CLARIS | LPB

SEVENTH FRAMEWORK PROGRAMME

CLARIS | LPB

A Europe-South America Network for Climate Change Assessment
And Impact studies in La Plata Basin

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Deliverables

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CLARIS LPB
A Europe-South America Network for Climate Change Assessment and Impact Studies in La Plata Basin

DELIVERABLES

D8.2: Identification of driving force – impact – response chain relationship between different climate change scenarios and/or induced anthropogenic reactions on land use, agriculture, bio energy and deforestation and towards related issues (hydrology, fire risk)

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BRIEF REPORT OF DELIVERABLE 8.2

This deliverable presents the adoption of the Driver – Pressure – State – Impact – Response (DPSIR) framework to analyse four case studies regarding major land use systems and their dynamics in LPB. Considering the complexity of the issues at stake – climate change, its impacts and the anthropogenic reactions on land use – a framework is needed that allow to structure the complex cause-effect relationships behind land use dynamics, and to guide further studies on the design of adaptation strategies as response to expected climate change, improving decision making. In this regard the DPSIR framework and its elements are discussed. The joint process of how different case studies within the frame of CLARIS-LPB adapted the DPSIR framework and how site-specific issues on climate change effects were structured are outlined. The four case studies addressed different but interrelated topics. The first case study aimed at approaching the most important land use sectors in Brazilian LPB as well as the changes observed in past years, and evaluating the perceptions of stakeholders (farmers and policy makers) on climate change and adaptation strategies in Anchieta, Santa Catarina state, Brazil. In the Argentinean study case based on DPSIR, two dimensions of the State element, land use change and the characteristics of the productive systems, for Balcarce, Junin and San Justo in Argentina, were described. In the case study about fire risks, the DPSIR chain that can lead to the different fire regimes in LPB and its potential changes under climate and socio economic changes based on analyzing recent fire history from five global remote sensing fire products, several land use/land cover datasets, have been investigated. In Uruguay, the DPSIR framework was adopted to analyze the pastured based systems. Although a direct comparison among the DPSIR case studies and its single elements was not the major aim, under the influence of similar drivers, these DPSIR case studies identified some common trends in the dynamics of land use for different regions within LPB. The presented case studies revealed important causal relationships that might be taken into consideration for vulnerability assessment and the design of adaptation strategies to climate change in agricultural land use. These case studies allow for understanding how certain elements of the current situation being addressed are linked, and to which extent they might contribute in the magnitude of the climate change impact.

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LIST OF ABBREVIATIONS

ACE – Farmers with adaptation strategies
AEES – Strategic Area of Economics and Sociology (Argentina)
AR4 – Forth Assessment Report
ASE – Farmers without adaptation strategies
ATSR – Along track scanning radiometer
BAE – Burnt area estimates
BASUR – Regional Project Balcarce South (Argentina)
CERBAS – Buenos Aires South Regional Center (Argentina)
CNA – National Agricultural Census (Argentina)
DAR – Rent out land
DIEA – Department of Agriculture Statistics (Uruguay)
DM – Decision makers
DoW – Document of Work
DPSIR – Driver – Pressure – State – Impact – Response
EEA – Agricultural Experiment Station (Argentina)
EEA – European Environmental Agency
EMBRAPA – Brazilian Agricultural Research Corporation (Brazil)
EPAGRI – Rural Extension Service and Research Corporation of Santa Catarina State (Brazil)
FCA – Factorial correspondence analysis
FUNJUSA – Foundation Fighting Fever Disease (Argentina)
GLOBSCAR – Global burnt area
IBGE – Brazilian Institute of Geography and Statistics (Brazil)
IIASA – International Institute for Applied System Analysis (Austria)
INAC – National Beef Institute (Uruguay)
INPE – National Institute for Space Research (Brazil)
INTA – National Institute of Agricultural Technology (Argentina)
IPCC – Intergovernmental Panel on Climate Change
LPB – La Plata Basin
LR – Legal reserve
LU – Land use
MAPA – Brazilian Department of Agriculture (Brazil)
MINAGRI – Ministry of Agriculture, Livestock and Fisheries (Argentina)
MODIS – Moderate resolution imaging spectroradiometer
NDVI – Normal difference vegetation index
NDWI – Normalized difference water index
NGOs – Non-governmental Organizations
NOAA – National Oceanic and Atmosphere Administration (USA)
NPCC – National Policy on Climate Change (Brazil)
NUMAVAM – Research Group on Environmental Monitoring and Appraisal (Brazil)

OPyPA – Office for Planning and Policy (Uruguay)
PPAs – Permanent preservation areas
PU – Productive units
RIAN – National Agricultural Information Network (Argentina)
SENASA – National Health Service and Food Quality (Argentina)
SIDRA – System of Automatic Data Retrieving (Brazil)
SIIA – Integrated Agricultural Information System (Argentina)
TAR- Rent in land
TDU – Land worked by the owner
UFSC – Federal University of Santa Catarina (Brazil)
UNICA – Brazilian Sugarcane Industry Association (Brazil)
WP – Work Package

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1. INTRODUCTION

In the last decade, evidence of human-induced on global warming and climate change has been extensively discussed in scientific literature. These evidences caused a broad political and societal discussion on the adequate ways and needs to adapt to and to mitigate the causes of global warming (e.g. CO_2-emissions). However, less agreement is seen in terms of the extension of their impacts on ecosystems and society, and how to tackle them properly. As has been discussed by Ison (2010), this is because climate change is among those situations that should be considered as “wicked problems”, or “wicked situations”, because it is a ‘pressing and highly complex policy issues involving multiple causal factors and high levels of disagreement about the nature of the problem and the best way to tackle it’.

In this regard, the information base for better policy decision making should be improved by structuring the complexity of these “climate change wicked situations”. Applying a proven, reliable and tested conceptual framework appears to be an adequate way to illustrate functional relationships in these situations for improved decision making.

Therefore it might be helpful to adopt a framework like the Driver – Pressure –State – Impact – Response (DPSIR) framework not only with the aim to shed some light on the relationships from which the “wicked situation” global warming and climate change is possibly emerging, but also to structure the research process across various work packages of the CLARIS LPB Project.

1.1 Objectives

The main objectives of the deliverable 8.2 are:

- To report the surveys carried out for specific study sites within LPB to allow for a better understanding on causal relationships between different climate change scenarios and/or induced anthropogenic reactions on agricultural land use, agro-systems and rural development, fire risks, pastures, and other related issues (sections 3.1 to 3.4 on this deliverable);
- To describe the joint process of adopting a common framework as a methodological base for analyzing the selected study sites in terms of research issues, allowing comparative analysis of possible climate change impacts on land use;
- To structure the complex cause-effect systems of interrelations regarding anthropogenic climate change and land-use/land-cover changes in different parts of La Plata Basin;
- To discuss the adoption of a common framework to guide further studies on the design of adaptation strategies as response to expected climate change and associated land use dynamics.

2. THE NEED OF A FRAMEWORK

Climate change characterizes a “wicked problem” (Rittel and Weber, 1973), or a “wicked problem-situation”, and in such situations different researchers may have not only different perspectives on the issues at stake, but they can be even very controversial. Usually it seems that the more intensified the controversial discussions are, the higher also the divergences and distinguishing issues are among different analyzed regions. Therefore, the adoption of a framework like DPSIR may help the process of structuring and harmonizing the cause-effect relationships analyzed in different case study regions. Within the CLARIS LPB project the major purpose of applying the DPSIR framework is to facilitate the discussion among all involved stakeholders. The participative process of the involvement of all actors is an evident key for developing tailor made, region explicit and socially accepted good practices to better adapt to climate change.

The DPSIR framework has been proven to be an useful tool to analyze many different problem-situations (Rodríguez-Labajos et al., 2009; Holman et al., 2008; Bouma and Droogers, 2007). One of the strengths of the DPSIR framework is the generic way of addressing problems across different scales such as from global systems to small watersheds. This is the major reason why DPSIR is widely disseminated among research and policy decision levels. Among a wide range of environmental issues, it has been also widely adopted to address the issue of climate change.

In projects like CLARIS LPB where scientists from different disciplines with different backgrounds are committed to work together, the adoption of a common framework also facilitates communication and exchange of ideas. In other words, the adoption of the framework might create the necessary relational domain for collaborative work. The DPSIR framework might be therefore a way to improve the communication creating a common understanding of the research topics and to ideally transform these findings into policy measures.

2.1 The DPSIR Framework and its main elements

The DPSIR conceptual framework was developed by the European Environmental Agency (EEA) in 1999 (Smeets and Weterings, 1999). The approach of this framework identifies a causal link between “driving forces D” (human activities) through “pressures P” (emissions, waste) to “states S” (physical, chemical, biological, socio-economical) and “impacts I” on the system leading eventually to political “responses R” as corrective policy actions. The causal chain from “driving forces” to “responses” allow for breaking down into steps by considering relationships and interactions (Frederiksen and Kristensen, 2008).

The DPSIR Framework is a useful approach to assess in parallel socio-economic and environmental issues for a given problem-situation. It is therefore useful as an integrative framework, since different but related assessments may be combined or compared. There already exists a vast literature on DPSIR, and a review will not be made here. Carr et al. (2007) summarizes the development of the DPSIR including its origins, applications and criticism. The key elements of the DPSIR and the necessary inputs for modeling results using the framework are presented in Figure 2.1.1.

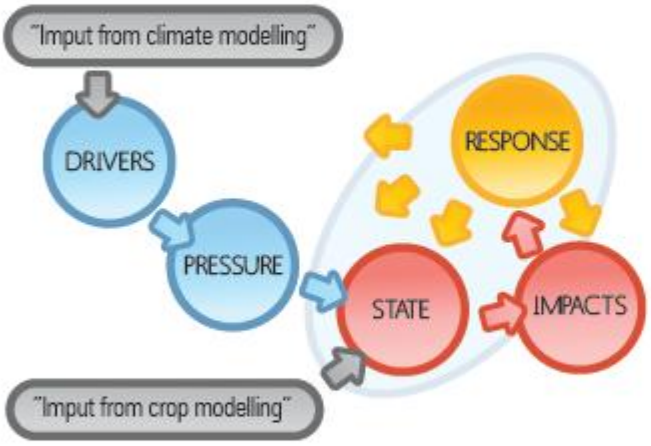


Figure 2.1.1: DPSIR elements and modeling input

In the Fourth Assessment Report of the IPCC (Carter et al., 2007), DPSIR is cited (Chapter 2, page 137, Table 2.1) as a research method for impact assessment. Therefore, in WP8 of CLARIS LPB, the DPSIR framework will be adopted to structure the complexity of causal relationships regarding anthropogenic climate change related to land-use/land-cover changes as one major driver. Therefore the DPSIR framework is most adequate to use within WP8 in order to address its research issues in the sense claimed by Ison (2010), for whom adopting an approach must be more than just choosing one approach among the existing ones, but should involve the process of contextualization of the approach in relation to the situation (section 3).

The main elements of DPSIR may be described as follows:

a) Driving forces

Driving forces within the DPSIR framework are defined by Holman et al. (2008) as "causes of environmental change which are exogenous to the region". This may be anthropogenic induced climate change, national and international policies or socio-economic changes. Driving forces define all reasons which determine resulting observed changes of landscapes (Bürgi et al., 2004). Briefly, driving forces are the factors which cause changes in a system. They may be social, economical or ecological and comprise positive or negative influences.

b) Pressures
Pressures within the DPSIR framework are on the one hand defined as the means through which drivers are expressed (temperature, precipitation …). On the other hand pressure stands for all activities which put pressure on the system itself. In that case, they are human activities and natural processes which result from the driving forces (in our case broadly speaking land use change as such).

c) State
State is the situation of the environment under current conditions. The combination of environmental and socio economic conditions define the state of the WP8 rural systems under study.

d) Impact
Impacts are the modifications of the state. It is useful to divide the impacts into direct impacts and indirect impacts. Impacts may be declining yields and declining food availability, changes in water quality, increase in fertilizer use, and as indirect (or secondary) impacts poverty, health problems, etc.

e) Response
Response refers to all efforts to address the changes in “state” and “impacts”. Generally, Responses refers to institutional efforts (formal policies, informal coping mechanisms etc.) to address the verified changes.

2.2 The joint process of adopting a common framework for CLARIS LPB

Especially in large, multidisciplinary projects like CLARIS LPB in which a high number of scientists collaborate, a framework helps to focus on the same set of research questions, and to foster common understanding of problems, methods and results. With this intention, the Driver-Pressure-State-Impact-Response (DPSIR) framework has been successfully used in several multidisciplinary research projects (Rodríguez-Labajos et al., 2009; Holman et al., 2008; Bouma and Droogers, 2007). Therefore, and based on previous experience with this framework of some researchers working in the CLARIS LPB Project, it was decided to adopt it to support the research activities of WP8.

In this sense, during the WP8 – WP9 meeting held in Curitiba, Brazil, from 22 to 24 June 2009, the DPSIR framework was briefly presented to the WP8 scientists. It was decided that the existing DPSIR framework should be used as a basis for the research process and that its single components (D, P, S, I, R) might be renamed, skipped or added following the ideas of the participants. After this presentation, each WP8 partner in charge of different research subjects linked its respective research to the logical chain of the DPSIR components. This exercise resulted in five “causal webs” based on DPSIR. Secondly, WP8 members agreed on how to fill in each DPSIR component to get one casual web as orientation for the ongoing joint work. The resulting agreed common DPSIR is presented in Figure 2.2.2, and each DPSIR element is described in the text that follows. Furthermore, it must be remembered that even this DPSIR might not be definitive. During the course of the research, it is expected that the DPSIR elements will be filled in by the participating stakeholder groups (farmers) and political decision makers. This may subsequently change “the picture” again. Therefore, the DPSIR of Figure 2.2.2 reflects a momentum, but should be dynamic over time.

Beyond that, in the CLARIS LPB M26 Meeting, held in Florianópolis, Brazil, from 8 to 12 November 2010, the whole process of defining DPSIR elements within WP8 was revised again, and resulted in the specific case studies described on section 3 of this deliverable.

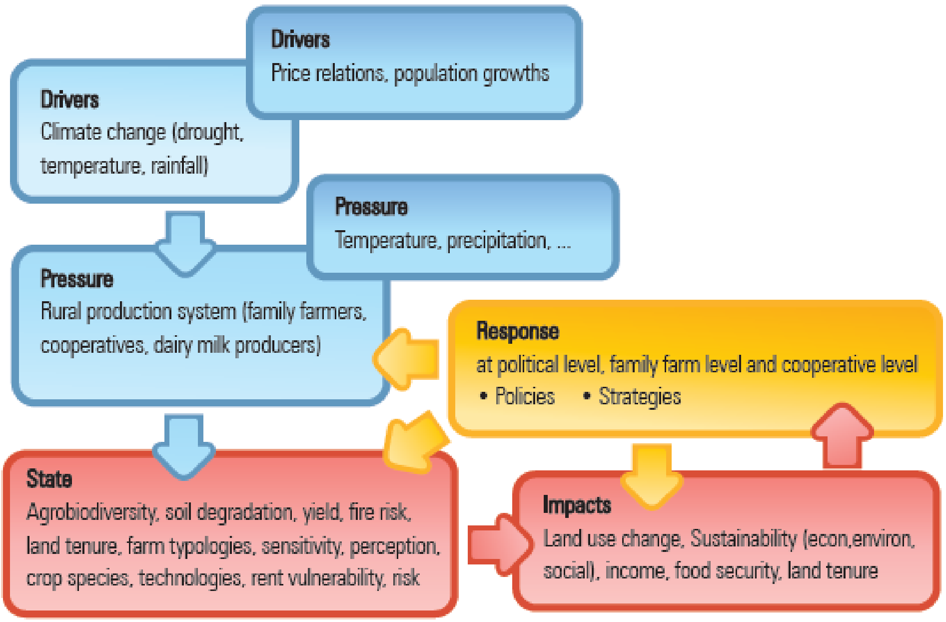


Figure 2.2.2: DPSIR of WP8 as agreed during the WP8-WP9 Meeting in Curitiba, Brazil

In the sequence, each element of the agreed DPSIR of Figure 2.2.2 will be briefly explained.

Drivers: Drivers or driving forces lead to pressures on the environment. For CLARIS it is considered as “anthropogenic produced climate change” as one major driver. The driver climate change is defined by three main indicators: drought, temperature increase and rainfall intensity. But climate change seemed not to be the only recognizable driver in LPB. It was decided that major economic and demographic drivers (price relation, population growth) will be also observed and discussed in the research. Major reason for this decision were experiences in other projects related to applications of modelling approaches and resulting driver sensitivity on impacts (Helming et al., 2011);

Pressure: Pressures are on the one hand the means through which drivers are expressed (e.g. temperature, precipitation, etc.) and on the other hand the system the pressure "attacks". It was agreed that WP8 will carry out research with emphasis on different rural production systems as family farmers, cooperatives, dairy milk producers etc. (including land use sectors as forest, transport etc.);

State: The combination of environmental and socio economic conditions define the state of the rural systems. The state element was filled with the indicators the different sub-groups work with: agro biodiversity, yield, fire risk, farm typology, crop species, and soil degradation;

Impact: Impacts are the effects resulting from the change in the state caused by driver changes. For CLARIS WP8, the thematic area of land use and changes in land use is of major importance here. Additionally, effects on sustainable development, land tenure, income and food security issues might be analysed;

Response: A response can be described as a reaction to changes in the "State" and to effects on the "Impacts". It was agreed that in WP8 responses at political level, family farm level and cooperative level will be objective of analysis. Policies and management options as well as attitudes and strategies will be taken into account as well.

3. CASE STUDIES BASED ON DPSIR

This chapter describes the application of the outlined DPSIR Framework for CLARIS LPB in the form of case-study-based analysis.

3.1 Land use

The La Plata Basin (LPB) is the most important region for agriculture and animal production in South America. Managed agricultural ecosystems in the basin play a central role in world food production and food security. Land use in rural areas in LPB is dominated by monocultures and cattle grazing and 40% of the land is cultivated by small-scale family farmers. The major products, mainly for exporting, are soybean, maize, cotton, sugar/alcohol (sugarcane), timber (planted forests), meat (in planted and native pastures), poultry, rice, wheat, coffee, and orange juice. The region has been subjected to processes of significant land use changes as a result of various policies implemented during the last 40 years. Current land use change processes can be generally categorized as i) the expansion of agriculture over natural forests; ii) the expansion of tree plantations over grasslands and conversion from natural forests; iii) the intensification of agricultural systems, and iv) grazing on natural vegetation (Baldi and Paruelo, 2008).

The intense human activity in LPB region and its associated rapid urbanization, accompanying deforestation of lands for farming, have increased runoff in rivers, modified local climatic conditions (e.g., rainfall, humidity, temperature, and wind speeds), and impacted the global climate due to the spatial scale of LPB (Coutinho, 2006). The trend for the mentioned region is an increase in pressures due to land use change in order to attend the demand for food of the growing population, with the consequent enlargement of the agricultural and industrial development bases.

In this report DPSIR framework was used to analyze the trends in agricultural land use in Brazilian territory of LPB based on two studies developed by UFSC/NUMAVAM research group. The first study aimed at approaching the most important land use sectors in LPB as well as the changes observed in the past years. The second one was a study case that evaluated the perceptions of stakeholders (farmers and policy makers) on climate change and adaptation strategies in Anchieta, Santa Catarina state. These studies are described in the next sections.

3.1.1 DPSIR for Brazilian LPB

The dynamics of land use in Brazilian La Plata Basin was structured according to the DPSIR framework (Figure 3.1.1). The Drivers “Population growth and consequently the demand for food” exerted pressure on land use by changing the land use/land cover in this area, mainly by the increase of areas for temporary crops and pasture. The increasing need for food production and goods, linked to the threats of climate change, pushed to studies related to agroecological zoning in order to assure suitable conditions for crop production in LPB area. Furthermore, environmental laws enforcement has provided the means to regulate the interaction of human activities and natural resources in order to assure a safe agricultural land use, especially in the representative area of Brazilian LPB. These DPSIR components are described in the following sections.

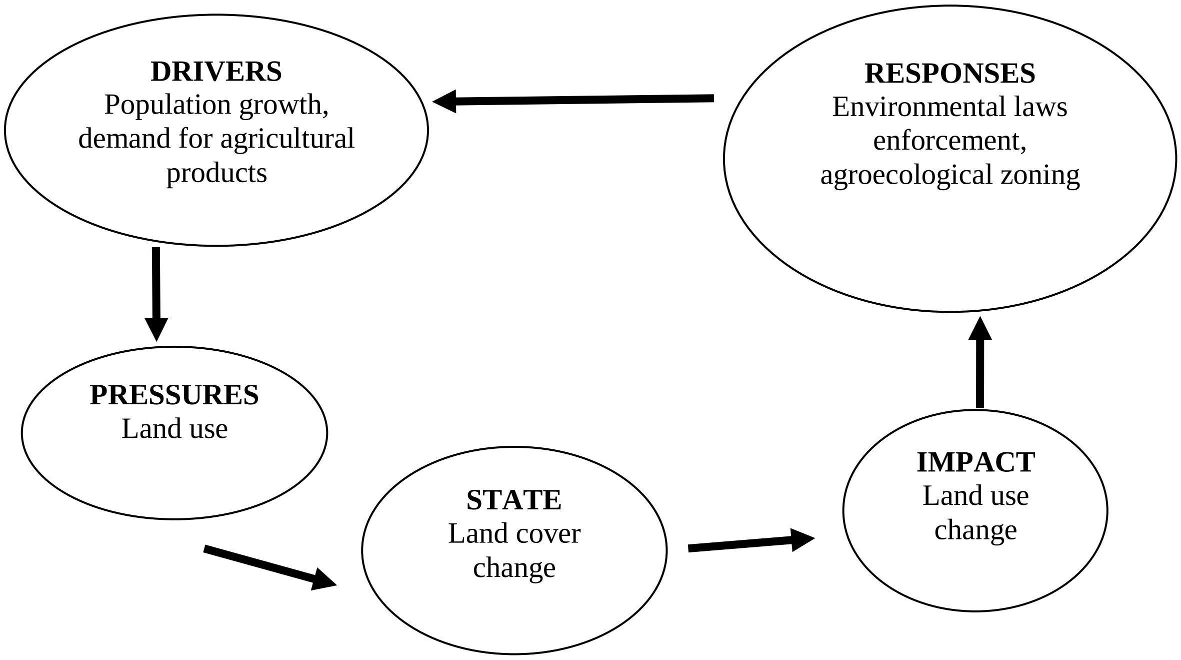


Figure 3.1.1: DPSIR for Brazilian LPB

3.1.1.1 DRIVERS: Demand of agricultural products and population growth

The La Plata Basin (LPB) has three main sub-basins: Paraná, Paraguay and Uruguay River systems. The LPB covers an area of 3.1 million km^2 with a population of over 100 million people of Argentina, Bolivia, Brazil, Paraguay, and Uruguay. Rural land use and industry in the basin are responsible for 70% of the Gross National Products of the LPB countries, being in a process of continuous change, as a response to drivers such as market trends, infrastructure and technology developments, societal evolution, and the dynamics of national policies.

Globally, agricultural systems have been changing over time in terms of intensity and diversity, as agriculture undergoes transition driven by complex and interacting factors related to production, consumption, trade and political concerns. There are a multitude of agricultural systems worldwide and they range from small subsistence farms to small-scale and large commercial operations across a variety of ecosystems and encompassing very diverse production patterns (Wiebe, 2003). In LPB three agricultural sectors have been responsible for most of the land use changes in the last thirty years:

international commodities (soybeans, etc.), forestry (eucalypt and pine), and meat (cattle). Soybean and other grain crops, as well as cultivated pasture (*Brachiaria spp.)* are widespread in the LPB, and have replaced portions of all of the basin's biomes. Biofuel crops, such as sugarcane, are increasing as a result of the growing international market, and national policies (Baldi and Paruelo, 2008; Coutinho et al., 2009).

