purchased grain at harvest time for sale to different consumers, including the maize nixtamal industry;

iv. Livestock producers' associations: they support supply of forage input in the harvest areas with credit, based on the correlation of prices available at that time between the cost of national or imported maize and sorghum, and

v. Large starch manufacturers: they define their volume purchase of maize in growing areas after a comparative analysis of domestic and import prices.

The main buyers of maize that have a great influence on aspects of maize quality valued by the market (color, size and hardness, among others) include the flour industry (MASECA and MINSA) and the growing livestock industry.

Maize consumption

Mexico is the world's fourth-largest consumer of maize, after the US, China and Brazil (FAOSTAT 2012) and accounts for highest per capita consumption, with an average of 255 kg/person/year and a high of 263 kg/person/year in 2012. Maize used for direct human consumption (food) for the period analyzed averaged 125 kg/person/year (estimates based on FAOSTAT data). In the same ten-year period, average maize consumption was five times greater than that of wheat and seven times more than that of soybean.

Since the mid-1970s, the growth in maize demand has constantly outstripped the growth in domestic production, with the shortfall being met with imports, primarily from the US. Since 1980, Mexico has become increasingly dependent on imports, especially of yellow maize, as a result of growing demand from the livestock sector and the inefficient distribution of grain nationwide. Other factors besides insufficient domestic production that have contributed to the rising levels of cereal imports in recent decades include the liberalization of trade under NAFTA and internal structural factors such as lack of access to credit, limited irrigation infrastructure, market concentration, little scientific research and limited subsidies granted by the Federal Government in comparison with those received by farmers in European countries and the US.

It is estimated that in Mexico maize is transformed into more than 600 different products in addition to tortillas, beverages and a wide range of traditional and special products, many of which require different types of maize produced in the country. Given its nutritional content and the preferences of the population, white maize is mainly used for human consumption, while yellow maize is primarily an important input in the livestock and starch industries. However, the growth of the livestock sector in recent years has led to it consuming more white maize. For example, in 2006 the feed industry consumed more than one million tons; while from 2008 to 2010, it is estimated that the figure averaged some 2.3 million tons. Due to the significant growth in the livestock sector and the industries producing starches, syrups, fritters and other derivatives, between 2004 and 2010 national production was used for the following purposes: 54% for human consumption, 30% for livestock, 11% for industry and 1% for seed. In the same period, the apparent national consumption increased at an annual average rate of 3%.

In 2010, farmers consumed about 6.7 million tons of their own production (self-consumption), 11.9 million tons was sold for direct human consumption, 7.7 million tons were consumed as feed by livestock and 2.4 million tons were processed by the industrial sector, making a total of approximately 28 million tons consumed per year.

The main sectors that consume maize are: i) the dough and tortilla industry, ii) the nixtamalized maize flour industry and iii) the livestock sector. The starch industry and the cereal and snack industry consume smaller amounts. Altogether, these sectors consumed an average of 24 million tons from 2008 to 2010. However, they require very specific types of maize that may differ significantly. The demand by type of maize in 2010 was as follows: around 13.2 million tons of white maize, 3.7 million of which were consumed by the dough and tortilla industry, 4 million by the flour-milling industry, 3.9 million by traditional tortilla production in rural areas and 1.6 million by animals. In the case of yellow maize, 64 percent of the 9.5 million tons available were consumed by the livestock industry, 25% by the starch industry and 3% by the cereals and snacks industry.

Direct human consumption

From the nutritional point of view, maize is the main staple and main source of calories for most of the Mexican population. Estimates suggest that, on average, maize accounts for 70% of the calories and 60% of the protein consumed in rural areas of Mexico; the figures for urban areas are 40% and 30%, respectively. On average, Mexicans consume around 88 percent of the maize produced, mainly in the form of tortillas and similar products (toasted maize and corn chips), which contribute approximately two thirds of the caloric intake and about one third of the protein in the diet of the average Mexican.

Mexico is the only country in the world where maize is a core component of the population's diet, consumed in the form of tortillas, a staple since pre-Columbian times. The highest levels of consumption are to be found among the poor population in the country's rural and urban areas. Average per capita consumption of maize in Mexico is approximately 261 kg per year, equivalent to 716.1 grams per day, and the amount continues to grow by 1.6% annually.