Agriculture as the source of human food, animal feed, fiber, and fuel plays a key role in efforts to achieve global sustainable development. Projections of the global food system indicate a tightening of world food markets, with increasing scarcity of natural and physical resources, adversely affecting poor consumers (FAO, 2006). Agriculture will need to respond to several key changes in driving forces in the next decades. Key drivers include an increasing global population, changes in dietary and in trade patterns, land competition, increases in agricultural labor productivity, climate change and demands for agriculture to provide ecosystem services. A driver is any natural or human induced factor that directly or indirectly influences the future of agriculture. Categories of indirect drivers include changes in demographic, economic, sociopolitical, scientific and technological, cultural and religious, and biogeophysical change. Important direct drivers include changes in food consumption patterns, natural resource management, land use change, climate change, energy and labor (McIntyre et al., 2009).

Around two hundred years ago, Malthus stated that while the populations of the world would increase in geometric proportions, the food resources available for them would increase only in arithmetic proportions. By 1960, his concerns appeared well founded. Growing at an unprecedented rate, the world's population reached 3 billion, of which about a third were chronically undernourished. Four decades later, the world's population has doubled to six billion, and demand for food has grown with it. But food production has grown even faster, and the number of people who are chronically undernourished has fallen. Growth in food demand has generated incentives to increase resource use and improve technology and efficiency much more rapidly than Malthus anticipated, particularly during the second half of the 20th century (Wiebe, 2003).

The consequences of population growth and economic expansion have been a reduced resource base for future agriculture; now there are pressing needs for new agricultural land and water resources. In recent decades the development of integrated pest/water/nutrient management practices, crop/livestock systems, and crop/legume mixtures have contributed greatly to increase agricultural sustainability, but further progress in these practices is needed, especially to combat declining soil fertility (Altieri, 2004).

Agricultural activities require change of the natural ecosystem to an agricultural system that is oriented towards human use. Deforestation is the first major step to convert primary tree vegetation into cropland or grazing land, thereby reducing biological diversity in most instances. Other environmental impacts are related to soil, physical, biological and chemical degradation and problems of water quality and quantity.

Humans are mostly dependent on agriculture for food. So much recent attention has been given to the question of whether agriculture, particularly modern agriculture, can maintain its current levels of production and those predicted for the near future. Agricultural development has also changed and it is altering the global pool of genetic resources (for example, loss of valued wildlife) and in a manner that may eventually undermine the sustainability of agricultural production. In recent times, doubts have arisen about whether intensive agriculture based on high inputs of capital and high use of resources external to farms, and relying on modern science, might be sustainable. It is claimed that the application of modern industrialized methods that have produced much agricultural growth are bringing environmental changes (and in some instances, social changes) that will undermine this growth eventually and depress the level of agricultural production (Tisdell, 2006).

The openness of modern industrialized agricultural systems compared to the traditional agricultural systems creates sustainability problems for modern agriculture. Potential obstacles to sustaining yields from modern agriculture include the following: possible lack of future availability of many external inputs, such as fossil fuels and some types of fertilizer, because global stocks are finite and they are exhaustible and non-renewable; reduced soil fertility due to long-term use of chemical fertilizers, for example, increased acidity of the soil, and impoverishment of soil structure due to frequent cultivation and lack of return of organic matter to the soil to provide humus; the widespread use of chemical pesticides and herbicides in modern agriculture can create resistance of pests to pesticides, impacting the soil flora and fauna, which can negatively impact on farm productivity; and pollution of shared water bodies, cause salting or water logging of soils over extensive areas and seriously disrupt hydrological cycles (Altieri, 2004; Tisdell, 2006).

Modern industrialized agrosystems are characterized by the use of few species on the farm, the presence of monoculture, and the use of varieties of crops that were not developed locally to suit local conditions, such as the varieties developed by companies (often multinational ones) specialized in plant breeding. In general, traditional agroecosystems are less vulnerable to catastrophic loss because they involve a wide variety of cultivars, including landraces (native parental varieties), which are genetically more heterogeneous than modern cultivars and offer a variety of defenses against external factors. In areas of crop diversity, traditional agroecosystems also contain populations of wild and weedy relatives of crops that enrich genetic diversity (Altieri, 2004).

Modern agriculture is associated with a global reduction in crop varieties and breeds of livestock as a result of the growing globalization, the development of food production technologies and methods that allow increased artificial manipulation of micro-environments in primary food production; and more widespread trade that reduces dependence of local agriculture on local material inputs. Market extension encourages greater specialization in agricultural production by farmers and the adoption of specialized breeds of livestock or varieties of crops, resulting in path dependence. Consequently, agricultural production systems become more specialized. This reduces the scope for their co-evolution at the local rural level, and agricultural innovations have primarily become dependent on large specialist corporations that supply inputs to farms (Tisdell, 2003).

Most discussions about agricultural development focus on the interaction of five main factors: innovation, inputs, infrastructure, institutions and incentives. Equity issues are inherent, though they may not be explicitly evoked, in the policy decisions that guide the investment of resources in these areas. For example, agricultural research and development is needed to generate productivity by enhancing technologies, but choices must be made to the orientation of research efforts. The improvement of local food crops to better satisfy nutritional needs, the development of drought-resistant breeds to provide a more reliable harvest to those living on marginal lands, or the development of horticultural production suitable for exporting may all be worthy goals in themselves, but they have very different potential beneficiaries (HDR, 2006).

There is evidence that the change in land use and land cover has brought about, and continues to bring significant impacts on local, regional and global environmental conditions, as well as on economic and social welfare. Agricultural activities have undergone important changes during the last decades because of technological improvements and new national and international market conditions. In LPB, the impoverishment of the native biota caused by the modification of ecosystem motivated by biotic invasion, grazing activities, and other factors, is one of the consequences of land use change, especially regarding to grassland areas (Baldi and Paruelo, 2008).

Projected changes in agricultural land use are caused primarily by changes in food demand and in the structure of production as defined by technology, input scarcity, and environmental conditions. Scenarios with a greater extent of agricultural land use result from assumptions of higher population growth rates, higher food demands, and lower rates of technological improvement that limit crop yield increases. Combined, these effects are expected to lead to a potentially large expansion of agricultural land use. In LPB, the growing demand for expanding agricultural land use is expected to continue pushing the convert of natural ecosystems – forests, savanna and grasslands. Conversely, lower population growth and food demand, and more rapid technological change, are expected to result in lower demand for agricultural land (McIntyre et al., 2009). In LPB region, however, a large portion of commodities supplies international markets, whose demand growth rates compared to increase in productivity due to technological advances are yet to be checked out.

Some studies (Kang, et al., 2009; Assad and Pinto, 2008; Seo and Mendelsohn, 2008; Zullo Jr. et al, 2006; Burton and Lim, 2005) have been developed in order to assess the increase in temperatures due to global warming, which can be threatening to agriculture and food security. In addition, a large set of these studies have focused on the reduction of yields of specific crops in warmer temperatures, since it is assumed that farmers make no changes in crops, predicting large yield losses from climate change and therefore large losses in net revenues. Studies that assume changes in crops predict that farmers will move away from crops with low yields and substitute them by new ones that will perform better in the new climate. Furthermore, the cost of a program directed to the adaptation of cultivars through genetic improvement and adaptation of management systems for through irrigation have been also evaluated (Burton and Lim, 2005; Seo and Mendelsohn, 2008). Some biotechnological solutions may be used, especially the genetic improvement of plants, searching for tolerant cultivars of soybeans, coffee, corn, rice, beans and cotton adapted to high temperatures and drought.

3.1.1.2 PRESSURE: Land use

The human actions that result from drivers directly alter the environment. The demand for agricultural products in order to supply the needs of growing population exerts pressure on land use, expanding and intensifying the agricultural activities, and modifying the land cover. These aspects will be discussed in relation to LPB in the next section, in which two elements of DPSIR are discussed together.

3.1.1.3 STATE – IMPACT: Land cover change/land use change

Changes in land use and land cover result from the complex interactions between economic, social and environmental aspects motivated to the need of expanding agricultural land in order to provide goods and services essential to human subsistence. In the Brazilian sector of the Uruguay River Basin, subsistence crops and pastures are alternated with soybean, maize, and wheat crops, depending on soil and climate characteristics. In the Paraguay Basin, land use changed rapidly due to the clearing of natural vegetation for extending agricultural production areas, further expanding soybean cultivation and livestock exploitation. These processes occur in the Planalto (Brazilian plateau) and in the Pantanal (Brazilian wetlands), although in the latter, the expansion of agricultural production is constrained to some extent by conservation priorities. Finally, in the Paraná Basin, the land use involves agricultural and livestock production, cultivated and native forests. The main agricultural and livestock activities are cattle raising and soybean, sugarcane and coffee crops. It is important to point out that about 10% of the Brazilian bovine herds are raised in the La Plata Basin (World Water Assessment Programme, 2007).

The estimation of the magnitude of climate change and its impacts on crop production is required to develop adaptation strategies. As the climate is likely to result in at least 2°C warming by the end of the 21st century (IPCC, 2007), agricultural systems need to adapt to this average temperature increase. In this sense, the identification of the most important land use sectors in a region as well as the changes observed in the past years are fundamental to recognize which agricultural areas are more vulnerable to climate change. The vulnerability of these systems is the main factor to be evaluated in order to design adaptation strategies, which have to be as far as possible anticipatory and preventative and wherever possible, mitigation and adaptation measures should be combined (Giddens, 2009).

Taking into consideration these aspects related to climate change and agricultural land use, a study was carried out in the Brazilian territory of LPB in order to identify the different land use sectors and the areas occupied by temporary and permanent crops, forests and pastures, as well as the magnitude of animal production. This survey might be considered one of the first steps to evaluate the last trends and changes in land use in the mentioned area, whose results may be helpful in guiding the design of adaptation strategies to face climate change and variability in the region.

The LPB area in Brazil includes eight states distributed in three geographical regions: south, southeast and middle west. The total area of Mato Grosso do Sul State (35.713.990 ha) is located in the basin. The other states present their area partially located in the basin as following: 21% of Minas Gerais (12.409.850 ha), 47% of Goiás (16.081.470 ha), 21% of Mato Grosso (19.062.270 ha), 93% of São Paulo (23.310.590 ha), 87% of Paraná (17.395.220 ha), 41% of Santa Catarina (3.968.870 ha), and 37% of Rio Grande do Sul (10.532.810 ha) States (Figure 3.1.2). The areas of the municipalities partially located within the basin were estimated from cartographic maps with a scale of 1: 2.000.000 (República Federativa do Brasil, s.d).

The major source of data used to characterize the dynamics of agricultural land use change in the Brazilian area of LPB was the System of Automatic Data Retrieving (SIDRA) of the Brazilian Institute of Geography and Statistics (IBGE) platform (available at www.sidra.ibge.gov.br). Data were selected from agricultural census carried out by IBGE in 1996 and 2008 regarding the total areas (in hectares) used for temporary and permanent crops in general, forests (natural and planted) and pastures. The total areas were obtained by the sum of all crops produced in the municipalities located within the basin. The data for land areas used for crops with major economical significance for the region as coffee, maize, soybean, sugarcane and wheat were considered and presented in this study. It is important to remark that some discrepancies in the total area for temporary crops may appear due the fact that rotation of crop systems are widely used in this region, as for example the crop sequence of wheat (winter crop) followed by soybeans and/or maize (spring/summer crops). Because of the relevance and impact on land use in the region, data for cattle, swine and poultry production were also evaluated in this study.

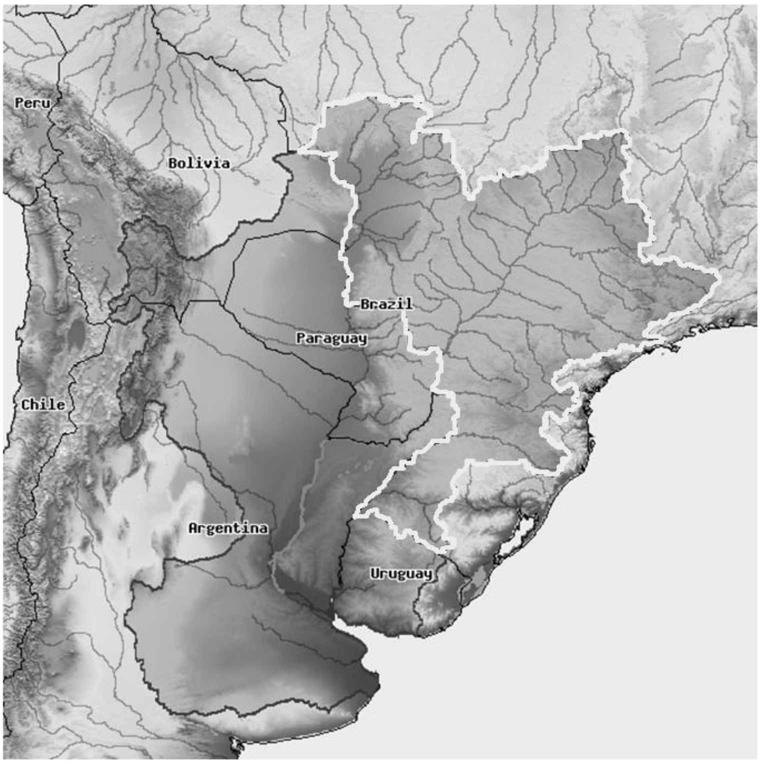


Figure 3.1.2: La Plata Basin area with Brazilian territory highlighted in white. (Adapted from http://www.eol.ucar.edu/projects/lpb/dm)

The categories of land use included in this study were described according to IBGE (2006), as following: temporary crops are plants presenting short or medium duration, generally with vegetative cycle inferior to one year. After harvesting, the land is available again for a new cultivation. Cereals and vegetables are the main temporary crops, but flowers, medicinal, aromatic, and flavor crops were also grown in the area. Semi permanent crops, such as sugarcane, cassava, and some forages are included in this category. Permanent crops are plants presenting long cycle and produced from plants which last for many seasons, rather than being replanted after each harvest. In this category, it can be included fruit trees, coffee, cocoa, and rubber trees. These crops can be grown in agroforestry or in monoculture systems. Pastures are land areas covered by grasses or leguminous plants used for grazing of livestock. Plants in these areas can range from some decimeters to a few meters. Forestry areas are managed with native or exotic species aiming to provide raw material for industry uses, like wood, cellulose, and paper. Pinus and eucalyptus are the main species used for foresting. Part of the land might be used as forestry legacy preservation areas.

Trends in agricultural land use changes varied across the study region during the considered time period (Figures 3.1.3 to 3.1.10). In Rio Grande do Sul, areas used for pastures decreased whereas areas used for forests and temporary crops increased (Figure 3.1.3), mostly soybean (Figure 3.1.12), wheat (Figure 3.1.15), and rice. The area cultivated with rice increased from 868,578 ha in 1996 to 1,065,633 ha in 2008 (Data not presented in the figures). We assume that pastures is the category of land use that showed the highest decrease in extension, mainly due to conversion into areas of planted forests and temporary crops.

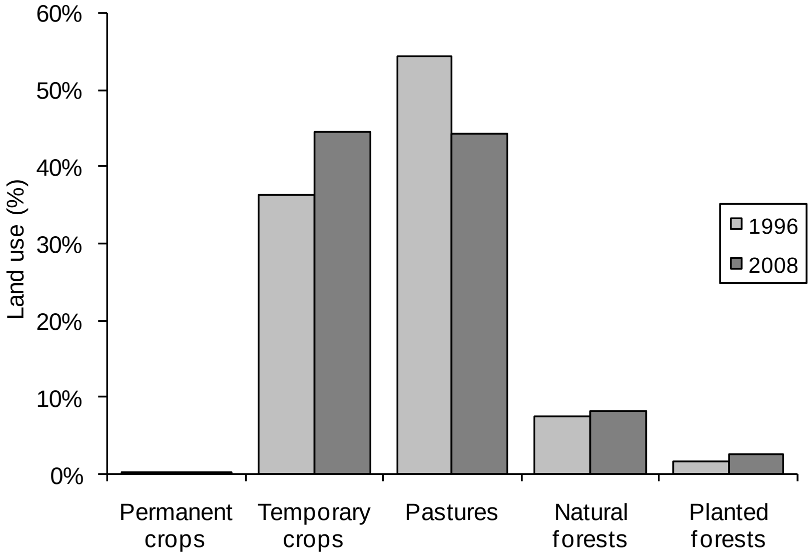


Figure 3.1.3: Agricultural land use in the area of Rio Grande do Sul State located within LPB in 1996 and 2008.

In Paraná State the area used with pastures decreased slightly from 1996 to 2008, and probably it was converted to temporary and permanent crops (Figure 3.1.4), especially soybean (Figure 3.1.12), sugarcane (Figure 3.1.13), and maize (Figure 3.1.14). Increases in the areas used with permanent crops were observed for orange (9,471 ha to 19,900 ha) and peach (865 ha to 1,596 ha) (Data are not presented in the figures).

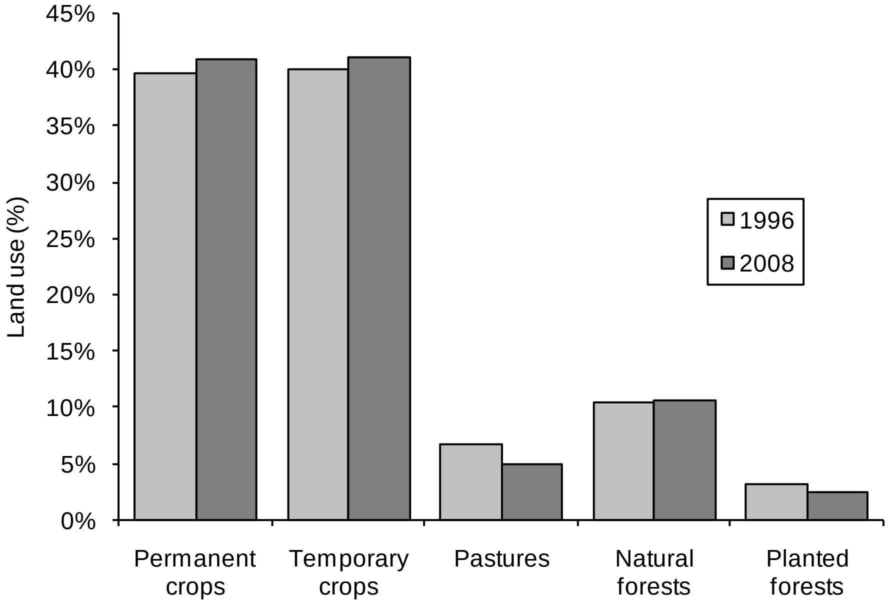


Figure 3.1.4: Agricultural land use in the area of Paraná State located within LPB in 1996 and 2008.

In Santa Catarina State the area used for pastures decreased, as they were replaced by temporary crops and forests (Figure 3.1.5). Soybean (Figure 3.1.12), sugarcane (Figure 3.1.13), and wheat (Figure 3.1.15) were the main crops responsible for the increment of 4% in the area used for temporary crops. The area used for forests increased 7% in Santa Catarina mainly due to reforestation with *Pinus* and *Eucalyptus* species for timber and paper production. The silviculture of these genera in South Brazil was a process established as a development strategy for the country in the 1960’s and 1970’s. Nowadays these man-made forests for wood production maintain a productive chain which has a fundamental participation for the country’s economy (Vasques et al, 2007). The south region in Brazil presents 77% of the area of planted forests with *Pinus* and *Eucalyptus*, which has increased in this region during the last years (ABRAF, 2009), much of it from planting directly over native grasslands.

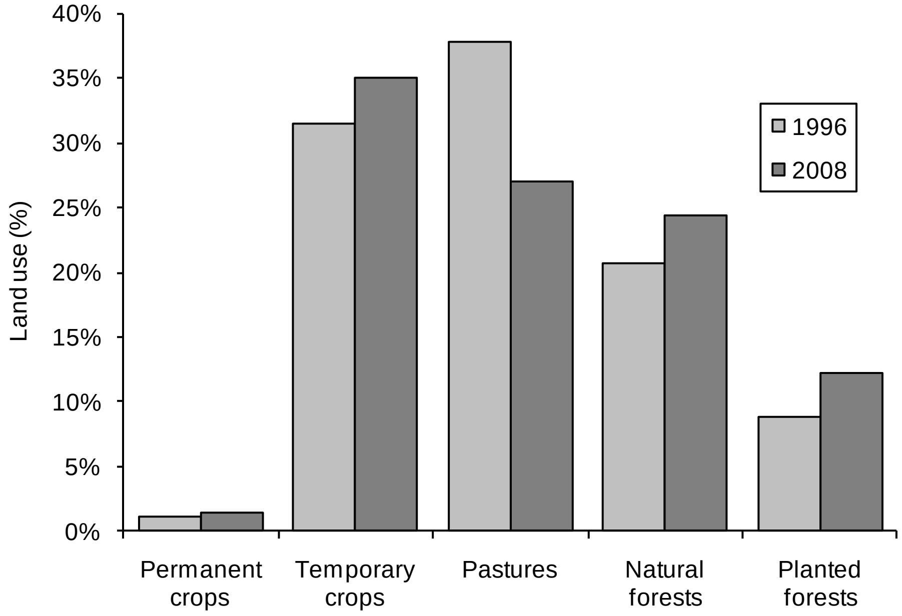


Figure 3.1.5: Agricultural land use in the area of Santa Catarina State located within LPB in 1996 and 2008.

Land use for temporary crops and pasture increased in São Paulo (Figure 3.1.6). New areas cultivated with sugarcane were the main change regarding temporary crops (Figure 3.1.13). A decrease in the area observed for permanent crops was due mainly to reduction of coffee (Figure 3.1.11) and orange cultivation (from 719,735 to 592,568 ha. Data not presented in the figures).

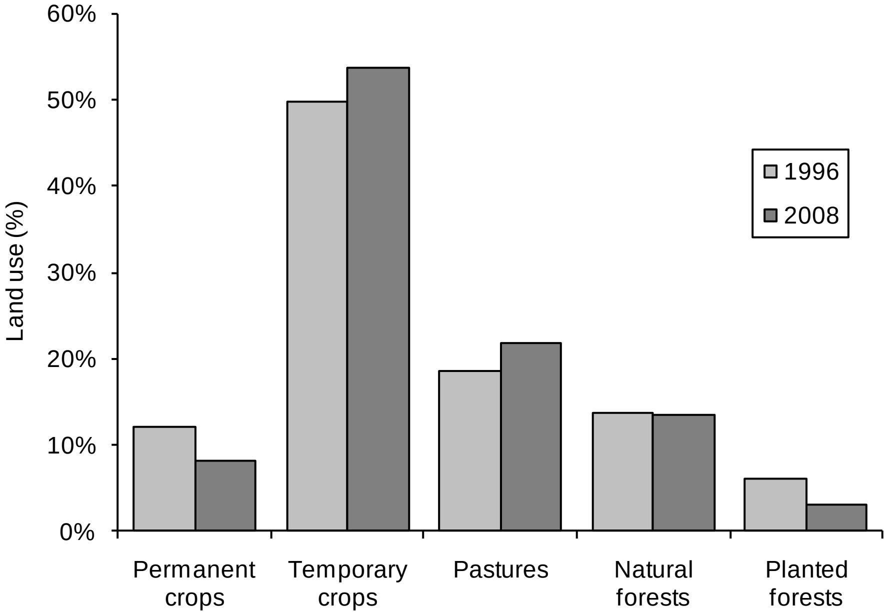


Figure 3.1.6: Agricultural land use in the area of São Paulo State located within LPB in 1996 and 2008.

Minas Gerais and Goiás presented similar trends in the dynamics of land use. In these States, some areas used for pastures were replaced by temporary and permanent crops as well as by forests (Figures 3.1.7 and 3.1.8, respectively). Coffee, soybean, sugarcane, and maize presented significant increases in their cultivated areas in the period of 1996 to 2008 (Figures 3.1.11 to 3.1.14). According to the Agricultural and Livestock Secretary of Minas Gerais State (www.agricultura.mg.gov.br), coffee is the main product for exportation and it represents around 55% of the agribusiness sector of that state, being one of the most important crops for the economy in the region.

The areas for pastures decreased significantly in these states. Over the years, agriculture has pushed livestock. At first, it moved into areas of degraded pastures. However, from 2002 to 2004 the prices of soybean and sugarcane reached high prices, causing the replacement of grazing land for these crops. Moreover, the high costs of livestock production and the low prices for beef in the internal market during this period were factors that contributed in decreasing the pasture areas (EMBRAPA, 2005).

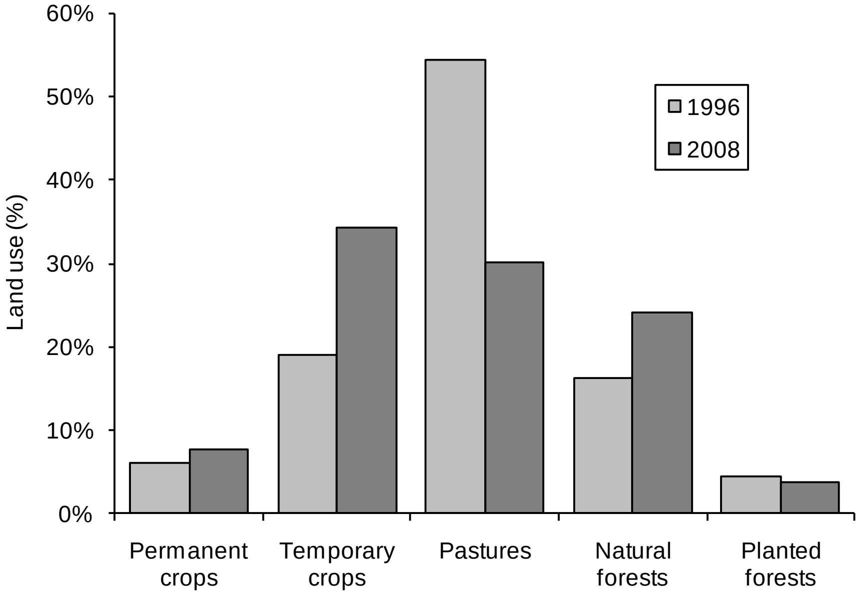


Figure 3.1.7: Agricultural land use in the area of Minas Gerais State located within LPB in 1996 and 2008.

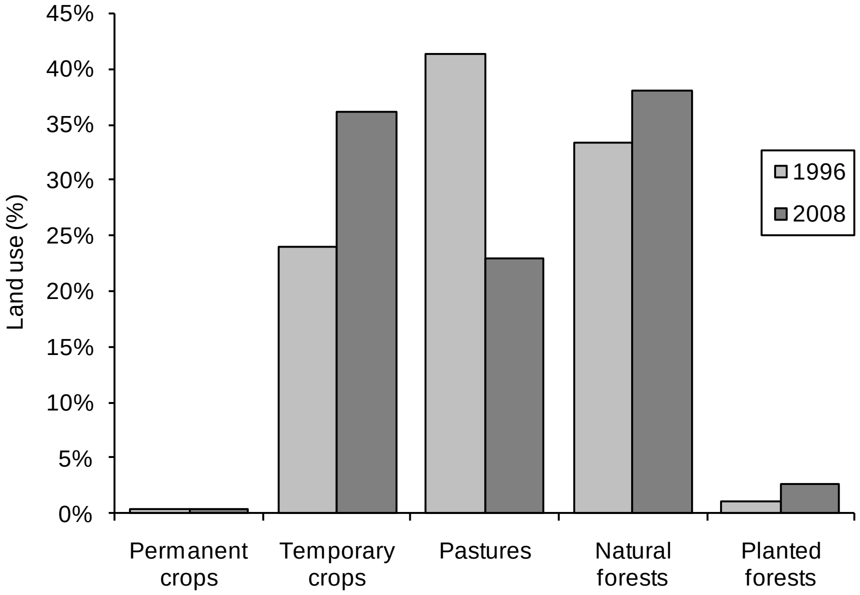


Figure 3.1.8: Agricultural land use in the area of Goiás State located within LPB in 1996 and 2008.

Areas within LPB used for pastures and natural forests decreased significantly, while it was observed an expansion of areas for temporary and permanent crops in Mato Grosso State (Figure 3.1.9). Soybean (Figure 3.1.12) and maize (Figure 3.1.14) are highlighted as the major crops responsible for these changes, but cotton is also pointed out as other important crop. From 1996 to 2008, the areas used for cotton cultivation increased from 55,155 ha to 539,586 ha (Data not presented in the figures).

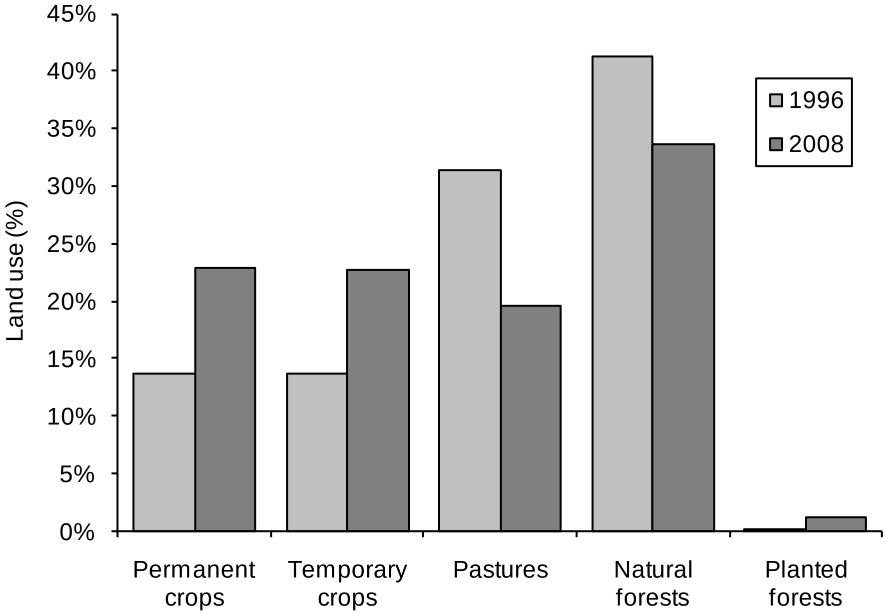


Figure 3.1.9: Agricultural land use in the area of Mato Grosso State located within LPB in 1996 and 2008.

Land use in Mato Grosso do Sul presented significant changes only for temporary crops (Figure 3.1.10), with the replacement of pasture areas mainly with soybean (Figure 3.1.12), sugarcane (Figure 3.1.13), and maize (Figure 3.1.14).

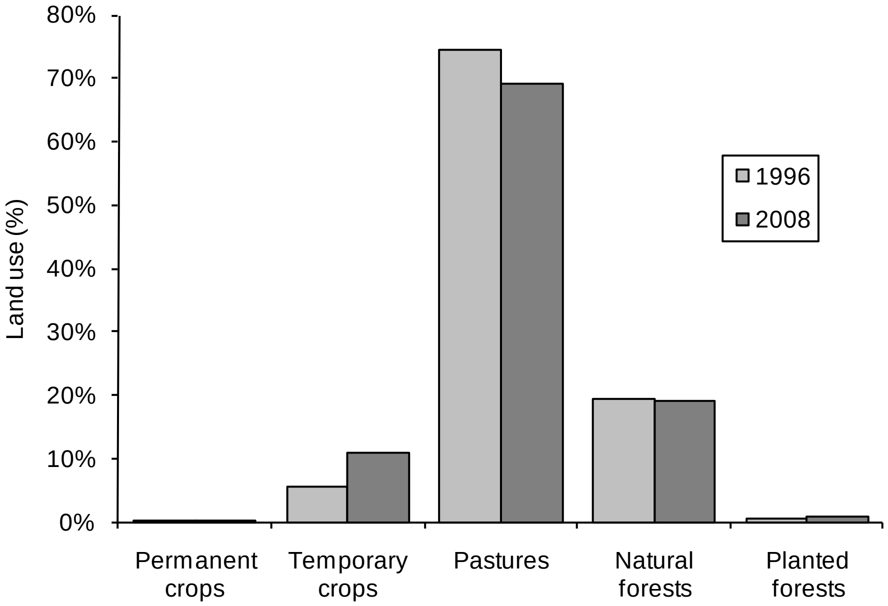


Figure 3.1.10: Agricultural land use in the area of Mato Grosso do Sul State located within LPB in 1996 and 2008.

In Figure 3.1.11 is summarized the changes observed in the areas occupied by the major temporary crops produced in Brazilian LPB states. Soybean, maize and sugarcane areas increased significantly in all states during the period of time of selected data, mainly in Mato Grosso do Sul state.

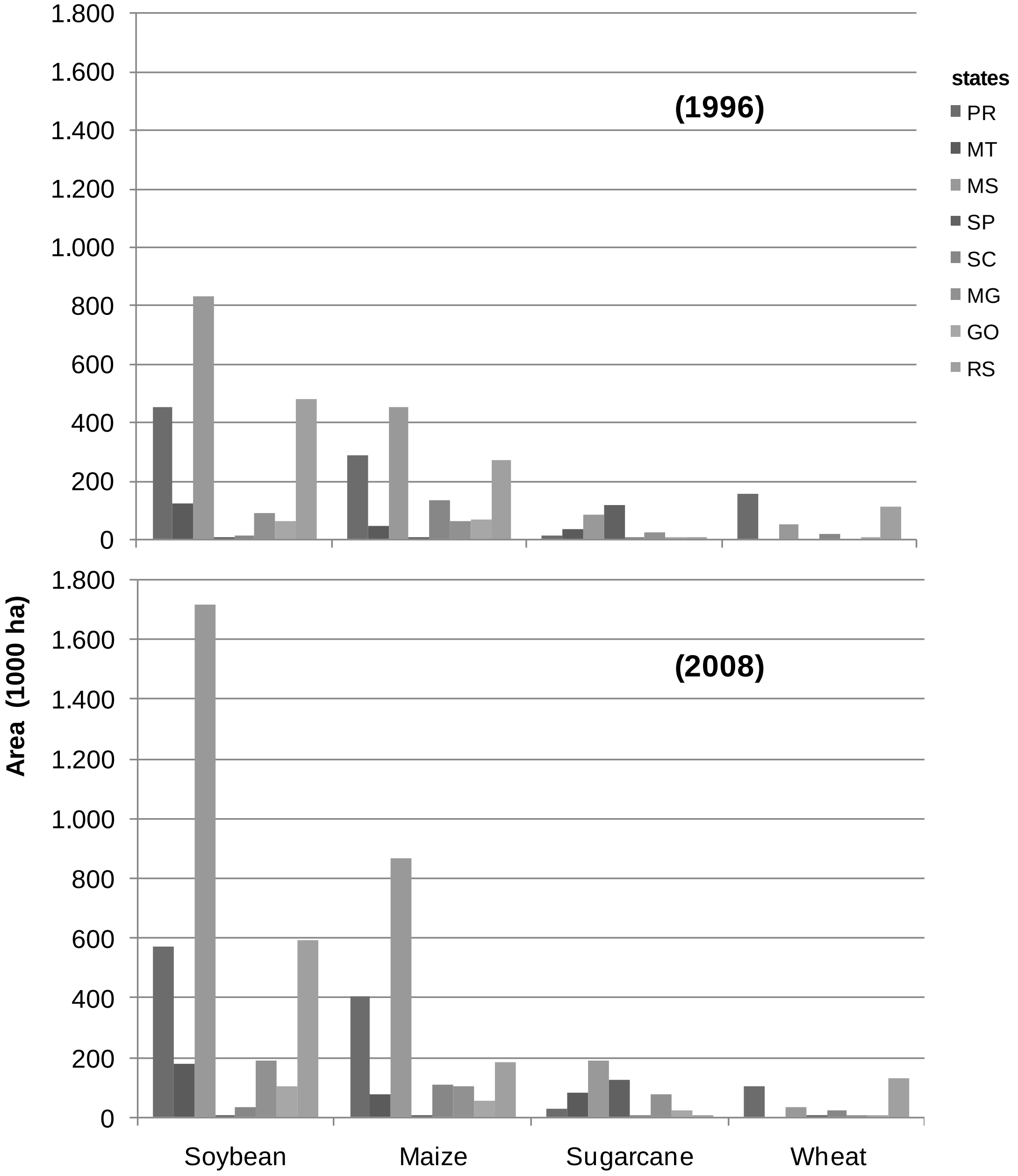
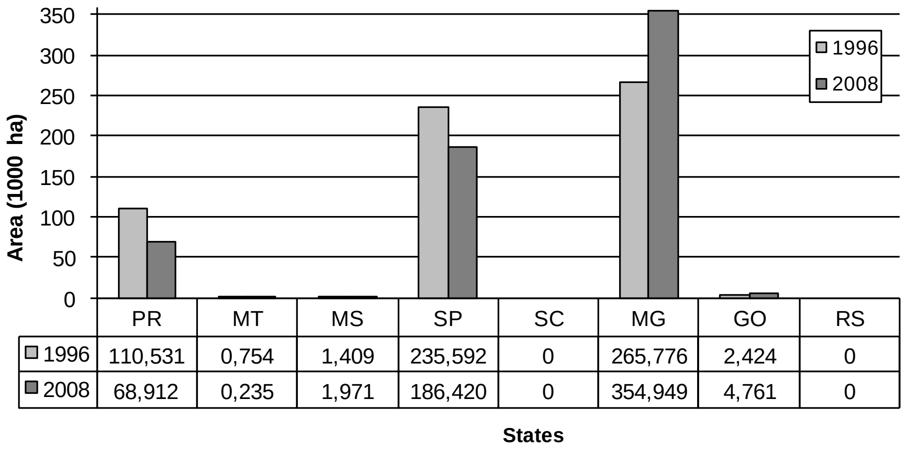


Figure 3.1.11: Area occupied by the major temporary crops produced within Brazilian LPB.

In the late 1960s, was registered a significant expansion of agriculture and changes in land use in Southern Brazil. Until 1990, most cultivation areas in Paraná and in Minas Gerais and a large area in São Paulo were used for coffee. Large areas of these plantations were destroyed by fire, causing major financial losses. Subsequently, annual crops such as corn and soybean replaced coffee in these areas (World Water Assessment Programme, 2007). According the results of the study being presented here, it can be still observed an increase in the land area used for coffee in Minas Gerais which increased 89,713 ha from 1996 to 2008 (Figure 3.1.12). On the other hand, the area occupied by coffee in Paraná decreased 41,619 ha from 1996 to 2008, and 49,172 ha in São Paulo in the same period (Figure 3.1.12).



	PR	MT	MS	SP	SC	MG	GO	RS
□ 1996	110,531	0,754	1,409	235,592	0	265,776	2,424	0
■ 2008	68,912	0,235	1,971	186,420	0	354,949	4,761	0

Figure 3.1.12: Area used for coffee in 1996 and 2008 in the area of Brazilian states located within LPB.

Soybean presented a significant expansion in the studied area from 1996 to 2008 (Figure 3.1.13). In Paraná, the area used for this crop increased 1,449,458 ha from 1996 to 2008. In the same period, soybean area presented increases of 886,077 ha in Mato Grosso do Sul, 253,489 ha in Mato Grosso, 313,305 ha in Minas Gerais, 114,634 ha in Rio Grande do Sul, 39,166 ha in Goiás, and 22,714 ha in Santa Catarina. In São Paulo, the area used for soybean decreased 23,992 ha in the same period. Research incentives from Brazilian governmental policies and from the agribusiness sector have supported the development of genetically modified soybean species which are more resistant to diseases and to extreme climatic events. Advances on developing new technologies plus the high prices in the international trade markets, adequate climate conditions to plant growth and the improvement of soils by fertilization and liming are some factors that contributed to the expansion of soybean areas in Brazil.

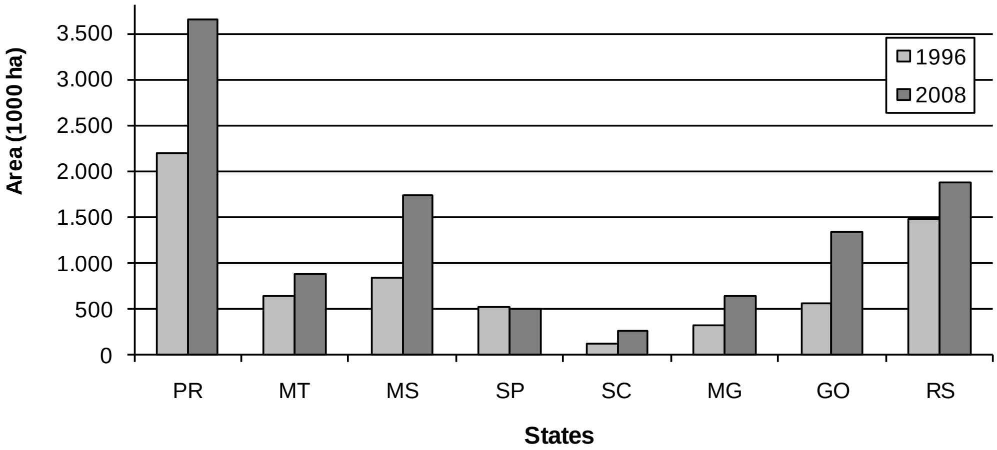


Figure 3.1.13: Area used for soybean in 1996 and 2008 in the area of Brazilian states located within LPB.

Sugarcane areas also increased in the study region (Figure 3.1.14). In Paraná, the area increased 285,599 ha from 1996 to 2008; in Mato Grosso, it increased 60,321 ha; in Mato Grosso do Sul, 170,459 ha; in São Paulo, 2,012,813 ha; in Santa Catarina, 1,566 ha; in Minas Gerais, 145,794 ha; and in Goiás, 77,847 ha for the same period. Rio Grande do Sul was the only state which presented small increases for sugarcane areas (315 ha from 1996 to 2008).

Sugarcane offers one of the most cost effective renewable energy sources that are readily available in developing countries. Climate, relief, soils and the development of new technologies are favorable factors in Brazil responsible for high sugarcane yields, as well as the policies adopted for the Brazilian Government to enlarge the area cultivated with this crop. For instance, in December 2007 there were 11 sugarcane mills operating in Mato Grosso do Sul State, and in the beginning of 2008 it was observed the implementation of 76 new projects, which will represent an expressive increase in the production of processed sugarcane until 2015, when they will work at their full capacity (Campelo and Michels, 2009).

The increasing importance of ethanol production for the Brazilian economy is certain. However, along with the expansion of the activity changes in some practices are expected in the sector, concerning social and ecological aspects of the production system. One of these changes is the elimination of pre-harvesting burning of the fields traditionally used to remove the mass of dead leaves just before harvesting. From May 2000 this practice has been progressively prohibited by law in some areas in Brazil. In addition to CO_2 emission, other pollutants are emitted during the burning causing respiratory problems and ash fall over urban areas. Even though the law will not be fully implemented before 2030, the adoption of mechanical harvesting has increased exponentially in Brazil during the last decade (Smith et al., 2008; Cerri et al., 2004).

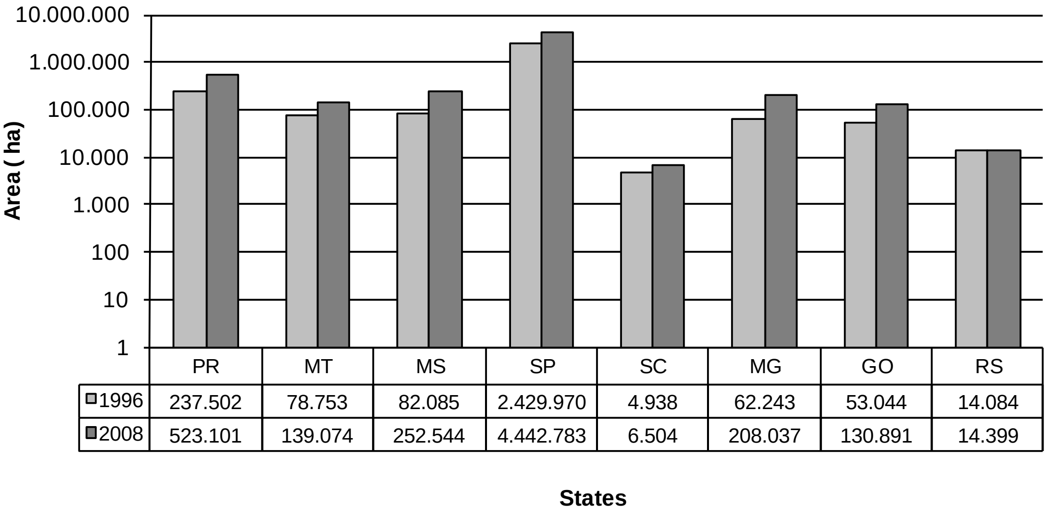


Figure 3.1.14: Area used for sugarcane in 1996 and 2008 in the area of Brazilian states located within LPB.

The areas used for maize (Figure 3.1.15) decreased during the period considered in this study in the following states: São Paulo (150,056 ha), Santa Catarina (93,690 ha), and Rio Grande do Sul (233,613 ha). Increasing areas were observed in Paraná (500,431 ha), in Mato Grosso (1,290,051 ha), Mato Grosso do Sul (536,920 ha), Minas Gerais (144,658 ha), and Goiás (105,408 ha). The production of maize and soybean when combined contribute with 80% of grain yields in Brazil. Whereas maize is destined for the internal market, soybean is mainly used as a commodity in international trade market. Increases in poultry production in the considered time period were observed for all states (Figure 3.1.16), being a factor that pushed the increase of maize and soybean areas in Brazil. Decreases observed in areas for maize in São Paulo probably resulted from the expansion of sugarcane areas, while in Santa Catarina and Rio Grande do Sul soybean probably has replaced maize cultivation due to droughts that severely affected the maize production from 2003 to 2008 in these states (CEPA, 2009). It is worth highlighting that the two crops compete for the same regions of cultivation in different seasons, soybean growths at the expense of corn or vice versa.