Despite the fact that annual per capita consumption fell from 120 to 105 kg between 1997 and 2010, tortillas are still the single most important component of the Mexican diet, with annual consumption put at more than 11.7 million tons. The biggest drop in consumption in recent years appears to have been in rural areas, where it decreased from 12.2 to 9.7 tortillas per day between 1998 and 2010. This fall can be mainly attributed to the urbanization process and higher per capita income. Greater urbanization entails a process of migration from rural to urban areas and a change in diet, as well as increased availability of substitute foods, such as bread, biscuits and instant soups, among others. Higher per capita income triggers a significant increase in the consumption of animal protein. In addition to tortillas, a wide variety of other maize-based products play an important nutritional role. They include corn on the cob, roasted maize, pop maize, tamales, *pozol* (sweet maize beverage), fried and other snacks, as well as a variety of regional specialties.

Livestock and industrial sector

The Mexican livestock sector is developing and changing rapidly due to higher per capita consumption of meat in Mexico. Yellow maize and sorghum are key ingredients in the production of balanced feed for the livestock sector, mainly for the poultry and pork industries. In general, forage grains (maize and sorghum) make up 65% of feed rations, 34% of which is yellow maize. Due to the rise in international prices of this type of grain, however, since 2008 the livestock sector has been demanding more and more white maize. Large industrial livestock producers are supporting the cultivation of yellow maize, particularly in those states with a strong livestock industry. During the period 2008-2010, the livestock sector used an average of 9.53 million tons—with (mainly imported) yellow maize accounting for 75% of the total and white maize for the other 25%. Before 2007, white maize did not account for more than 15%. In 2010, the amount of maize used for the livestock sector fell by 20%. This was due to the economic recession that hit the country; in 2009, GDP shrank 6.5%, the biggest drop in 30 years.

Biofuels

Although maize-based biofuel production is not significant in Mexico, the government has a policy in place designed to change the situation. At the end of 2006, the Mexican government began construction of the first plant for producing ethanol from maize, located in the municipality of Navolato, Sinaloa State. This plant, called Destilmex, started operations in 2013 and it is estimated that will have a nominal capacity of 30 million gallons of biofuel per year, as well as 100,000 tons of maize paste; for which 260,000 tons of raw materials (maize or sorghum) will be required per year.

Domestic prices of maize and its derivatives

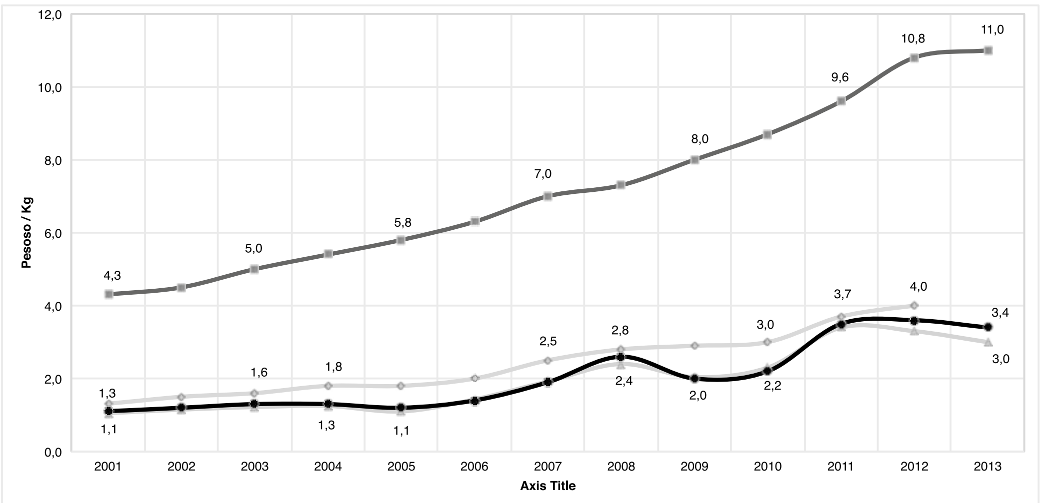
In general, maize prices are governed by the international market and the price paid by large industrial processors (e.g., MASECA). However, despite the rise in international maize prices in 2007, Mexican maize producers received prices far below what they needed to cover their production costs. It is estimated that the export price is 25-30% less than the cost of production. This highlights the vulnerability and low competitiveness of the Mexican MVCS. The situation is made worse by the agricultural policy of Mexico's main trading partner, the US, which grants producers high subsidies and keeps export prices low. Hence, Mexican industrial-scale companies prefer to import maize; in addition to better prices, US entities such as the Commodity Credit Corporation offer payment facilities.