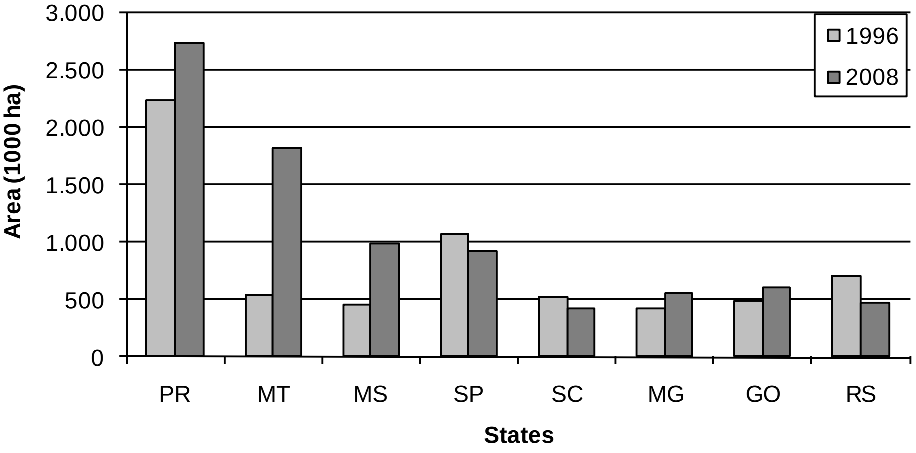
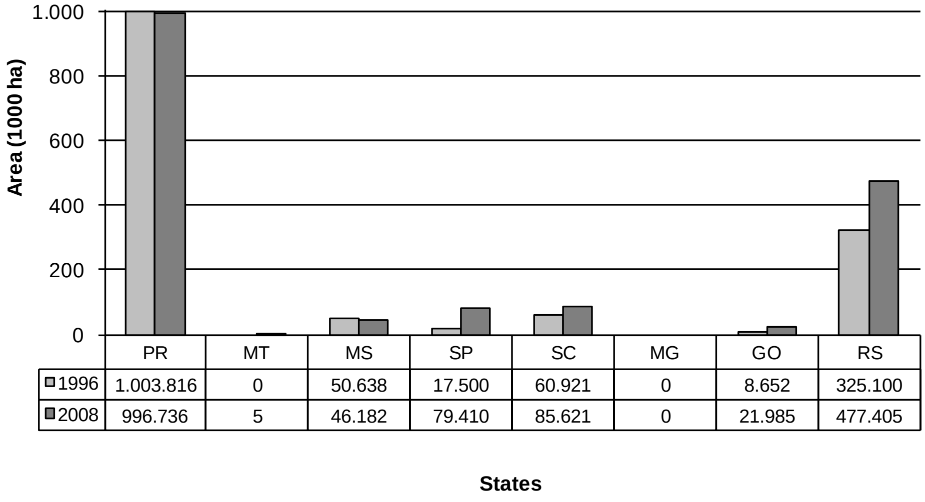


Figure 3.1.15: Area used for maize in 1996 and 2008 in the area of Brazilian states located within LPB.

The areas used for wheat presented different trends, as has been identified in this study. The results are presented in Figure 3.1.16 which also shows that the two most important producers are Paraná and Rio Grande do Sul, respectively. Decreases were observed in Paraná (7,080 ha), and in Mato Grosso do Sul (4,456 ha) from 1996 to 2008. It was observed increases in São Paulo (61,910 ha), Santa Catarina (24,700 ha), Goiás (13,333 ha), and in Rio Grande do Sul (152,305 ha) for the time period considered.



	PR	MT	MS	SP	SC	MG	GO	RS
▢1996	1.003.816	0	50.638	17.500	60.921	0	8.652	325.100
■2008	996.736	5	46.182	79.410	85.621	0	21.985	477.405

Figure 3.1.16: Area used for wheat in 1996 and 2008 in the area of Brazilian states located within LPB.

The adaptation of wheat to the weather and soil conditions in Brazil has been an important research subject for plant breeding programs and seed companies for many years. As a result, some cultivars with high yield potential have been developed, making this crop attractive for farmers in the southern Brazilian states, besides the fact that also the prices of wheat increased in the last years.

Representative increases in poultry production were observed for the considered period in Brazilian LPB, especially in Paraná, Santa Catarina, São Paulo and Goiás (Figure 3.1.17).

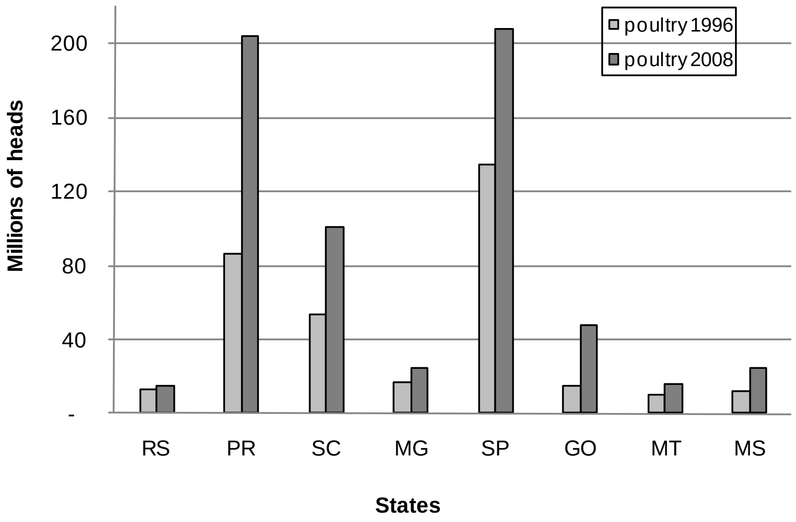


Figure 3.1.17: Poultry production in 1996 and 2008 in the area of Brazilian states located within LPB.

Poultry is one of the most dynamic meat production activities. In Brazil, industrial poultry production started in the middle of 1950 in São Paulo, being expanded later to other states in the South. The exportation of chicken has increased since 2000 and it totaled one billion dollars in exchange revenue in the mentioned year. In the internal market, it has been noticed a substantial increase in the consumption of chicken, characterizing an important change in the alimentary habits of the Brazilian population. Since the beginning of the poultry activity in Brazil, the production chain has been modernized in order to reduce costs and increase the productivity, and as a consequence, it has been one of the most profitable activities for Brazilian economy (ABEF, 2010).

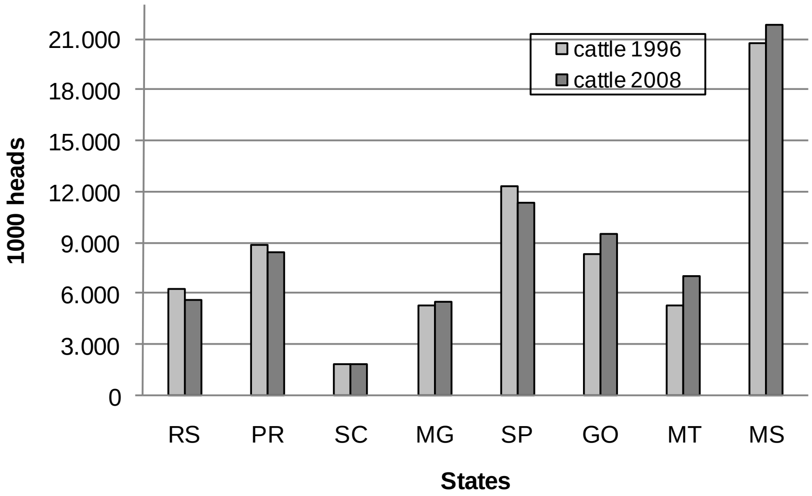


Figure 3.1.18: Cattle production in 1996 and 2008 in the area of Brazilian states located within LPB.

Intense transformations remarked Brazilian cattle production in the last decades, resulted mainly from the application of modern techniques (such as pasture rotation management, improvement of controlling cattle diseases, recuperation of soil fertility in degraded pasture areas) and stabilization of the economy in this country, what allowed the increment in beef exporting. These transformations aimed to keep this activity being profitable in face to the expansion of poultry production. It was observed in this study that the cattle production increased in Goiás, Mato Grosso, and Mato Grosso do Sul (Figure 3.1.18).

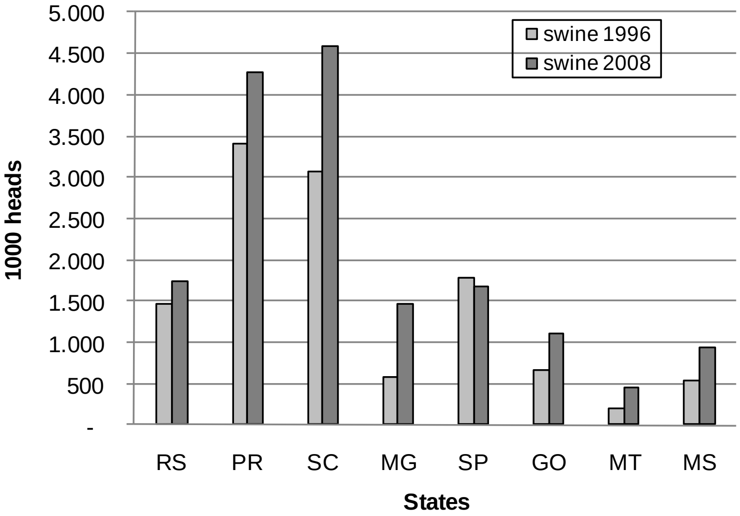


Figure 3.1.19: Swine production in 1996 and 2008 in the area of the Brazilian states located within LPB.

Swine production in Brazil is an important activity, and is concentrated in the southern part of the country. However, in the last decade it has been rapidly expanded into the central western region. This fact is presented in Figure 3.1.19, where can be observed that an expressive increment of swine production occurred in all the states located within the study region, with exception of São Paulo.

The structure of swine production in Brazil has dramatically changed in the last three decades, from a small and subsistence model to large concentrated animal feeding operations. This trend towards big industrial feeding operations is intended to reduce production and logistics costs for both farmers and meat processors. The production of maize and soybean in Brazil as well as the investment in new technologies are the major factors incrementing swine production and also decreasing the costs comparing to other countries, like China and the United States (Gonçalves and Palmeira, 2006).

Some studies (Kang, et al., 2009; Assad and Pinto, 2008; Seo and Mendelsohn, 2008; Zullo Jr. et al, 2006; Burton and Lim, 2005) have been developed in order to assess the increase of temperatures due to global warming, which can be threatening to the agriculture and food security. In addition, a large set of these studies have focused on the reduction of yields of specific crops in warmer temperatures, since it is assumed that farmers make no changes in crops, predicting large yield losses from climate change and therefore large losses in net revenues. Studies that assume changes in crops predict that farmers will move away from crops with low yields and substitute them by new ones that will perform better in the new climate.

Assad and Pinto (2008) studied how global warming could modify the current geography of agricultural production in Brazil based on The Fourth Assessment Report (AR4) of Intergovernmental Panel on Climate Change (IPCC). The scenarios A2 (it estimates an increase between 2°C and 5.4°C until 2100) and B2 (it estimates an increase between 1.4°C and 3.8°C until 2100) were used to simulate the changes in agricultural production in Brazil. According to these authors, increases in temperature would enlarge the areas with climatic risk due to high evapotranspiration rates and consequently hydric deficit for most crops, especially grains. Soybean production will probably be severely affected if none genetic modification is done. Until 2070, the area at low risk for soybean production in the country can be reduced to 60% of existing today as a result of increased water stress and possible most intense periods of drought. Some areas in southern Brazil currently affected by frosts would become more favorable for agricultural production form many crops. Sugarcane and cassava cultivation would not be affected by the warming.

The specific impacts of potential climate change in São Paulo in the agricultural zoning of coffee and maize in São Paulo were assessed by Zullo Jr. et al (2006) as indicated by

IPCC scenarios. According to these authors, increases in average temperature and precipitation, as presented by IPCC, would lead to decrease the areas for these crops and changeover to other regions the current suitable areas for maize production from October to December, and coffee year-round, without considering the adaptations and/or genetic modifications. Adaptive solutions, such as the development of cultivars adapted to higher temperatures, must be taken into account by policy makers in order to assist the farmers in their decisions. Strategic planning information for farmers is necessary and must be encouraged.

Knowing the current dynamic of land use change in the LPB may help to characterize not only the vulnerability of its agricultural production systems but also to understand how this dynamic may affect the future adaptation capacity to climate change and variability considering its significant impact on the ecological and socio-economic structure of this part of LPB. And these are aspects that must be taken into account in the learning process of designing adaptation strategies to climate change.

3.1.1.4 RESPONSES

A new generation of impact and adaptation studies is now beginning to address the need of developing assistance agencies to foster the incorporation of climate adaptation into national economic development policy and associated development assistance. National agricultural policy must be developed in the context of local risks, needs, and capacities, as well as international markets, taxes, subsidies, and trade agreements. Stakeholder participation in policy development is frequently recommended as a measure that can help to approach national policy processes and farm community level (Burton and Lim, 2005), and it is a necessary practice in the learning process of how to act in a world with a changing climate. In the following sections are described some aspects that have strong influence in guiding land use change in the Brazilian sector of LPB.

3.1.1.4.1 Agroecological zoning

The agricultural zoning is based on the integration of crop growth models, climate and soil databases, decision analysis techniques, and geoprocessing tools. In Brazil, the agricultural zoning has been updated every year with new crops, cultivars, climate data, and interpolation methods, improving it year after year (Zullo Jr. et al., 2006). The importance of agriculture for the Brazilian economy requires impact assessment studies not only for seasonal climate variations, such as that attributed to El Niño and La Niña, but also for climate change, such as that presented by the report of Intergovernmental Panel on Climate Change (IPCC, 2007).

In Brazil, agricultural losses in the middle of 1990s were limiting to the development of agriculture. These losses were caused by excessive rain during the harvest period and dry spells during the reproductive (flowering and grain-filling) stage. To decrease these two main climatic risks, EMBRAPA (Brazilian Agricultural Research Corporation) and the Brazilian Department of Agriculture (MAPA) started an official program of agricultural zoning in 1996 to define planting calendars for rice, beans, corn, soybean, wheat, sorghum, cotton, coffee, and fruits, based on simulation of cumulative water balance (Zullo Jr. et al., 2006).

Assad and Pinto (2008) simulated how the rising temperatures could affect the productivity of the major crops for Brazilian agriculture. According to these authors, the increase in the temperature will decrease the number of municipalities with agricultural potential in the years 2020, 2050 and 2070 compared with the current situation for almost all crops, except for sugarcane and cassava. Even if rising temperatures will reduce the risk of frosts in southern Brazil, enabling that areas now restricted to the cultivation of tropical plants become favorable to them in the future, it will not offset the damage of warmer weather. This new climate dynamics should cause a migration of crops adapted to tropical climates to areas farther south and higher altitudes to compensate for temperature rise. With this increase in temperature, is likely a displacement of areas with coffee and sugarcane crops to higher latitudes. Moreover, with rising temperatures, some areas in the southern Mato Grosso do Sul, in western Santa Catarina, Parana and Rio Grande do Sul states will suffer increased water stress, ceasing to be appropriate areas for planting some crops, such as soybean in Rio Grande do Sul state.

3.1.1.4.2 Environmental laws enforcement

3.1.1.4.2.1 Brazilian National Policy on Climate Change

In December 2009, the President of Federative Republic of Brazil approved the Federal Law N°12.187 establishing the National Policy on Climate Change (NPCC) and other issues, such as objectives, guidelines and instruments (PNMC, 2010). The NPCC proposes the Brazilian commitment to the adoption of means of decreasing deforestation in all biomes, measurable every four years to reach the so-called zero illegal deforestation. The document discusses the actions that the country could implement to combat global climate change and create internal conditions for coping with its consequences. The actions should be performed under the responsibility of political entities and the public administration, observing the principles of precaution, prevention, citizen participation, sustainable development and common responsibilities.

Measures to anticipate, prevent or minimize the identified causes of climate change with anthropogenic origin in the national territory should be taken, on which reasonable consensus within the scientific and technical occupied in the study of the phenomena involved are taken into account. Sectoral plans of mitigation and adaptation to climate change should be devised aiming at the consolidation of a low-carbon economy in order to meet targets of gradual reduction of anthropogenic emissions, considering the specifics of each sector. The objectives of the NPCC should be consistent with sustainable development in order to seek economic growth, eradicating poverty and reducing social inequalities. The NPCC is part of a recent policy in Brazil that aims to establish actions also for agricultural practices, fostering food production systems with minimal emission of greenhouse gases. Since this law is recent, its results are yet to be verified.

3.1.1.4.2.2 Forest Code

The worldwide growing concern with environmental degradation strongly influenced the debate on land use in the last decade, and it is likely to influence land use in LPB, especially in Brazil.

In Brazil, land use restrictions in privately owned lands in rural areas are in place since 1965, when the Forest Code (Federal Law Nº4.771) was issued, establishing rules for conserving patches of natural vegetation, water and soil. The code defines two categories of preservation areas: a) Legal Reserve (LR): a percentage (20 to 80% depending on the biome) of the area covered with natural vegetation in each property, which should be set aside for the preservation of significant samples of mature ecosystems, including the biodiversity and the ecosystems functions; b) Permanent Preservation Areas (PPAs): areas that should be protected to conserve the water production and quality as well as the soil. Riparian forests, water springs, and steep slopes are among the cases classified as PPAs. Both LRs and PPAs areas compete directly with other land uses, especially cash crops and cattle raising. Because land owners are not rewarded for the ecosystem services these areas provide, they strongly oppose to the law.

Although the Forest Code is not new, the Brazilian environmental agencies only recently started enforcing the strict observance of conservation of LR and PPA areas. Moreover, land owners who had converted natural ecosystems to agricultural land uses beyond the limits ruled by the law are now obligated to restore the ecosystems. The tension of the situation reached the high hierarchical level of government institutions, opposing the Ministry of Agriculture, which advocates in favor of farmers, to the Ministry of Environment, which pushes the enforcement of the Code. The tension escalated more recently as a new Forest Code is about to be voted in the House of Representatives, whose discussion is exposing the opposition of interests of land owners and conservationists. The issue is directly related to the increasing demand of agricultural commodities as further expansion of crop and pasture areas have relied essentially on the clearance of natural forest and savanna (*cerrado*, in Brazil) ecosystems in the Brazilian part of LPB.

Another closely related issue is the conversion of natural grassland into tree plantations. The replacement of natural grasslands by *Pinus* and *Eucalyptus* plantations is taking place in southern Brazil, Uruguay, and northern Argentina. The increasing rate of the conversion is already raising concern among environmental agencies and NGOs. The vast use of these exotic, highly productive tree species is an extra issue on the discussion, especially in Brazil.

In addition to economic issues related to the advancement of the frontier of even age forests, this conversion of land use brings also changes in regional socio-cultural structures. For example, the adherence of small farmers to *Eucalyptus* and *Pinus* forests imply the abandonment of their low input cropping systems, from which most of the table food is produced in the region. In the case of conversion of natural grasslands to planted forests, it seems inevitable the loss of the culture associated with traditional systems of beef cattle and sheep raising, especially in southern Brazil and Uruguay and Argentina.

It is worthwhile to note that although land use changes in LPB will strongly impact socio-cultural, economic and environmental regional structures, related regulations and their enforcement apparatus have been mostly anchored solely on environmental issues. On the other hand, the vanishing cultural heritages of peoples in the basin remain forgotten in the discussion and in the policies designed for the region.

3.1.1.4.3 Management of natural resources

The management of natural resources would be indirect responses to the drivers highlighted in the DPSIR for the Brazilian region of the LPB. Although land use is driven mainly by demand for agricultural products and population growth, different agricultural practices can assure that the soil productivity basis can be maintained. The sustainable use and management of natural resources presents a critical factor for future agriculture. The development and adoption of appropriate agricultural technology and management practices will be needed to ensure food security and agricultural livelihoods. One of the greatest challenges likely to continue facing global agriculture is resolving conflicts caused by growing competition for soil, water, and other natural resources on which agriculture depends. Conversely, the sustainable management of these natural resources will determine productivity in agriculture and food systems (Antle and Capalbo, 2002).

Water availability for agriculture is one of the most critical factors for food security in many regions in the world, and with the increasing population, urbanization, changing diets and higher living standards, the water demand is increasing rapidly. The last 50 years saw great investments in irrigation infrastructure as part of a successful effort to rapidly increase world staple food production and ensure food self-sufficiency. Many projections agree that water will increasingly be a key constraint in food production in many developing countries, and call for the need to improve water management and increase water use efficiency (CA, 2007).

Sustainable management of soils is vital to agricultural productivity and food security. Population growth, land use planning and policies, land development and growth and demands for agricultural products operate directly and interact in different ways to produce positive (sustainability) and negative effects (degradation) on soils. Crops are highly dependent on an adequate supply of nitrogen, phosphorus and potassium fertilizers. The use of mineral fertilizer has increased significantly over the last 50 years, from 30 million tons in 1960, to 154 million tons in 2005 and it is expected an increase by 188 million tons by 2030 (FAO, 2004). The increased and more efficient use of fertilizers is one of the key drivers to attain these higher crop yields.

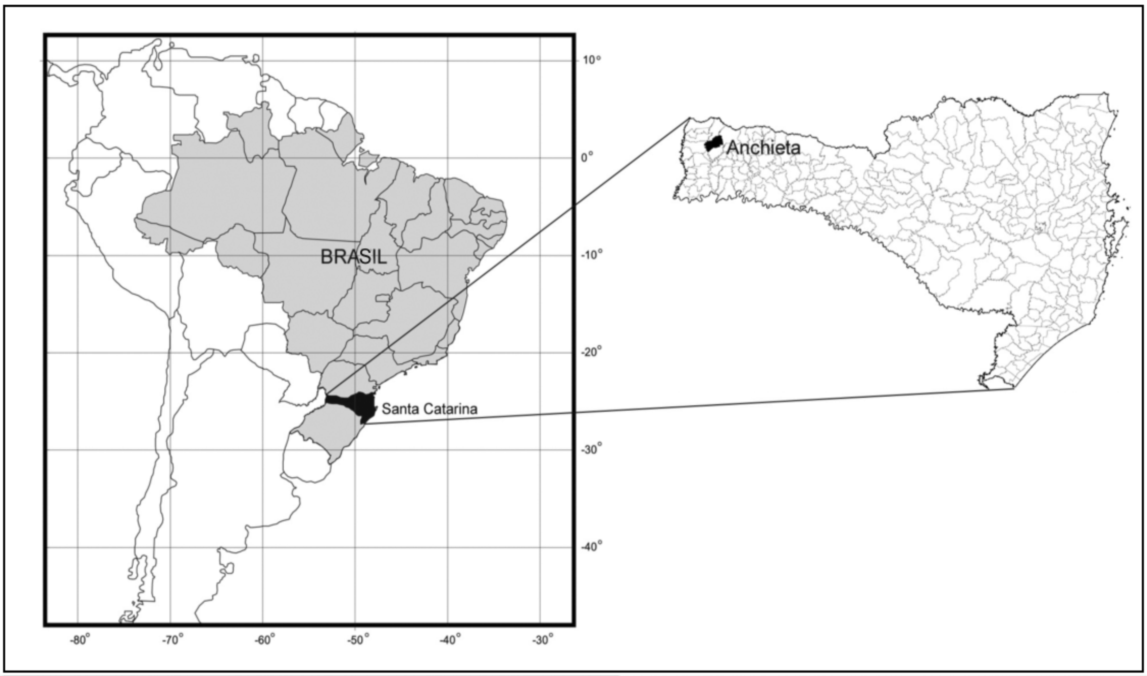
Agroforestry offers a partial solution: biological nitrogen-fixation by leguminous trees/shrubs and crops can substantially increase crop yields, since it restores soil organic matter and nitrogen, and also provides some phosphorus to the crops, improving its chemical and physical properties, the water holding capacity of soils and minimizing soil erosion (Choudhury and Kennedy, 2004; Sanginga, 2003). There are many indigenous tree species that have the potential to play these important ecological roles and also produce marketable food and nonfood products. In this way, the ecological services traditionally obtained by long periods of unproductive areas are provided by productive agroforests yielding a wide range of food and nonfood products. Some of these tree species are currently the subject of participatory domestication programs using local knowledge (Altieri, 2004).

No-tillage and other types of resource-conserving crop production practices can reduce production costs and improve soil quality while enhancing ecosystem services by diminishing soil erosion, increasing soil carbon storage, and facilitating groundwater recharge. Reduced tillage has well known positive effects upon soil properties and it also prevents further water erosion losses, increases water use efficiency, soil organic carbon sequestration, and maintains good structure in topsoil (Cerri et al., 2004).

Growing demand for food, feed, fiber and fuel, as well as increasing competition for land with other sectors drive the need for change in the use of land already dedicated to agricultural production, and often for additional land to be brought into production. The significance of the cumulative historical growth in demand for agricultural products and services is reflected in the fact that agriculture now occupies about 40% of the global land surface (McIntyre et al., 2009). Brazil is a major producer of agricultural commodities and its production increased substantially in the last years to supply the increasing demand of the world market. As a result, agriculture in Brazil has expanded over new land areas, also in the Brazilian LPB.

3.1.2 DPSIR for Anchieta

Anchieta is located 26º30' South latitude and 50º30' West longitude of Greenwich, in Santa Catarina State, Brazil. It is located 750 kilometers from the capital Florianopolis and 65 kilometers from the province of Misiones in Argentina (Canci, 2004) (Figure 3.1.20).



Source: Zuchiwschi (2009)

Figure 3.1.20: Localization of Anchieta in Santa Catarina State, Brazil.

The climate is classified as Cfa (subtropical climate): temperate, humid, mesothermal with warm rainy summer (Canci, 2004). The average annual temperature is 18ºC, with occurrence of frosts and temperatures up to 33ºC. The relief is mostly steep (75%) (Campos, 2007). The territorial area of the municiplality is 229.53 km², which is divided into 31 communities and 20 associations of farmers. The farms are up to 30 hectares and the main activities are cultivation of maize, tobacco, beans, and soybean as well as milk production (EPAGRI/CEPA, 2007).

The DPSIR framework based on information from a field study carried out in Anchieta from June to October 2009 (Bonatti, 2009) is presented in Figure 3.1.21.

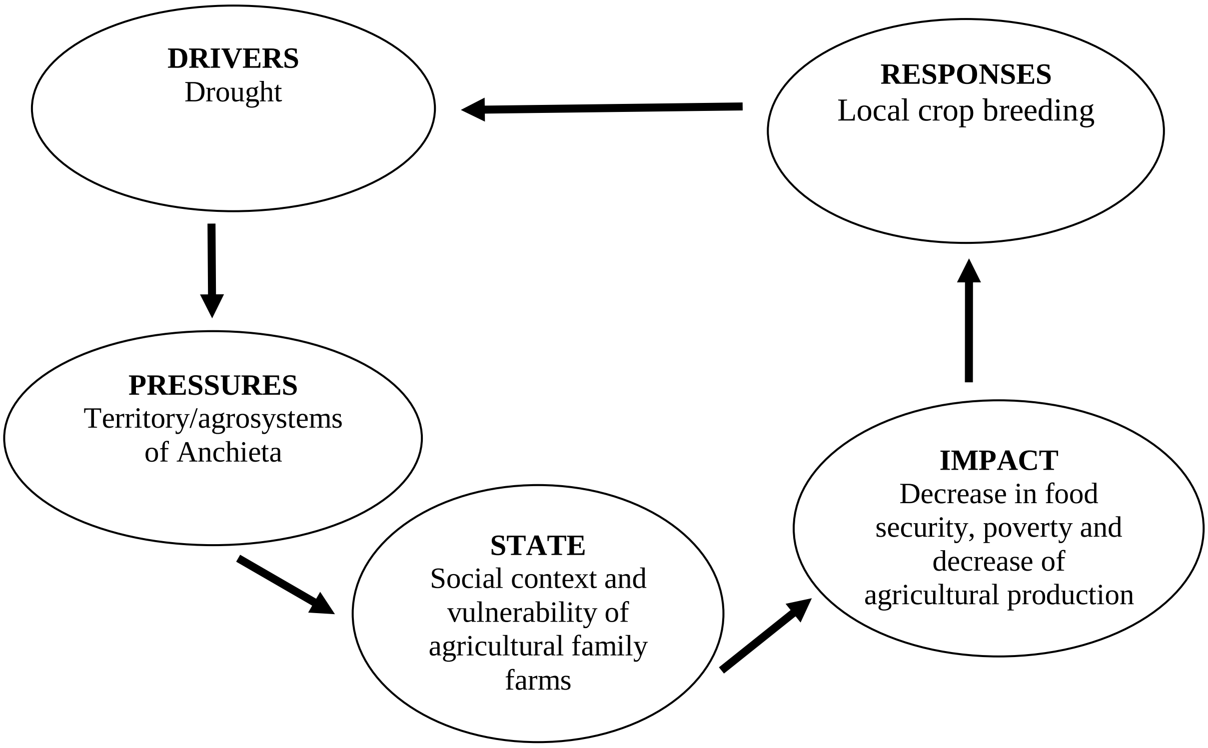


Figure 3.1.21: DPSIR for Anchieta.

3.1.2.1 DRIVER: Droughts

Climate changes have promoted and motivated cultural transformations in different periods of evolutionary history (Fagan, 2009). Evidence of these changes is seen especially in agriculture, as it is strongly conditioned by climatic factors. Although technological advances have made it possible to mitigate some negative effects of climatic events, such events still have great influence on the dynamics of ecosystems. In this sense, adverse weather conditions that may intensify due to climate change are taken as a major driver in rural communities. In Anchieta, adverse weather has followed this path, or at least there is a perception by local farmers that extreme events have intensified in the last decades.

Campos et al. (2006) report that studies in Southern Brazil monitored last century meteorological data and it was observed increase in air temperature and precipitation, with important impact in the agricultural sector. Drought and heat stress affected animal welfare as well as caused losses in plantations and increased the number of forest fires. Higher intensities of rainfall generated flooding and reduced water infiltration into the soil due to the intense runoff.

The adversity of the climate has significantly affected Santa Catarina state, mainly through the following events: high amount of rainfall, which result in large areas affected by landslides and floods, often involving large numbers of people; droughts affecting agriculture and livestock production, causing losses in the farmers' income as well as in the production chain; and severe storms, which often generate winds, hail, and tornadoes, destroying homes and plantations. In addition to this damage, other sectors of municipal infrastructure, especially communication services, electricity and water supply are also affected by climate adversities.

In 2008, Santa Catarina state was affected again by adverse weather conditions: a prolonged drought in the early months of spring followed by continuous heavy rains that caused flooding and landslides. Earlier that year, 67 municipalities in the western region of the state were in emergency state in face of drought. The phenomenon lasted more than 40 days, causing severe crop damage. In September 2009, Santa Catarina suffered with severe storms with hail and winds over 180 km/h in several municipalities. The extreme events occurred in almost all the State territory. In Guaraciaba, a municipality neighbor to Anchieta, the powerful storm lasted about one and a half hour, causing four deaths, leaved 310 people homeless, and destroyed or severely damaged 209 houses.

3.1.2.2 PRESSURE: Territory/agrosystems of Anchieta

Agricultural production in Anchieta has suffered severe pressure from adverse weather, specially the occurrence of droughts. Maize crop is a major agricultural activity of family farmers in the region, along with swine and poultry production. These activities have been threatened by climate adversities along the years.

3.1.2.3 STATE: Social context and vulnerability of agricultural family farms

Risk of disaster depends on two factors: threat and vulnerability. Threat is caused by an external factor of risk and, therefore, although it can be often predicted, usually it cannot be controlled. Climate change is an example of threat. Vulnerability, however, corresponds to the internal risk factor, and it is given by the state presented by the system (Cardona, 2001).

Anchieta presents characteristics of vulnerability to adverse climatic change due to its biophysical and sociocultural conditions. The agricultural system is based on family farming, with small area of farms (up to 30 hectares), prevailing family labor, limited financial resources and focus on subsistence. Other aspects of vulnerability in Anchieta include exposure to extreme events, limited access to resources (credit and water) and income strongly based on agricultural activities.

In this problematic context, farmers in Anchieta have developed a local maize breeding program. Starting in 1996, they have selected plants that are more tolerant to adverse weather conditions, especially drought. The program is part of a broader strategy to rescue and maintain locally produced seed, an adaptation strategy to assure their independence from seed companies, but that has tolerance to drought as a major branch. In Anchieta, all the process of maintenance of old seeds is in fact an *on farm* breeding program. The seeds now used have been cultivated locally by farmers' ancestors. They are maintained in several open pollinated varieties, each one designated to a particular usage, a characteristic of the rich cultural background of local farmers.

The intense interactions among local stakeholders are critical to the emergence of a significant adaptation strategy for maintaining agricultural production in Anchieta against adverse weather. Bonds built by their engagement in a political movement to produce their own seeds are fundamental to the continuity of their breeding program to produce locally adapted varieties. The gathering around political movement has also provided the stage for the farmer to reinforce their cultural values, turned explicit in recent years as a desired of rescuing their self-esteem in belonging to a farmers' community.

Their relationship with other institutions, mainly the Federal University of Santa Catarina and the State agency for rural extension have also contributed to the achievement of their goals by bringing scientific and logistic support to conservation and improvement of local germplasm.

To better understand the various aspects of this socio-cultural context a study was carried out with family farmers in Anchieta. Of especial interest was to understand their perceptions about climate change and the relationship of climate change with local plant breeding as a strategy of adaptation. For the sake of this study, we divided the farmers into three social categories: farmers who use adaptation strategy (ACE), farmers who do not use adaptation strategy (ASE), and the decision makers (DM)[1]. The four central issues guiding the research and that has organized the semi-structured interviews carried out with farmers were: A) the recognition that climate change has happened; B) the perception of the influence of climatic changes in their daily life; C) their perception on the causes and responsibilities related to climate change; and D) an assessment of suggested adaptation strategies to deal with climate change.

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[1] The criteria selected for ACE and ASE categories were: a) to represent the different social contexts in Anchieta on the adoption of the adaptation strategy, and specifically b) to respect and consider the possible differences in perception among farmers in Anchieta, since there is a difference between the adoption of the adaptation strategy. In order to obtain representative data of the two categories of farmers, two different farming communities – Sao Domingos and Sao Judas – were included in the study. The community of Sao Domingos was chosen as the area where all members produce and select local varieties of maize, the adaptation strategy under investigation. These farmers were assigned a category ACE. In contrast, in the community of Sao Judas farmers do not cultivate local varieties of maize, and were classified in this study as non users of the adaptive strategy (ASE).

Issue A can be regarded as the assumption of the research and it underlies the formulation of the others. Issue B sought to reveal the actors' perception about the influence that possible climate changes would have on their daily lives, helping to diagnose how they feel affected by such changes. Issue C sought to investigate the perceptions about the causes of climate change and issue D sought to investigate the perception of the importance and feasibility of adaptation strategies suggested by experts.

A semi-structured interview was done to investigate the aspects A, B and C. To investigate the aspect D, a questionnaire was applied. The questionnaire evaluated the importance and feasibility of a list of strategies (Table 3.1.1) built with the help of experts[2]. The degrees of significance chosen for the assessment of adaptation strategies were: no importance, low importance, medium importance and high importance. To evaluate the feasibility of adaptation strategies the same scale was used. The answers were later transformed in values as follows: no importance = 0; low importance = 3.3; medium importance = 6.6; high importance = 10. Results were presented as averages.

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[2] A total of nine experts from institutions like the Federal University of Santa Catarina (UFSC), the Brazilian Agricultural Research Corporation (EMBRAPA) and the Enterprise for Agricultural Research and Rural Extension of Santa Catarina (EPAGRI) were consulted. These experts are recognized professionals in five areas of academic study, namely: Climatology, Agronomy, Environmental Engineering, Environmental Law and Sociology.

Table 3.1.1: Average scores obtained from 17 general adaptation strategies (issue D) by research category

Adaptation Strategy	**Category**					
	Importance			Feasibility		
	ACE	ASE	DM	ACE	ASE	DM
Improved local species	10.0	5.0	8.5	10.0	5.0	8.5
Transgenic species	0.8	5.0	1.1	9.6	8.3	9.2
Agroforestry	10.0	10.0	9.6	9.2	8.3	10.0
No tillage farming	9.6	10.0	9.2	9.2	8.3	8.1
Resilient species	10.0	6.5	8.9	6.7	5.0	7.4
Wastewater treatment	8.3	10.0	8.9	8.7	10.0	10.0
Rainwater harvesting	9.6	10.0	10.0	8.8	10.0	8.5
National policy on climate change	8.8	10.0	9.6	8.7	5.0	3.3
Environmental control institutions	9.2	5.0	3.7	8.7	10.0	9.6
Integration policies	8.8	10.0	10.0	8.7	5.0	5.5
Hiring professionals to act on climate change	9.2	5.0	6.3	8.8	10.0	9.6
Environmental services	10.0	10.0	10.0	7.1	6.7	6.6
Studies of local climate variables	7.5	6.7	7.0	8.7	6.7	9.2
Information courses	9.2	6.7	10.0	9.6	8.3	9.2
Agricultural financing and insurance	9.2	10.0	9.6	9.2	10.0	10.0
Carbon credits	10.0	10.0	7.1	10.0	10.0	5.9
Biodigesters	9.6	10.0	8.9	9.2	8.3	6.6

The responses to questions relating to aspects A, B, C and D are systematized in Table 3.1.2 and in the Figures 3.1.22, 3.1.23 and 3.1.24 (for issues A, B and C) and Table 3.1.1 (for issue D). In relation to the aspects investigated through issue A), the following questions were asked: "*How is the weather in this region?*", "*What are the main features in this region?*" and "*How the weather has been over the years?*"

All respondents affirmed that the climate has changed in recent years. This perception of climate change is certainly associated with the occurrence of droughts in the region and its intensification in recent years, as presented in Table 3.1.2. In addition, the increase in average temperature was noted as evidence of climate change. For decision makers, the perception is mostly related to the increase of extreme weather events, like heat waves and heavy rain.

Table 3.1.2: Nature and distribution of interviewees' answers to the questions related to issues A, B and C

Category		**Without strategy (ASE)**	**With strategy (ACE)**	**Decision makers (DM)**
Aspect A and B	Belief in climate change	Droughts: 90%; more heat and heavy rains: 15%	Droughts: 90%; more heat and heavy rains: 90%	Droughts: 35%; more heat and heavy rains: 90%; rising in temperature average: 45%
	Consequences	Yield losses: 70%; water shortage: 50%	Yield losses: 70%; diseases (epidemic): 40%	Yield losses: 35%; diseases (epidemic): 35%
Aspect C	Causes of climate change	Deforestation: 50%; pesticides: 35%; God’s punishment: 20%	Pesticides: 100%; deforestation: 90%; pollution: 50%	Deforestation: 60%; pollution: 45%; agriculture: 35%; pesticides: 25%; fossil fuel: 25%; greenhouse effect: 25%; industries: 25%; others: 25%
	How to mitigate and to adapt	To forbid pesticides: 65%; take care of water: 35%; reforestation: 35%; don’t know: 65%	To forbid pesticides: 100%; to pray: 25%; reforestation: 65%; behavior: 25%; landraces: 65%	Reforestation: 70%; agroecology: 35%; tanks: 25%; other energetic model: 25%; don’t know: 10%
How the climate will be?		To get worse: 65%; don’t know: 65%	To get worse: 65%; depend of us: 20%; to get better: 15%	To get worse: 60%; introduction of other agricultural crops: 20%

To investigate the aspect B, questions like "*What does happen to it?*" (What does the climate change cause?) and "*What does this cause*?” (What are the consequences of climate change?) were asked. All three categories of interviewees indicated the loss of agricultural yields as a negative influence of climate change in their daily lives. In addition, the increased occurrence of diseases was identified as an important negative impact of climate change that has being perceived.

The questions "*Why does this happen?*” and "*For you, what has influence on climate*"? were formulated to investigate the aspect C. In general, the interviewees listed human actions as the main cause of climate change. Among the human activities most often mentioned were the use of pesticides and deforestation. It is important to note that for some farmers the cause of climate change is a God’s punishment. Answering the question "*Do you believe you can do something for the climate?*", the interviewees in all categories indicated reforestation as a possible attitude.

Although the occurrence of extreme weather events indicated in this study has been mostly related to the daily lives of the interviewees, other causal relationships were also found. Global problems, such as industrial pollution and the burning of fossil fuels, were pointed out instead of local context causes. The same happens when farmers mentioned the prohibition of pesticide use, repeating a speech that falls within the international movement for sustainable agriculture without pesticides or free of harmful substances. These results also reveal the hegemonic structures of power, i.e., they reflect the influence of mainstream discourse on countries like Brazil, or of certain domestic discourses.

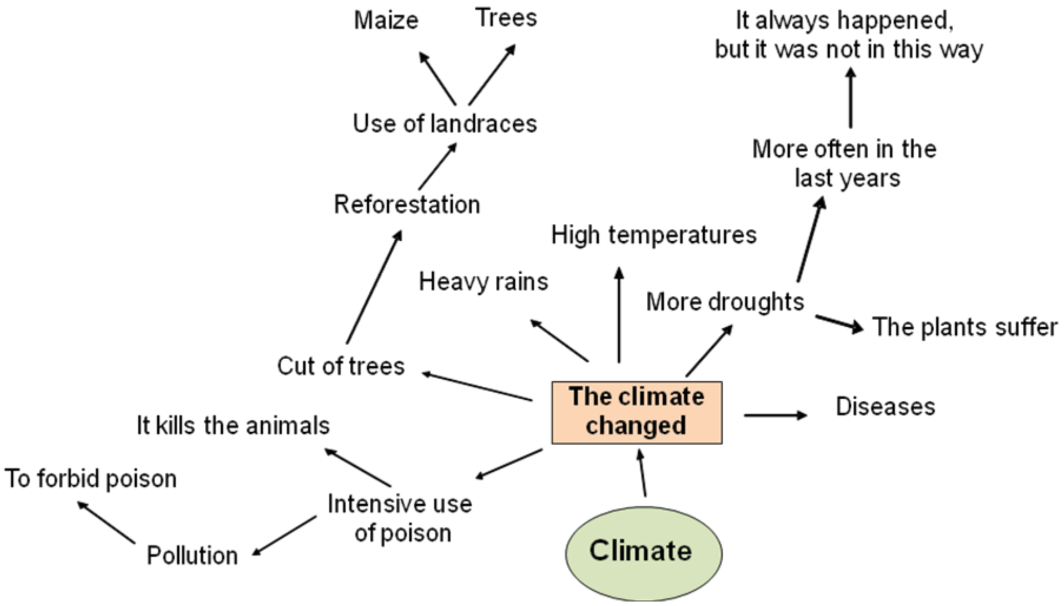

Figure 3.1.22: Representations map of farmers who use adaptation strategy (ACE research category).

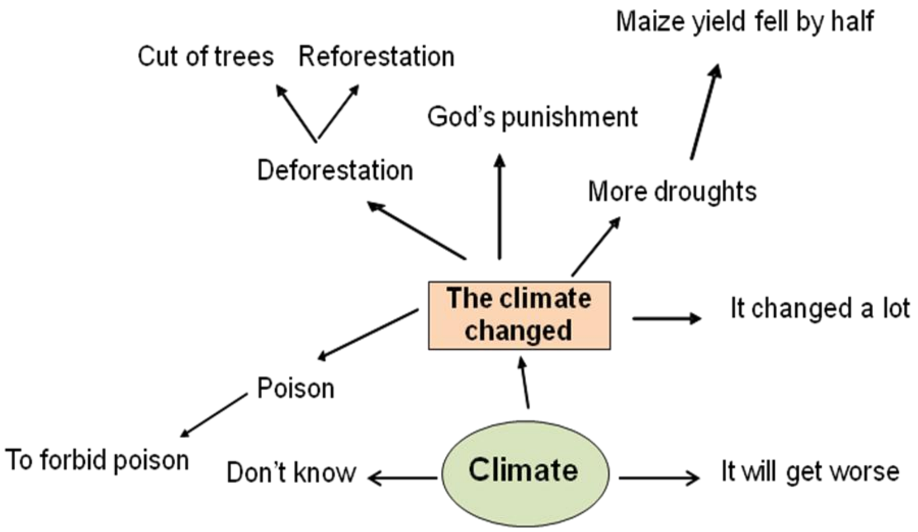

Figure 3.1.23: Representations map of farmers who do not use adaptation strategy (ASE research category).

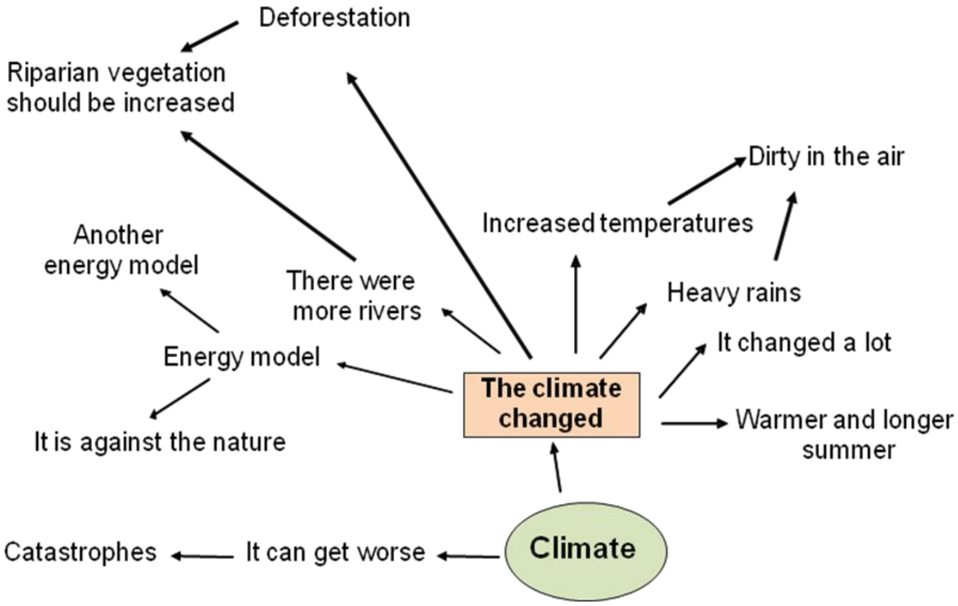

Figure 3.1.24: Representations map of decision makers (DM research category).

The perception of farmers (ACE) on climate change is strongly associated with their ecological rationality because of their constant interaction with the environment where they live. The livelihood is intrinsically linked to the dynamic relationship between the factors of climate, soil, animals, etc. Thus, the structure of agricultural production of these stakeholders is encouraged to interact with environmental factors. Other important factors related to the context in which they produced the representations are social cohesion, autonomy regarding seeds availability, self-esteem. Knowledge on adaptation strategies for farmers (ACE) may reflect, in addition, the processes of power in the construction of production choices (and life).

As major differences of perception between the categories analyzed, the data show differences mainly in the perception of the occurrence of extreme weather events other than droughts, such as heavy rains and heat waves. Thus, 90% of farmers who grow landraces of maize varieties perceive the occurrence of other extreme weather events, while only 15% of farmers that do not cultivate these varieties of maize show the occurrences of these same phenomena. This discrepancy confirms that perception is not an objective phenomenon, independent of the observer. This result may also be due to the fact that the work of selecting varieties of maize landraces requires greater attention on the observation of weather phenomena by farmers.

For most interviewees, climate change represents an environmental problem and its harmful effects are generated by human activities. However, from the discourse of farmers it was not possible to identify that they are able to distinguish between climate variability and climate change. Moreover, although farmer pointed to different intensification of extreme weather events, they did not verbalized some well known expressions that are related to the discussion on climate change, such as "global warming" or "greenhouse effect". Thus, these interviewees probably do not understand climate change as a global phenomenon, but as an intensification of local climatic variations.