For many years, the Government of Mexico subsidized maize as a way to help small maize producers; however, as part of the structural adjustment policies implemented during the second half of the 1990s, in the wake of NAFTA, the government abolished price controls and removed subsidies for the tortilla industry. In instituting these measures, the government hoped that lower maize prices would push down tortilla prices. In fact, the opposite occurred: the changes triggered increases in tortillas prices in real terms that averaged almost 130% per year during 1997 and 1999, and 22% between 2000 and 2002. The underlying causes of this increase relate to the institutional characteristics of the tortilla market, which is characterized by low levels of competition among flour producers, who have considerable power to set prices that maximize profits.

It should be noted that the real price of tortillas has increased constantly since the mid-1990s, rising by an average of 8.8% per year in the period 2001-2012.

The benefits are distributed throughout the maize value chain at three levels of marketing. During the past three years (2010-12), wholesale distributors obtained the biggest margin (about 55% of the final price), while producers received less than 39%. For example, in 2012 the producer obtained an average price of 4 pesos/kg, the flour industry sold it on at 5.6 pesos/kg and the end consumer paid an average of 10.1 pesos/kg.

Figure 23. **Evolution of domestic maize and tortilla and international maize prices. 2001-2013**



Source: Saravia 2013

4.5 Outlook for the MVCS in Northern Latin America

Constraints to the growth of productivity and efficiency in NLA

The following SWOT analysis (Figure 45) describes the main factors perceived as limiting the growth of production and productivity.

Table 45. **SWOT analysis of the MVCS in Mexico**

Strength	Weakness
Agro-ecological diversity of maize-producing areas Cultural, social, economic and political importance of maize Farmers in transition from traditional to commercial agriculture In the case of yellow maize, the business-oriented sector has started to develop contract agriculture Seed companies have promoted a rapprochement between producers and consumers of yellow maize to consider the requirements of each Brokers' capacity to fill gaps not met by government, such as access to credit and inputs	*Improved seed sector* Weak national and regional seed companies High production cost of improved seeds Insufficient number and size of seed producers that multiply improved maize varieties released by INIFAP Lack of seed microbusinesses with local focus and best distribution and evaluation networks Seed companies produce without taking the specific market requirements into account Lack of investment in the long term to generate hybrids demanded by the industry (yellow hybrids) Limited availability of optimal hybrids and specific maize for forage by agro-ecological region There are no improved varieties or technologies for areas less than 500 meters above sea level Lack of resistant varieties and improved seeds for environments of intermediate agriculture and subsistence. Technical and managerial weakness of multiplier organizations Social economy and business culture Low educational level of producers and strong resistance to change Poor integration among producers Most producers are geared to self-consumption and not to the market Niche markets have not been identified Producers' negotiating capacity is limited Little power to compete in a market economy. Absence of vertical integration and contract projects *Production* High production costs and low profitability for traditional farmers and transition Enormous technological gaps in the white maize chain among small, medium and large producers Limited access to improved farmer seeds Adaptation problems of varieties to which producers have access Serious deficiencies in the handling of seeds (genetic material) and warehouse pest control Insufficient dissemination of information about productive aspects (fertilization, planting, new technologies, dates) and marketing issues (market demand) Ignorance of the quality parameters required by the market and the environmental factors that have a direct impact on quality Lack of technical advice for correct crop management Farmers do not have economic organizations Cultivation on marginal lands, on very small properties with degraded soils The production of traditional farmers has no value added Agents involved in primary production, processing and marketing are not linked There are no appropriate technological packages for agro-ecological zones The growing importance of the production of maize and other pigmented maize is not considered Technology transfer and research Low utilization of existing technology Ignorance of the use of transgenic materials, as well as genetic erosion and traditional systems