3.1.2.4 IMPACT: Decrease in food security, poverty and decrease of agricultural production

Anchieta has been impacted by the effects of adverse weather in the last decades. The impact of these adversities has generated losses in agricultural production and disasters in the region. Agriculture is strongly influenced by climatic changes and in Anchieta the intensity of droughts has affected agricultural production. Thus, in the case of an increase in extreme weather events generated by climate change, the local agriculture will be severely impacted due the social and environmental conditions in Anchieta. The risk of drought in Anchieta has been frequent due the interaction between local vulnerability (local conditions) and threats (adverse weather).

Also, it is possible to divide the impacts into direct impacts and indirect impacts in Anchieta. Direct impacts are mainly decrease in production and farmer’s income, while decline of food availability to urban zone of Anchieta and health problems (such as respiratory diseases) are examples of indirect impact.

3.1.2.5 RESPONSES: local crop breeding

Farmers in Anchieta have developed a program to select local varieties of maize that are more adapted to local farming conditions. It is part of a broader strategy to rescue and maintain the germplasm that has been under cultivation for generations. The strategy, by its turn, it is part of a deliberate police to achieve a state of food sovereignty, which includes independence from industrial seed sources through the production of their own seeds every year. Another goal of their police is to produce their own food, which should be free of agrochemicals.

As one can see, the development of a strategy to achieve food sovereignty is clearly guided by a political framework. This framework gives the farmers the social cohesion necessary to secure the advantages of acting as community. However, in the plane of seed and food production itself no mistakes can be made – in this realm, techniques are what counts, and the practices done in the fields must be well coupled with the local environmental conditions. Observing and interpreting these conditions are then requirements to succeed in their purpose.

Because farmers in Anchieta have to perform all the steps of production of crops they cultivate, their ability to read the local climate is expected to be sharper compared to other farmers who specialized in a determined crop or step of its production system. This case study reveals that although farmers who produce their own seeds may not understand the causes and consequences of climate change, they are much aware of the intensification of extreme events occurring in the region. For example, at least in their perception, droughts have been more frequent in the last decade.

The fact is that farmers in Anchieta do recognize the importance of carefully selecting maize plants during droughts. As they preserve the seed pools as open pollinated varieties, the final result is a continuous selection of these varieties to better cope with water availability shortage. Although these varieties may have lower productivity in regular years compared to industrial hybrids, their strategy is a safe net for the harsh years. Securing a base level production every year is a fundamental trait of their goal of achieving seed and food independence – because most of their labor force produces non-cash income, they would be in trouble if they were to buy food in the market.

This case study is a clear example of the complexity of the interaction of people and the environment, which is expected to get even more complex under climate change. Conserving and breeding local germplasm by farmers in Anchieta implies a permanent process of adaptation. Social and economic constraints may guide important decisions of the community. However, environmental conditions represent bottom lines that cannot be overlooked. More than this, extreme events are bottlenecks for their strategy, and must be always under close inspection.

Whether or not the recent droughts in Anchieta are becoming more frequent as a product of climate change or they represent events that are part of the local climate variability is still a matter of debate. However, it is interesting to notice the ability of farmers to respond to the threat. More than this, their response is timely: if climate is changing, their response is opportune; otherwise, it is at least anticipation to worse climate conditions.

It is worthwhile to point out that the ability of farmers to develop a local program on conservation and breeding of an important crop as maize under a complex social and economic blueprint reveals that crop breeding may represent one of the most important strategies to cope with climate change.

3.2 Agro-systems and rural development

In this Argentinean study case based on DPSIR, two dimensions of the state of the study sites, land use change and the characteristics of the productive systems, for Balcarce, Junin and San Justo in Argentina, are described. The DPSIR framework used to guide the analysis is presented in Figure 3.2.1, and only the state element will be described in detail here. The other DPSIR elements will not be addressed.

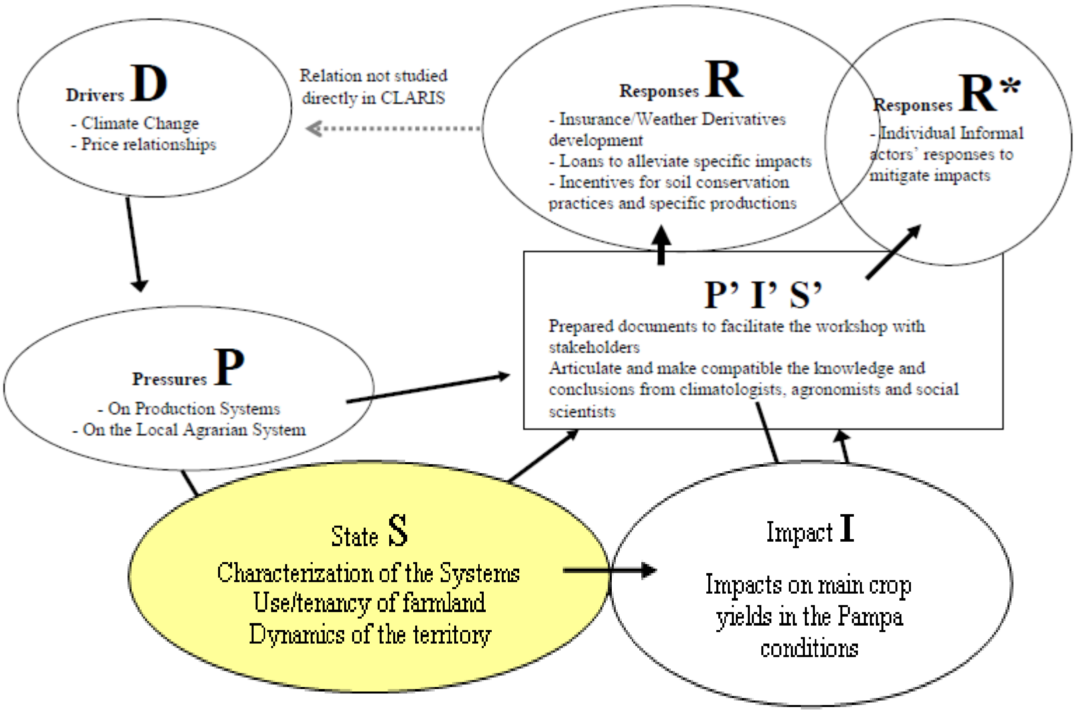

Figure 3.2.1: DPSIR framework currently being followed by the UBA/INTA/IRD team to develop the Deliverable 8.6 in Argentina.

3.2.1 Land Use Changes: Balcarce

The area planted with annual crops in Balcarce grew rapidly from 1992/93 to 1999/00 reaching a maximum of 170,000 ha, and exhibiting a decreasing trend afterwards (Figure 3.2.2).

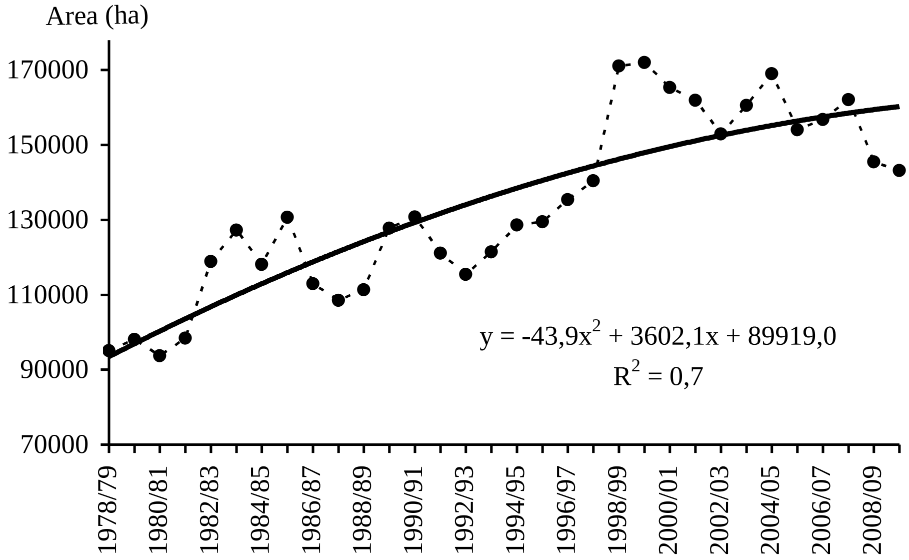

Figure 3.2.2: Area planted with annual crops in Balcarce, 1978/1979 -2009/2010 (Source: Agricultural Estimates Department - SIIAP, Ministry of Agriculture, Livestock and Fisheries (MINAGRI)).

In the past five years the district experienced six years of average or below-average rainfalls (Figure 3.2.3) and a deep drought in the fall of 2008 and 2009. These factors could have contributed to a lower acreage reached in the last two growing seasons. Also, the recent increase in livestock prices likely contributed to the decrease in the area planted with annual crops in 2009 and 2010. Live cattle price increased from 6.13$/kg to 8.31 $/kg between March 2009 and February 2011 (Source: Mercado de Hacienda de Liniers).

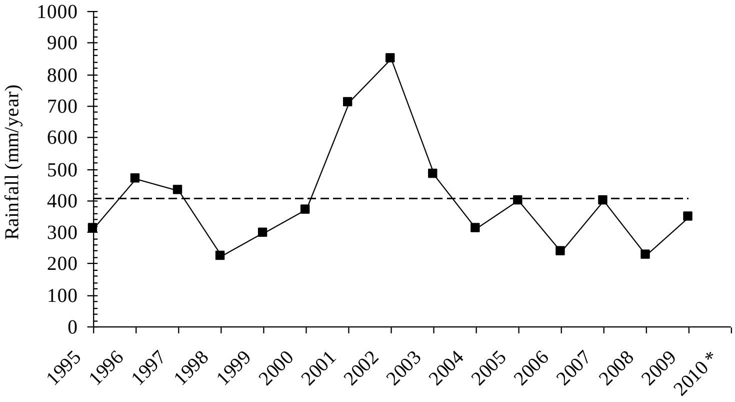

Figure 3.2.3: Crop-growing-season rainfall at Balcarce, 1978/79-2009/10 (Source: Agricultural Meteorology Dept., EEA Balcarce, INTA – Argentina).

The increase in the area planted with annual crops was led by wheat until 2001/02, after that season wheat was progressively replaced by soybeans that grew 244% between 2001/02 and 2009/10 (Figure 3.2.4).

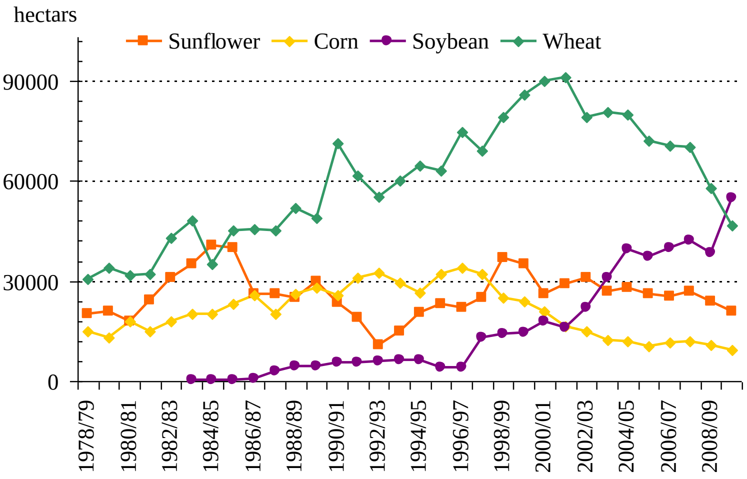

Figure 3.2.4: Area planted with the main annual crops for the district of Balcarce. (Source: Agricultural Estimates Department - SIIAP, Ministry of Agriculture, Livestock and Fisheries - MINAGRI).

Several factors likely contributed to these trends. First, wheat and corn have exhibited decreasing financial yield since 2002/03. In monetary terms, soybean and sunflower have been the most productive crops since the 2004/05 season, clearly outperforming wheat and corn. However, wheat was more profitable than corn and soybeans from 1999/00 to 2004/05, in terms of expected revenue/expense ratio (Figure 3.2.5).

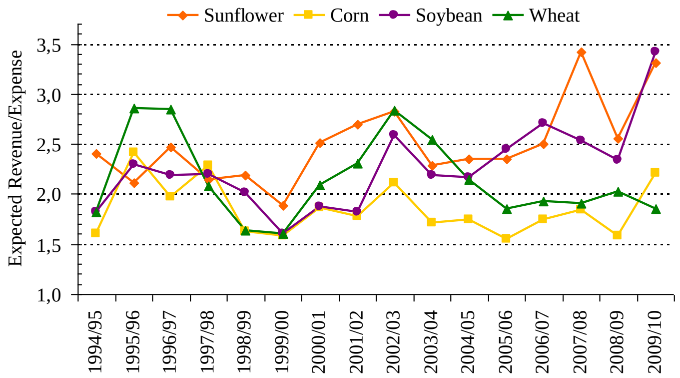

Figure 3.2.5: Expected revenue/expense ratio for the main crops grown at the district of Balcarce (Source: Proyecto Regional Sistemas de Información Productiva, Socioeconómica y de Fortalecimiento de la Capacidad de Gestión Local de los Territorios del CERBAS - BASUR 720071).

Another factor that might have contributed to the decrease in the area planted with wheat is the trade regulation system. Argentina's trade regulations for trading wheat have been particularly intricate. After harvest, producers have faced difficulties to find buyers and frequently received discounted prices as a consequence of trading restrictions. Finally, weather conditions also might have contributed to the decrease in the area planted with wheat. The fall of 2009 was especially dry for main wheat-producing area (*i.e.*, the south of the Buenos Aires province). Rainfalls occurred late during the fall 2009 improving in part the conditions for wheat planting (Figure 3.2.6). Later in the spring, soil water content reached normal levels allowing a timely planting of summer crops.

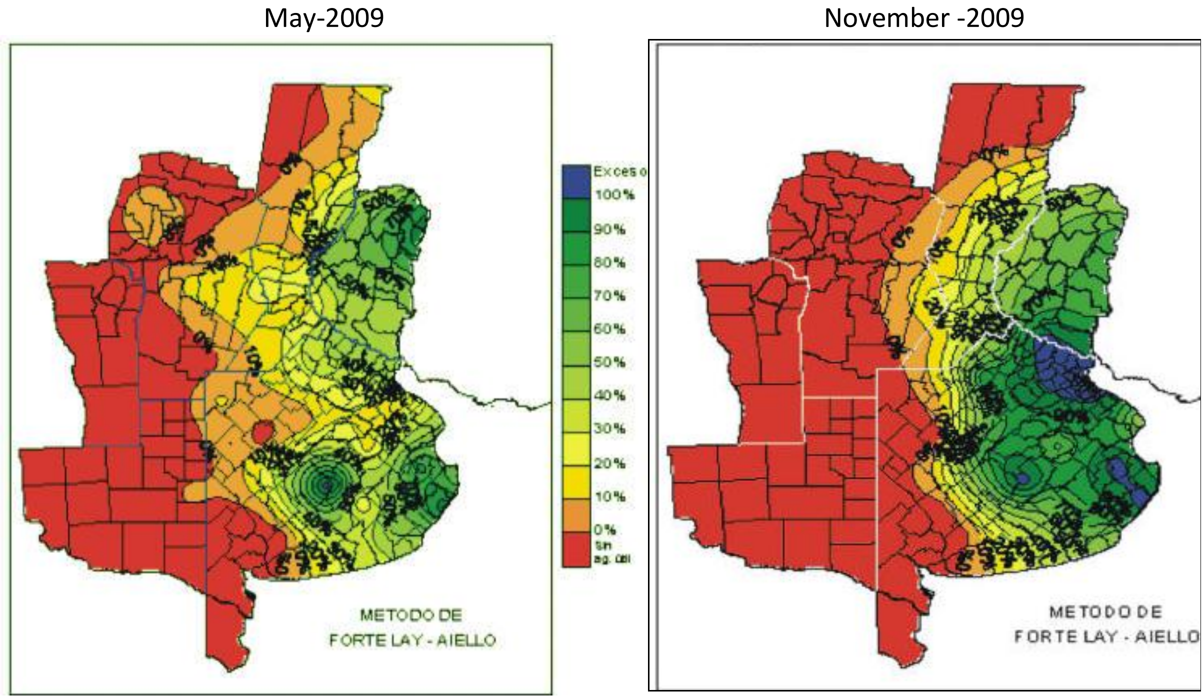

Figure 3.2.6: Plant-available water as percentage of soil water holding capacity. May – 2009. (Source: Red de Información Agropecuaria Nacional -RIAN and National Weather Service)

Sunflower is a highly profitable crop, but constitutes a riskier crop and producers are aware of that. A panel of 11 producers agreed that the yield distribution of soybeans has higher mean, a higher maximum, and lower probabilities of lower yields than the distribution of sunflower yields (Figure 3.2.7). Examining historical yields confirms producers' perceptions. During the last 26 years, the distribution of soybean yields has a mean of 1.88 tons/ha, a median yield of 1.92 tons/ha and a maximum of 2.7 tons/ha, while the same parameters for the sunflower yield distribution are, respectively, 1.64 tons/ha, 1.60 tons/ha, and 2.2 tons/ha. These differences in yields can explain the preference of local producers to devote a larger proportion of farmland to soybeans rather than to sunflower.

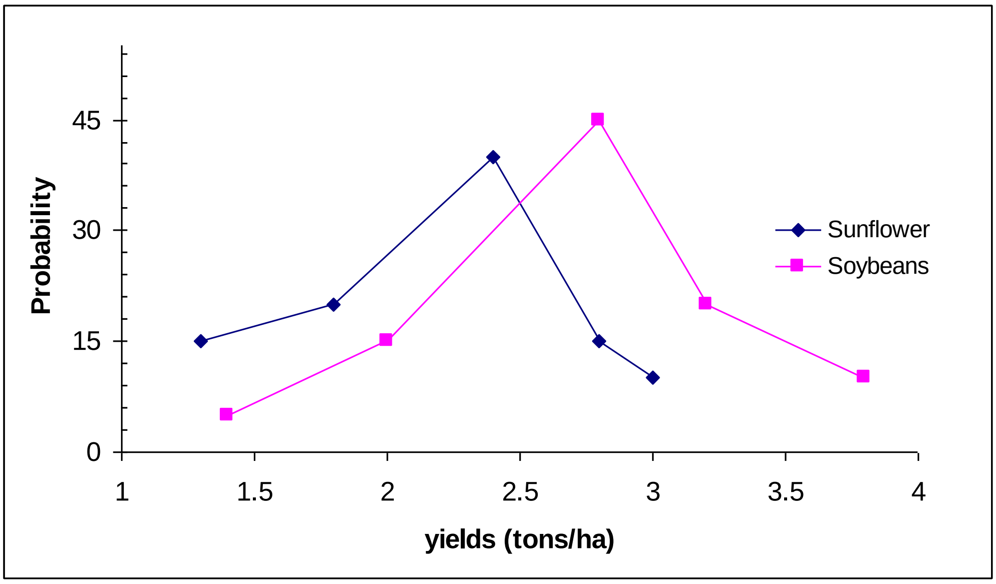

Figure 3.2.7: Subjective yield distribution for sunflower and soybean for the district of Balcarce (souce: Proyecto Competitividad y Sustentabilidad de los Sistemas de Producción, INTA-AEES-302442).

3.2.2 Land Use Changes: Junin

Historically, in Junín, the annual average precipitation is about 900 mm. Nevertheless, 2008 showed the lowest average in the last 20 years (Figure 3.2.8) which will be reflected in crop yields for the 2008/09 season (Figure 3.2.9)

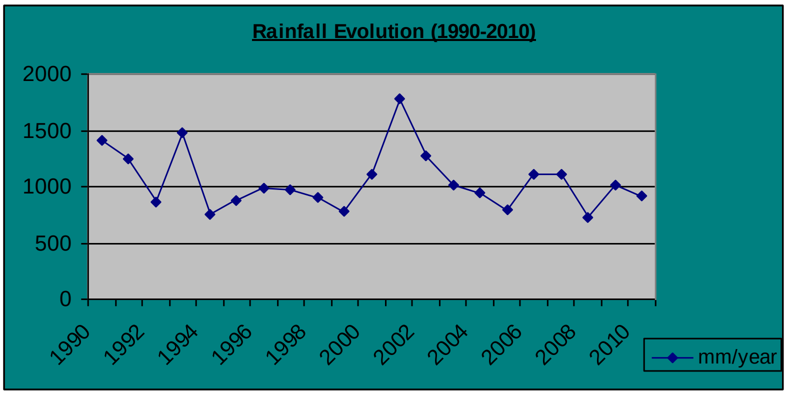

Figure 3.2.8: Rainfal evolution- Junín (1990-2010). Source: Own elaboration based on data collected during the field work, complemented whit data of Municipality and INTA (Junín)

The water deficit in the 2008/2009 drought was just at the time of the cycle determination of yields (Figure 3.2.9), being damaged both agriculture (directly) and livestock (directly and indirectly).

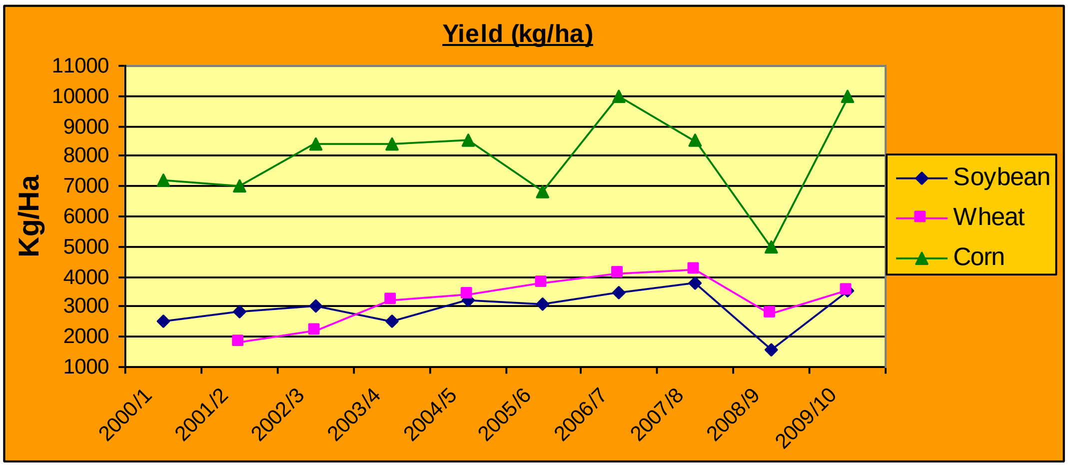

Figure 3.2.9: Yield at Junín. Source: Agricultural Report 2010, Production Secretary of Junín

In relation with land use changes, we observe an increase in agricultural area, with a consequent decrease in the area dedicated to mix activities (crops and livestock) and only to livestock activity. In this sense, as the graph shows (Figure 3.2.10), we can note a decrease or a corner of the livestock activity, aiming to release land for crop activity.

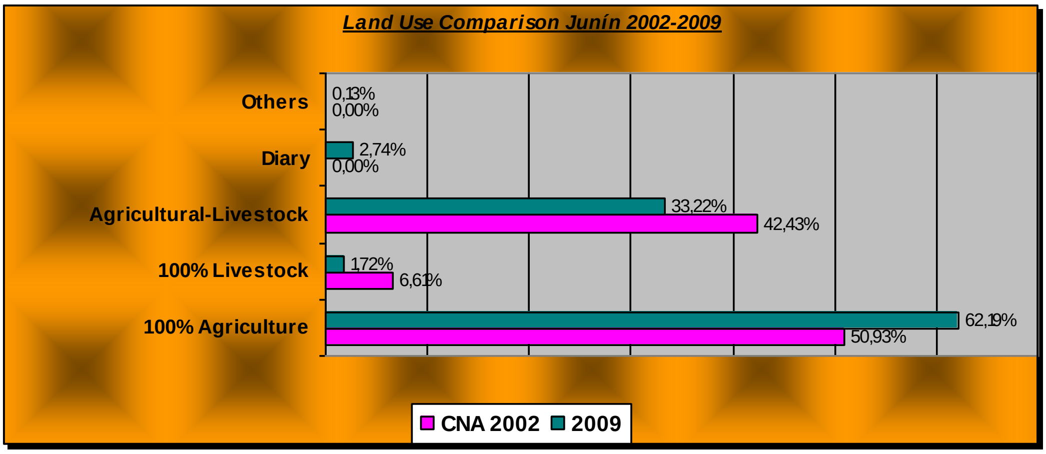

Figure 3.2.10: Land use comparison Junín 2002-2009. Sources: CNA 2002, CLARIS LPB Territorial Scan 2009

In the 1970`s livestock activity grew up to a maximum of 180.000 heads, an amount that was oscillating and gradually decreasing until becoming nowadays 83.179 heads (Figure 3.2.11).

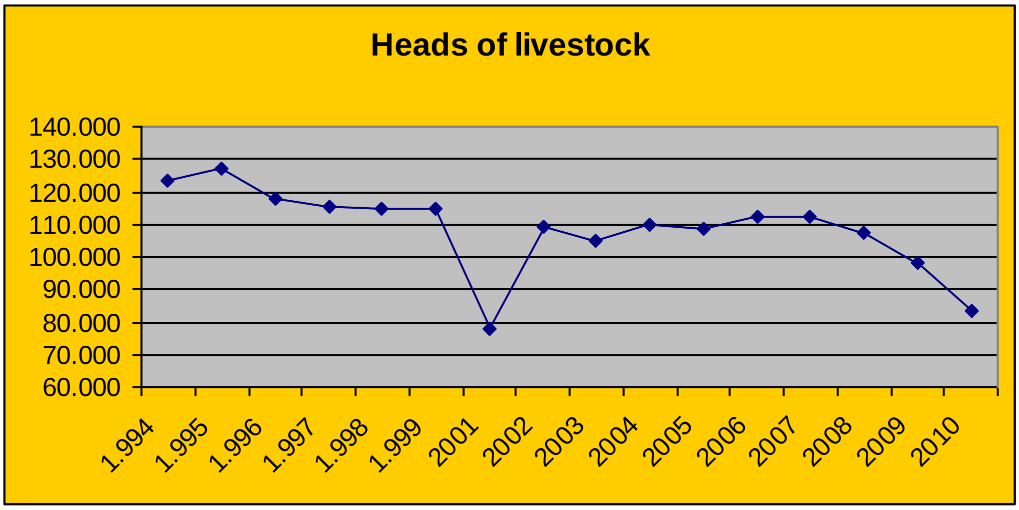

Figure 3.2.11: Heads of Livestock. Source: Report of the vaccination campaign against the disease. FUNJUSA (Own compilation) and Co.Pro.SA

With relation to the dairy farms, according to the census of 1988, 76 establishment had dairy activity, 66 in 1995 (all with mechanic milking), but then, from 2009 to 2010, they went from being 17 to be 12[3]. That is due the fact of the low level of technology that have had some dairy farms in a scenario of highly competitiveness, and the increase of imports products subsidized, leading to a capital low return.

Since the agriculturalization process in the region, livestock activity had been displaced to areas of lower agricultural quality in the southern part of the party or out of the county, using this land for agriculture. Extensive livestock production is being replaced by feed-lots, while extending the mixed fattening (stockyard /grazing). In the Production Secretary of Junín in 2008, 9 feed-lot establishments were registered, increasing to 27 in 2009 and 34 in 2010. The sudden change reflected and registered during the first year, could be due to the fact of the organization of a regularization campaign made in this period, because some of them existed, but they not were registered until 2009. Therefore, the amount of feed lots had increased, but livestock area had decreased at the same time.

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[3] Tauber, Fernando. Junín Municipality. Reflections and data for a development strategy. FUNJUSA

The increase related to the annual crop area was dominated by soybean according to the advance of the soybean production process ("sojización") characteristic of the corn-belt zone (Figure 3.2.12).

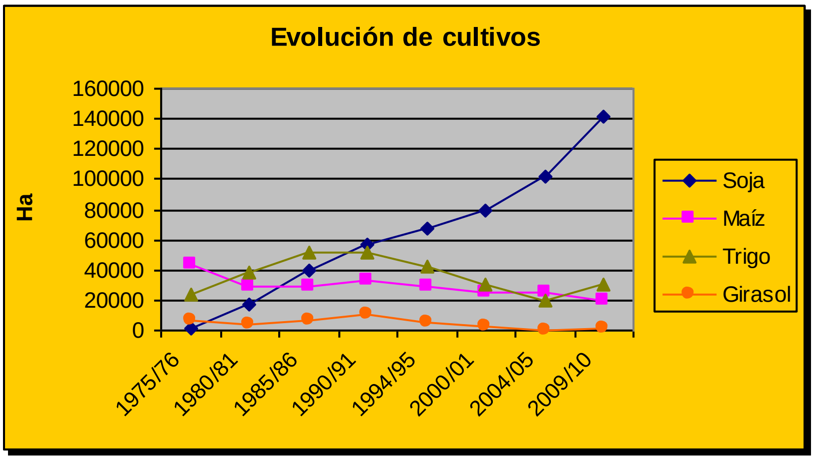

Figure 3.2.12: Crop evolution. Source: Own calculations based on data from Fernando Tauber, Junín Municipality, Production Secretary.

Main crops are, firstly, soybean, occupying an area of 141,000 ha, 72% of the cropping area. Moreover, wheat was cultivated in 30,300 ha; corn occupied 20,000 ha, and in lesser extent we can found oat, barley and sorghum. Soybean found in this zone excellent conditions for its production since 1977/78, so this crop had extended not only in the area of other crops since the mid 1990's, but also in the area freed by the displacement and decline of farming in last years. Although sunflower has reached a peak in the 1990's, nowadays this crop can not be found in the area, as it has been replaced by soybean (Figure 3.2.12). Wheat still remains relatively stable corresponding to the rotation of crops, while corn, due to its high production costs, is decreasing in the planted area. The introduction of soybean in this area involved the adoption of new technologies and resource management, which brought many changes in the production process as well as in the social structure.

3.2.3 Land Use Changes: San Justo

In the case of San Justo, the annual crop planted area grew steadily from 1994/95 to 2006/07 reaching a maximum of 250,000 ha. Though there is a marked decrease during 2008/09, related to the intense drought that was affecting this region, the growing trend continues afterwards going from 160,000 ha in 2008/09 to 208.000 ha in 2009/2010 (Figure 3.2.13).

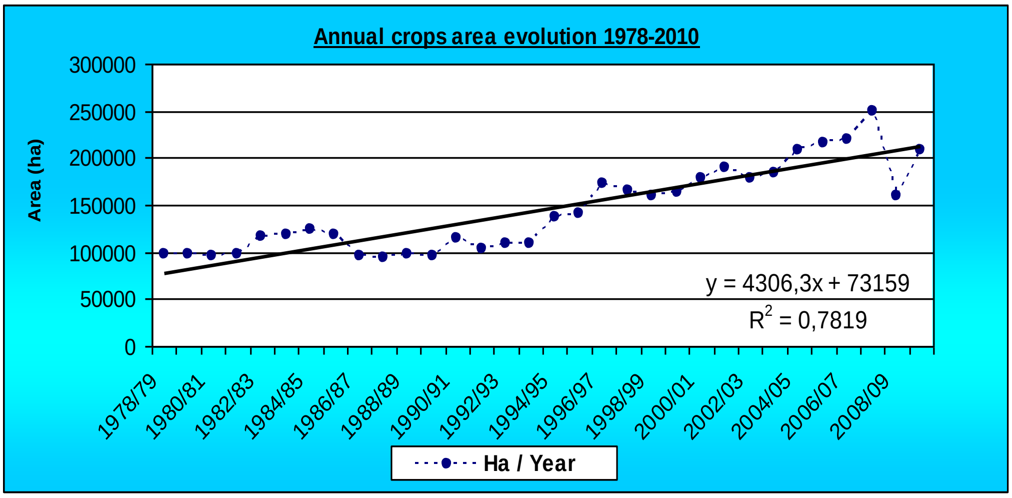

Figure 3.2.13: Area planted with annual crops in San Justo, 1978/1979 -2008/2009 (Source: Dirección de Estimaciones Agropecuarias- SIIAP (MINAGRI).

The average annual precipitation in San Justo is 1150 mm (variation WE = 100 mm), with extremes between 500 and 1800 mm/year. According to Hotschewer (1953, cited by Espino et al., 1983) the theoretical dividing line between areas of subtropical and temperate climate is seen to parallel 30º S and 20º C isotherm, and both lines cross the northern of Santa Fe Province, giving to its climate a transitional character and the existence of “climate edges”. Variability is a characteristic of the lands located in those edges. The variations that occur are originated by periodical transgressions of the semi-humid climate from the east, and semi- arid from the west. As we mentioned before, such instability is typical of the regions defined as marginal, in which, for example, the average rainfall is not in any way a safe index to assess the environmental conditions of humidity, because years with abundant rainfalls are followed by periods of intense drought. In the past five years San Justo department has experienced several below-average rainfall years and an intense drought during the period 2008-2009 (Figure 3.2.14).

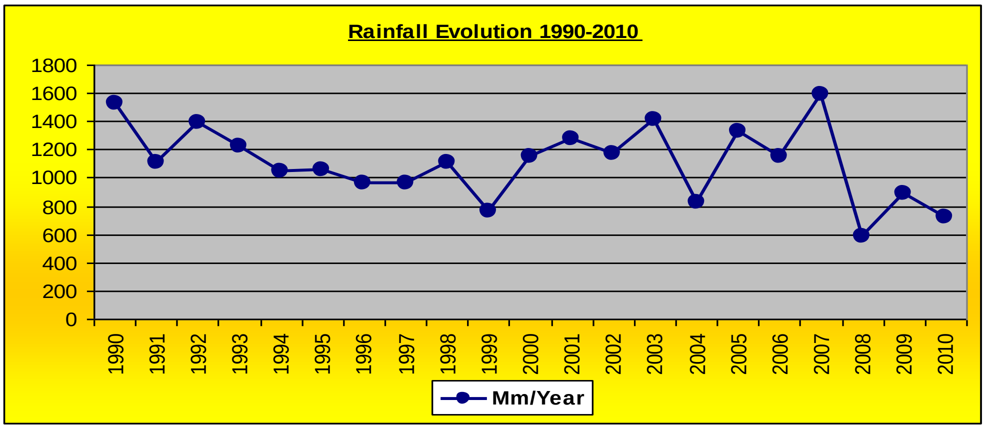

Figure 3.2.14: Rainfall evolution at San Justo, 1990-2010 (Source: EEA San Justo, INTA – Argentina).

The 2008/2009 drought effects are directly reflected on the crop yields shown on Figure 3.2.15. The economical losses were valuated in $350,000.000 (considering yields and livestock losses) and according to the local rainfall records it was the worse drought in the last 70 years. However, although this rainfall instability has historically been the main threat for agricultural producers in San Justo, it is important to underline that this precipitation dependence is not homogeneous across our study area. While at the Central Zone (East Dome) the soils (Argiudolls) are well to moderately well drained, at west and east landscapes associated to the Salladillo Amargo (bitter) and Saladillo Dulce (sweet) streams soils present saline- sodium and sodium contents (Natracualfes) and very poor drainage capacity which makes this areas more vulnerable to extreme precipitations.

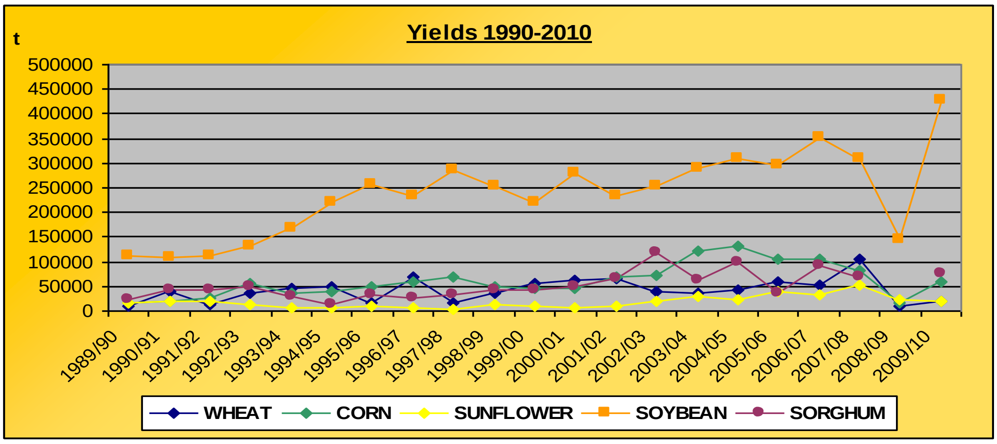

Figure 3.2.15: Agriculture yields in San Justo, 1990-2010 (Source: Dirección de Estimaciones Agropecuarias- SIIAP (MINAGRI)

In order to understand land use change in San Justo area, we must mention that the region was characterized until the early 1990's for its mix exploitations (i.e. agriculture and livestock activities), with a predominance of livestock activity. The growth of the annual crops area was led by linen until the season 1885/86, being replaced by soybean which had been introduced in the area on 1972 (Figure 3.2.16).

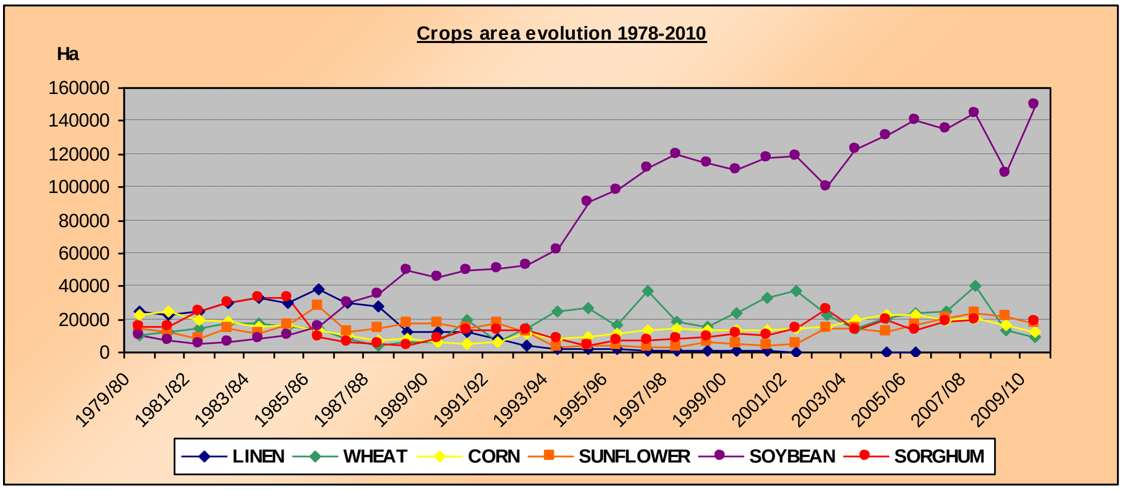

Figure 3.2.16: Area planted with the main annual crops for the department of San Justo. (Source: Dirección de Estimaciones Agropecuarias- SIIAP (MINAGRI).

The rapid increase of soybean area by the end of the 1990's and its constant growth since 2001/2002 is related to the adoption of transgenic soybean (RR), in association with direct sowing technique and the use of agrochemicals. This technological package allowed a larger production scale and larger yields reaching a peak of 428,700 tons of soy (Figure 3.2.15) for the season 2009-2010. However, when we analyze the yields per hectare (figure 3.2.17), the soybean yield for that season was 2858kg/ha, thus we can infer that the total yields increase in soybean production is more related to the increase of soybean surface than in larger yields per hectare.

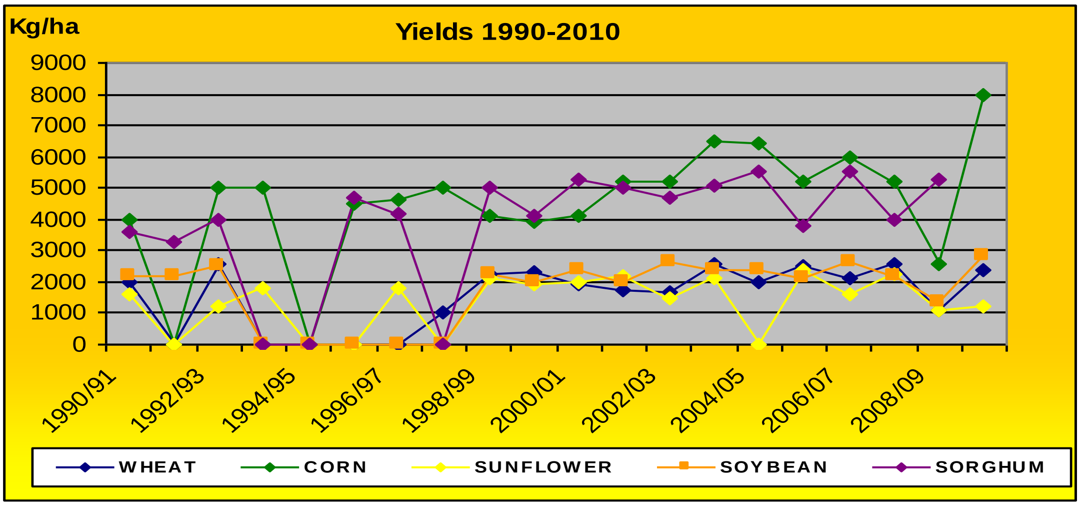

Figure 3.2.17: Agriculture yields per hectare in San Justo, 1990-2010 (Source: Dirección de Estimaciones Agropecuarias- SIIAP (MINAGRI)

After soybean, wheat shows an increase (though in a much less extent) going from 25,000 ha in 1993-1994 to 40,000 ha in 2007-2008, followed by corn, sunflower and sorghum. This last crop growth during 2009-2010 (19,000 ha) is related to drought and the fact that it is more resistant to water deficits than wheat. Sorghum yield for that period shows a total of 76,850 tons (5300kg/ha), against a total of 21,150 tons for wheat (2350kg/ha) (Figures 3.2.15 and 3.2.17). Last, while corn yields are higher than soybean, reaching a peak of 8000 kg/ha on 2009/2010 (figure 3.2.17), corn production surface decreased (figure 3.2.16).

The increase on soybean production surface produced also a decrease on livestock production surface and an increase of mix exploitations surface (i.e. livestock-agriculture exploitations) as shown in figure 3.2.18, since many livestock producers have now included agriculture production on their exploitations and others have turned to 100% agriculture producers.

The total number of livestock heads in San Justo reduced from 532,000 on 1989 to 320,000 in 2009 (Source: SENASA, 2009). We may say that the agriculturization process (Hernández, 2007) experienced in San Justo has displaced livestock activity to areas of lower agricultural quality in the northern part of the department and to the neighbors departments of San Cristobal and San Javier. Extensive open field livestock production is also being replaced by the installation of feed-lots, while extending the mixed fattening (stockyard /grazing). Regarding milk production the establishments reduced from a total of 112 in 2004 to 15 in 2009.

Land Use Summary

The three study sites show a clear trend to the increase in the area sown with annual crops, a decrease in the area used for livestock raising activities and an increase in the number of feed-lots facilities. These trends appear to be caused mainly by the relative economic yield of crops and of beef production activities. However, the increase in the area of annual crops, and especially of soybeans, is also supported by the good weather conditions experienced by the Pampas, in recent decades. It is worth noting that soybeans found in the Pampas excellent growing conditions, which made it especially attractive to producers in different sub-regions. Finally, domestic beef prices have exhibited an increasing trend during the last two years, which is contributing to slowing down the increase in the area sown with crops and helping to increase the national beef stock.

3.2.4 Productive systems present in Balcarce

This section provides descriptive statistics of the sample farms aiming at describing the state of the district and to understand the dynamics of land use and of land tenancy.

The farm size brackets (Table 3.2.1) were constructed to achieve an even distribution of cases in each bracket. Farm sizes in the sample range from 0,25 ha to 10,962 ha, with a median of 266 ha and a mean of 630ha. This distribution is consistent with that reflected in the 2002 National Agricultural Census for the district of Balcarce which indicates a median farm size of 239 ha and an average farm size of 595 ha. The 2009 data indicate a tendency to land ownership concentration as the average farm size grew by 6%.

Table 3.2.1: Distribution of farm sizes in Balcarce

Farm Size Brackets	Number of Farms
< 90 ha (a)	58
90, < 200 ha (b)	47
200, <500 ha (c)	58
500, <1000 ha (d)	43
=> 1000 ha (e)	41

The 247 farms in the sample cover an area of 155,691 ha, twenty percent of which (30,904 ha) is farmed by tenants. Renting land to tenants is a usual practice, as 129 farms rent out some land. The fifty nine farms (22% of the sample) that rent out part of their land rent on average 36% of their total area, with a minimum of 3% and a maximum of 90%. On the other end, 70 farms rent out their entire land to tenants (Table 3.2.2).

Table 3.2.2: Productive units renting in and renting out land

Rent In Number of cases		Rent Out Number of cases	
Renting In	24	0 %	118
Not Renting In	223	3 – 90%	59
		100%	70

Renting out land appears to be more important for small size farms (Figure 3.2.19). In the sample, the median size for farms renting out "all" their land is of 158 ha, while the median size for farms renting out "part" of their land is 454 ha and the median size for farms renting out "nothing" is of 344 ha.

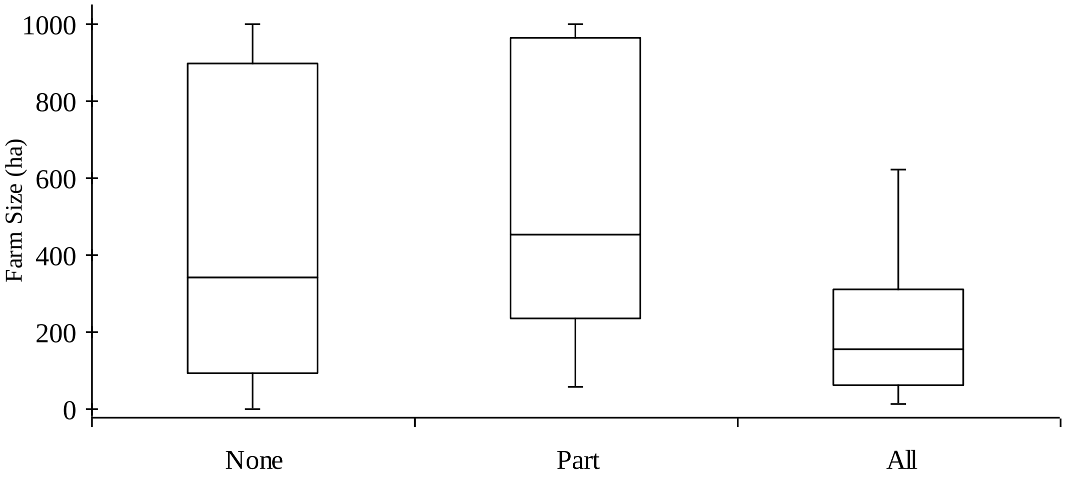

Figure 3.2.19: Farm size according to percentage of land rented out (farm size truncated at 1000 ha).