Opportunities	Threats
Final products of the corn market changing relatively quickly Agricultural development driven by markets, not the supply, so production, marketing and consumption are more dynamic Changing consumption patterns of the Mexican population Changing needs of today's market (increased demand for yellow corn) Increased pressure to meet quality and food safety standards High demand for specialized corn, which sells for a good price in the market Probability of drought tolerance in native maize, which has several potential uses Potential market niches for pigmented maize, which are in the hands of small producers (choice of gourmet tortillas) Expansion of contract agriculture for white maize required by the business sector, to ensure prices and reduce smuggling or buying and selling through intermediaries The public sector has a lot of germplasm. More knowledge is needed about its quality characteristics, as well as information to determine the regions/conditions for which it is recommended. Exponential growth of information and communications technologies Promotion of special maize Identification of maize graded by quality	Input suppliers act in an unfair way Lack of infrastructure for production with a local focus Modification of consumption pattern of traditional foods Increased demand for yellow corn Shortage of maize breeders, human resources trained in specific biotechnology required on the farm Technical assistance linked to politics and its continuity depends on that consideration rather than the needs of the farmer Lack of policies aimed at improving the productivity of the corn chain and its competitiveness in the domestic market Government's unilateral management of import quotas Economic competition policy mainly benefits large monopolies Biotech revolution is taking off, especially where private companies are concerned Companies generate and disseminate technologies for their own use Increasing concentration of agroindustries and global expansion of major consortia Multinational corporations concentrate their R&D capabilities in their main offices Innovation processes are not national in character Reduction in public funding of R&D activities Little consideration being given to impact of global climate change on food systems, plant location and water availability Increased incidence of pests, diseases, abiotic stress and drought, related to GCC Price volatility. Emergence of biofuel industry and possible conflict with food production and the sustainability of major ecosystems Structural inefficiencies (lack of infrastructure, credit, irrigation systems) Inefficient transport characteristics of monopoly systems Collection and storage infrastructure is in the hands of private individuals

Source: Saravia 2013

Maize R&D Priorities in Mexico

One of the major problems faced by the maize sector in Mexico is the need to raise yields. Experts agree that the country should start correcting soil quality problems, increasing the use of improved seed and improving rainfed production systems, particularly on hillsides.

It is estimated that in the medium term Mexico will require about 3000 tons of seed to plant approximately 100,000 hectares (assuming a density of 30 kg/ha). Maize breeding must not only increase maize yield but also address the challenges posed by climate change, overcoming cultural barriers, as well as provide uniform materials acceptable to the industry. In terms of quality, it is necessary to strengthen the laboratory infrastructure in order to test maize for quality.

It is necessary to adapt the technology that already exists in each maize ecological zone. The high-priority technologies identified include soil and water conservation systems, soil leveling and soil analysis, precision seeders, selection and conservation of seed for sowing, metal silos and moisture gauges, among others. In the social and economic field, it is necessary to improve the impact evaluation system and ensure continuity of the programs based on feedback information obtained from producers and other participating agents. Furthermore, the impact post-NAFTA suggests a need to explore new opportunities to increase the value of maize in Mexico, adopting a two-pronged approach: i) identification of (domestic and international) niches and differentiated markets for Mexican maize, and ii) exploration of different ways to leverage existing value chains (differential maize).

Another area in need of further research is links with the industrial sector. A strong industrial sector is important to give momentum to and spur the development of primary maize production in Mexico. For this sector to grow, it is necessary to ensure a stable supply of quality grain, develop processes that raise productivity, generate new products for the market and comply with environmental regulations regarding sources and emissions.

Finally, a better understanding of public policy with respect to maize production is needed. At a seminar called, "Mexican Agriculture and the Challenges of 2008," held at Mexico's congress, it was observed that a maize development policy should address at least the following issues: (a) gear the supply to the different niches; (b) strengthen partnerships between producers and research and education institutions; (c) promote production by means of agreements on price and quality; (d) make credit available more equitably for maize producers; (e) renegotiate the terms governing maize and beans in the NAFTA; (f) strengthen economic and social farmers' organizations; (g) regulate the authorization of maize quotas; (h) develop a regulatory framework for contract agriculture; (i) promote the establishment of a national storage system; and, (j) consolidate a financial system for maize producers.

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