In general, the rented tend to be small. The median size for the 129 plots that are rented out is of 150 ha and the average size is of 239 ha, but only 15 are larger than 500 ha and only 5 are larger than 1000 ha. Also, there are differences in the size of the plots that each type of tenant rents (Figure 3.2.20). Tenants from the local area (*i.e.*, tenants from Balcarce, Mar del Plata or surrounding districts, but that are not neighbors of the farm), tenants with unknown residency "unknowns" [4] and neighbors rent plots with median

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[4] In some cases, it was not possible to establish the tenant's place of living, in such cases tenants were labeled "unknown".

sizes of 92, 161 and 68 ha, respectively, while pools rent plots with a median size of 338 ha.

Pools or sowing pools are common in Argentina. These firms, initially created to solve agricultural credit constraints, work like investment funds that develop a business plan and offer it to potential shareholders. Sowing pools are normally organized by agricultural consultants who gather investors and manage the logistics of the production process hiring land and custom farm labor. Given the recent boom in commodity prices, substantial amounts of investment funds were directed into the crop production, especially soybeans, through these pools.

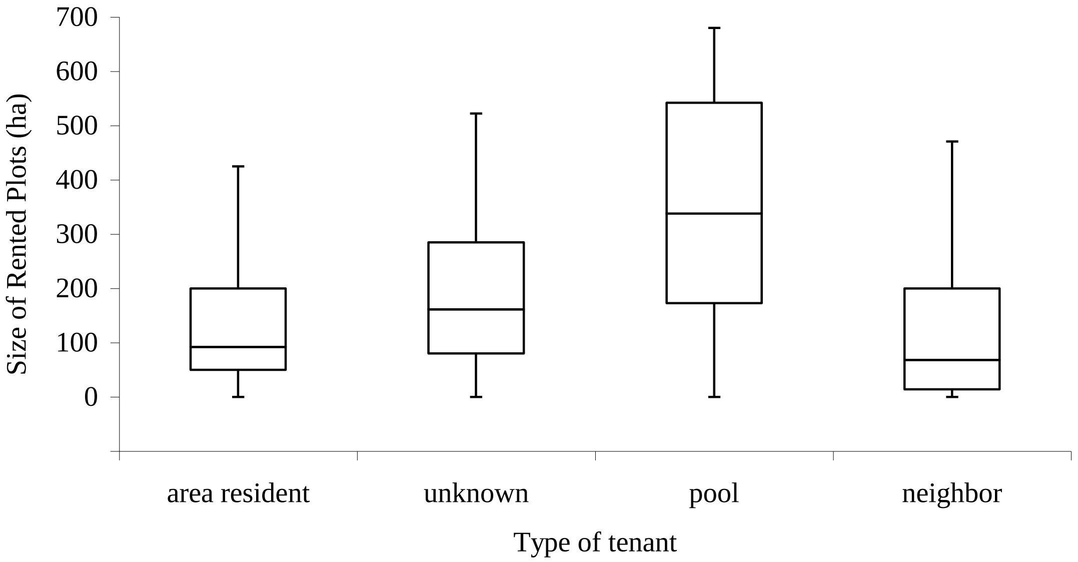


Figure 3.2.20: Size of the plots rented by type of tenant

About half of the sample farms (55% of the cases) combines livestock and farming activities. 87 farms (35% of the sample) cultivate only crops, and 23 farms (9%) raise only livestock (Table 3.2.3). The variable TDU (“work their land”) shows similar information to that contained in DAR (“rents out”). Briefly, 45% of the owners (112 cases) farm their entire land, 21% of the owners (53 cases) farm part of their land, and 33% do not farm any part of their land.

Table 3.2.3: Production activities and land tenancy

Type of Production	Number of cases	Work his/her Land	Number of cases
Agriculture only	87	Nothing	82
Mix	137	Part	53
Livestock only	23	All	112

Livestock only farms exhibit a diversity of sizes from 0.25 ha up to 1814 ha, but have a median of 201 ha. Crop-only farms tend to be the smaller with a median size of 108 ha, and mix farms include a wide range of sizes from a minimum of 18 ha to a maximum of 10,962 ha and with a median of 515 ha.

3.2.5 Productive systems present in Junin

In Junín, the sample is of 409 producers covering a total of 72,749 ha of the county. The farms size in the sample range from 5 to 2,566 ha, with a mean of 177 ha. As we mention before, in Junín the area of the farms are small, most of them are smaller than 200 ha (Table 3.2.4).

Table 3.2.4: Distribution of farm sizes at Junin

Size Brackets	Nº of cases	%
< 90 ha (a)	183	44,74%
90, < 200 ha (b)	128	31,30%
200, <500 ha (c)	71	17,36%
500, <1000 ha (d)	20	4,89%
> 1000 ha (e)	7	1,71%

So, in this case, we redefined the ranges aiming to have similar number of cases in all of them (Table 3.2.5).

Table 3.2.5: Redefined farm size brackets

Ranges	Nº Cases
1- <= 49 ha	85
2- 50 – 80 ha	82
3 - 81 – 130 ha	82
4 - 131 – 260 ha	81
5 - > 260 ha	79

In this sample, 40% of the cases work 100% of their land, 23% work only a part of their farmland and the other portion is rented out to a tenant. Finally, the remaining 37% of the farms rent out their entire land to tenants. Also, the group of farms renting most of their land to tenants is formed by the smaller farms in the sample, with a median of 75 ha. Farms renting out a “part” of the land to a tenant, have a median size of 131 ha, and farms renting out “nothing” have a median size of 115ha.

There are differences in relation whit the tenant residence. Junín is not an attractive county for pools, because the plots are too small for their bigger production scale. So, we found that the rent lands of the pool (it is a local pool) are in the biggest size exploitation, while the people of out of the county rents smaller plots (Figure 3.2.22). Generally the tenant lives in Junín or in a village near Junín (General Roca, Agustina, O´Higgins, etc).

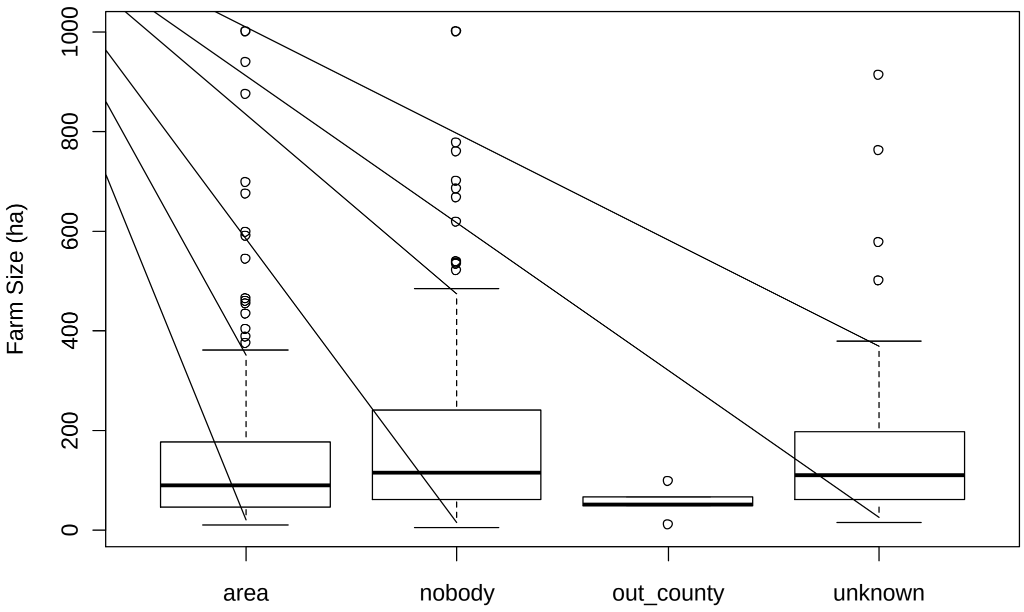


Figure 3.2.22: Tenant place of living

Owners producers the larger plots live outside the county, following this group in relation whit size farm are those whose owners lives in Junín. Finally, the smaller farm size corresponds to those who live near or in the farm. (Figure 3.2.23)

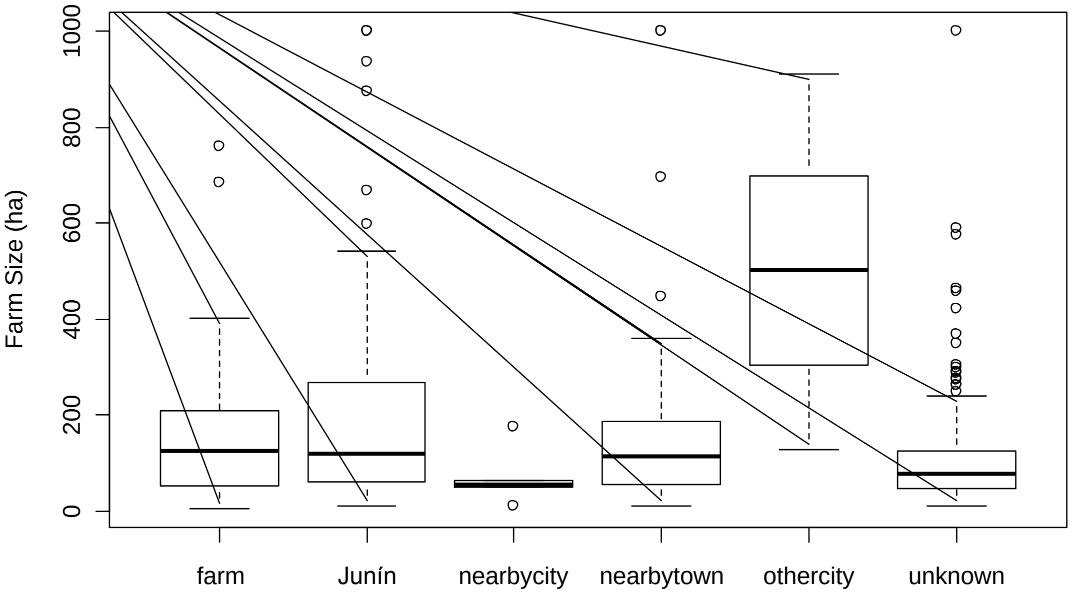


Figure 3.2.23: Owner´s place of living

About 70% of the sample is only farming activity (A), 29% of the farms combine livestock and farming activities (A/G), while the remaining 1% is only livestock activity (G). We can establish the relation between productive activity and the size of the farms. The median of the farm size dedicated to livestock is 326,5 ha, the median for the mix activity (agriculture and livestock) is 151 ha, and the median of the farms that only rise crops is 90 ha. This corresponds with the actual process of “agriculturalization”. The plots that are rented out are the smaller ones that could not update their technology and scale to stay profitable. Generally, in Junín all the rented plots produce soybean, sometimes combined with wheat, and are usually the smaller ones.

3.2.6 Productive Systems Present in San Justo

In San Justo, we have considered a sample of 495 productive units (PU) covering a total of 93,004 ha. Thus, we have found the PU size in the sample ranges from 10 to 7,229 ha, with a media size of about 187 ha. Most of the PU has less than 90 ha (52%) and between 90 and < 200 ha (29%) while only 2% of the sample owns more than 1,000 ha (Table 3.2.6).

Table 3.2.6: Productive units size brakets

PU Size Brackets	Nº of cases	%
< 90 ha (a)	256	52
90, < 200 ha (b)	142	29
200, <500 ha (c)	65	13
500, <1000 ha (d)	22	4
=> 1000 ha (e)	10	2

Considering this, we have redefined these ranges in order to have a comparable number of cases in each range (Table 3.2.7).

Table 3.2.7: Productive unit ranges

Ranges	Nº of cases	%
<= 40 ha	106	21.41%
41 – 70 ha	105	21.21%
71 – 110 ha	94	18.99%
111 – 200 ha	93	18.79%
>= 200 ha	97	19.60%

On one hand, from the total 495 PUs only 5,86% (29 cases) rent in land, i.e.: they rent extra land from the one they own. On the other hand, 50,30% of the cases rent out their lands entirely totalizing an area of 34,278 ha (36,86% of the sampled surface) which is farmed by tenants, and 55 PUs (11,11% of the sample) that rent out part of their land rent on average a minimum of 3% and a maximum of 90% covering 16,960 ha (18,24% of the surface) in mix exploitation. The remaining 191 PUs (38,59%) are farmers who exploit their land in property covering an area of 41,766 ha (44,91% of the surface) (Table 3.2.8).

Table 3.2.8: Productive Units Renting In and Renting Out Land

TAR (Rent in)	Cases	%	DAR (Rent out)	Cases	%
Yes	29	5.86%	0%	191	38.59%
No	466	94.14%	3-90%	55	11.11%
			100%	249	50.30%

We can also observe on that smaller PUs (with a media of 70 ha) are the ones who tend to rent out the entire surface (1), the ones with an intermediate size of 144 ha tend to rent out part of it (2) and the ones who do not rent land out (3) have a media of 94 ha (Figure 3.2.24).

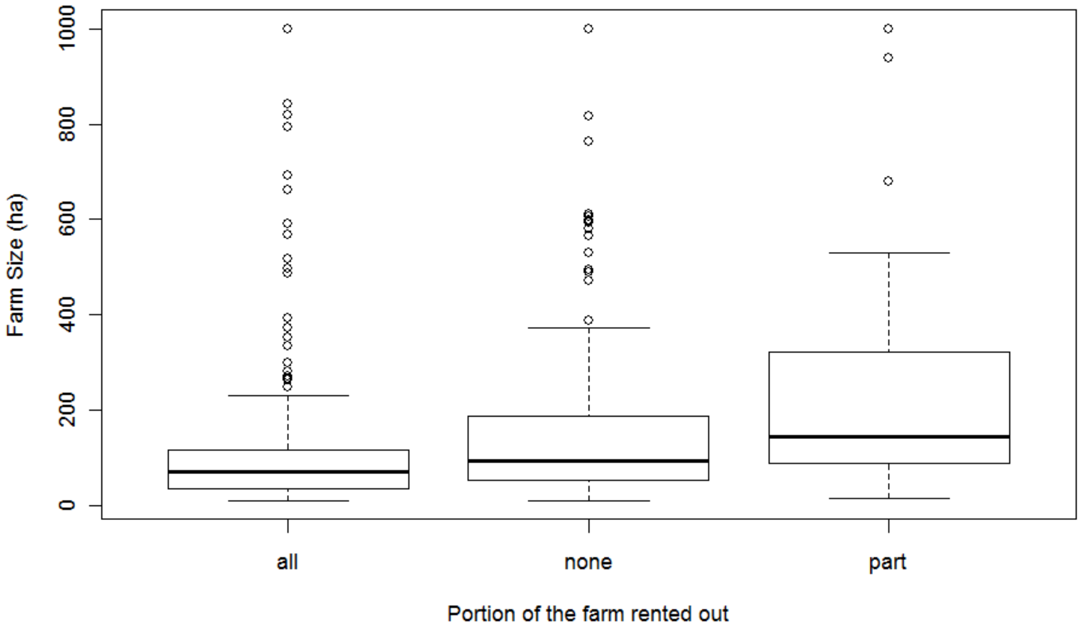


Figure 3.2.24: Portion of the farm rented out at San Justo

In table 3.2.9 is presented the residence of the land owners. In relation to the tenant's residence most of San Justo owners live in the city and rent their lands to people of the area (Table 3.2.10). However, is interesting to notice on table 3.2.11 that although there are few local pools (27 cases) these rent larger exploitations than tenants (274 cases), and international pools rent larger exploitations than the formers, but compared to the majority of the cases pools surface represents only 9.22% of the total surface.

Table 3.2.9: Residence of the land owners

Residence of the owner		
In the country	36	7.27%
In a town nearby	33	6.67%
In San Justo city	380	76.77%
In a nearby city	22	4.44%
Others	24	4.85%

Table 3.2.10: Residence of the tenants

Residence of the tenants		
In the country	0	0.00%
In a town nearby	20	6.62%
In San Justo city	277	91.72%
In a nearby city	5	1.66%

Table 3.2.11: Type of tenants

Tenants		
A neighbor	4	1.31%
Someone from the area	274	89.84%
Pools (national/international)	27	8.85%

Regarding the productive orientation of the productive units, about half of the sample (55.56% of the cases) raise only crops, 31% combines livestock and agriculture activities, fifty seven PU (11.52 % of the sample) raise only livestock and 8 farms (1.62%) are used for other productive activities (mainly forestall) (Table 3.2.12). This data is coherent with the agriculturalization process (Hernández, 2007) experienced in the area.

Table 3.2.12: Productive activity

Reference	Productive activity	Cases	%
1	Agriculture	275	55.56%
2	Agriculture/Livestock	155	31.31%
3	Livestock	57	11.52%

The Figure 3.2.25 shows the distributions of farm sizes according to their type of production. The median of the PU size dedicated to livestock is 108 ha, the median for the mix activity (agriculture and livestock) is 115 ha, and the median of the PU that only rise crops is 68 ha.

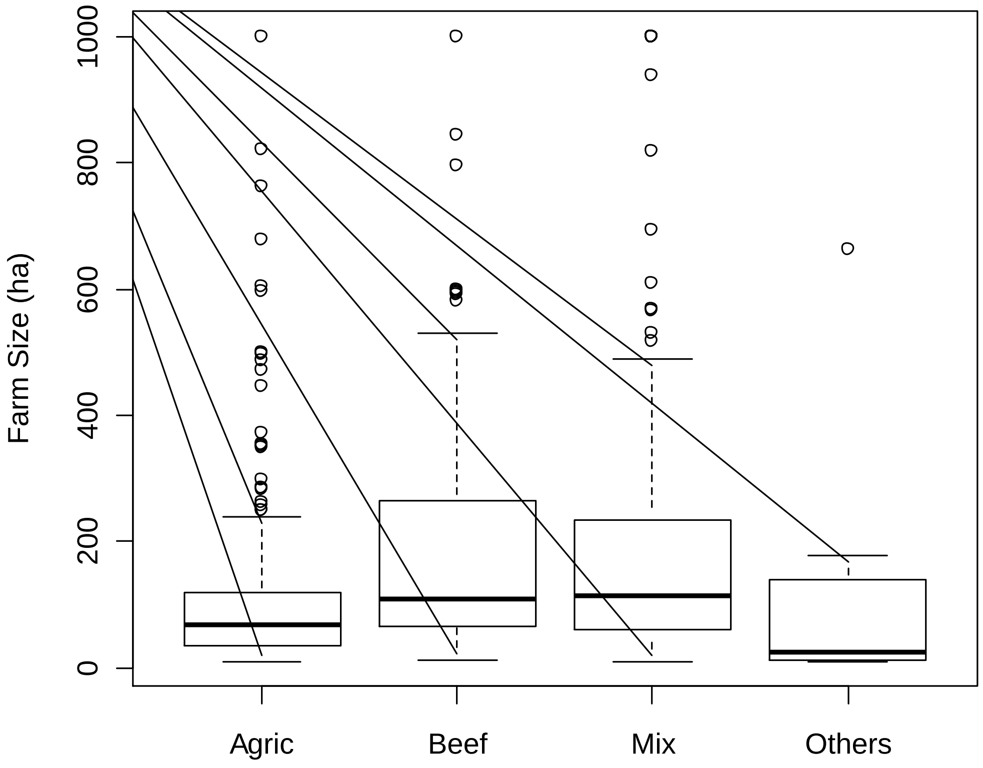


Figure 3.2.25: Farm size according to PU production activities (size truncated at 1,000ha)

The variable TDU ("work their land") shows similar information to that contained in DAR ("rents out"). Summing up, 52.12% of the owners (258 cases) do not farm any part of their land, i.e. they rent it out, 38.38 % (190 cases) farm their entire land, and the remaining 9.49 % of the owners (47 cases) farm part of their land (Table 3.2.13).

Table 3.2.13: TDU ("work their land")

TDU	Cases	%
Nothing	258	52.12%
Part	47	9.49%
All	190	38.38%

3.2.7 Typology of plots of Balcarce

Typologies of plots for each of the three study-sites are being developed to characterize the types of production systems present in the study site. Our overarching hypothesis is that different types of systems will have varying capacities, or flexibilities, to adapt to climate change. The typology is done using Factorial Correspondence Analysis (FCA). FCA is a statistical method used to describe and reduce the variability among observed variables in terms of fewer constructed variables called factors. The observed variables are grouped in linear combinations that explain the largest possible amount of variability. The factors yield groups of observations (i.e., farms) that share common factors and that can be classified in groups that share similar characteristics. These groups form the typology.

Previously, the sample farms were categorized in 4 types according to characteristics such as, the percentage of area produced by the owner and by the tenant, the type of tenant, size of the farm, and whether or not they include cattle production. The classification of farms was updated to 7 types, because this classification allows for a more clear separation of farms according to their productive strategies. Key features of each of the seven types are presented in Table 3.2.14 and Table 3.2.15. In farm type 1, 13% of the farms raise crops only, 83% of the farms raise annual crops and livestock and 4% of the farms raise livestock only (Table 3.2.15).

Table 3.2.14: Description of farm size and percentage of the farm rented out by farm type

		Farm Size (ha)			Rented out %		
	N	Min	Average	Max	Min	Average	Max
Type 1	24	18	763	3888	0	4	45
Type 2	47	60	747	6381	0	35	100
Type 3	57	33	416	1519	0	85	100
Type 4	19	1022	2662	10962	0	0	0
Type 5	56	2	307	937	0	0	0
Type 6	22	14	47	80	100	100	100
Type 7	22	0.25	441	1814	0	25	100

A classification of each type according to it’s flexibility to adapt to climate change is being developed. We hypothesize that farm characteristics such as, size, percent of farmland rented out, and productive activities indicate the capacity to adapt to different climate scenarios. These variables will be used as proxy to assess farms adaptive capacity to climate change.

Table 3.2.15: Percentage of farms raising crops, raising crops and livestock and raising livestock only in each farm type

	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
Avg. Farm Size	763	747	416	2662	307	47	441
Crops only	13	26	54	0	34	100	0
Mix	83	74	46	100	66	0	0
Livestock only	4	0	0	0	0	0	100

3.2.8 Typology of plots of Junin

For Junin, the typological classification of the farms yielded 5 types according to the variables collected in our field work. The farm size increases with type. In all types the percentage of farms that take plots renting-in are similar.

Table 3.2.16: Description of farm size and percentage of the farm rented in by farm type

	Farm Size					Renting In		Renting In	
	Nº cases	Total has	Min	Max	Media	Yes	No	Yes	No
Type 1	36	4938	10	696	137,17	5	31	13,89%	86,11%
Type 2	93	13926	5	2566	149,74	15	78	16,13%	83,87%
Type 3	34	5403	13	700	158,91	5	29	14,71%	85,29%
Type 4	83	13920	10	875	167,71	15	68	18,07%	81,93%
Type 5	163	34562	10	1450	212,04	23	140	14,11%	85,89%

The information of Table 3.2.16 indicates that type 1 tends to rent most part or some part of the field, type 2 tends to work the own field, type 3 tends to rent most part of the field, type 4 tends to work the own field and type 5 while variable, it tends to rent most part or nothing.

In all types of farms, it is more relevant the activity dedicated only to crops than mix activity (crops and livestock), but only in type 2 and type 4 we found farms raising only livestock. Farms raising livestock as their only activity are 1 in type 2 and 3 in type 4 (Table 3.2.17). Table 3.2.18 shows the percentage of cases that rented out their own field to a tenant.

Table 3.2.17: Percentage of farms raising crops, raising crops and livestock and raising livestock only in each farm type

	Type 1		Type 2		Type 3		Type 4		Type 5	
	Nº Cases	%	Nº Cases	%	Nº Cases	%	Nº Cases	%	Nº Cases	%
Only Crops	22	61,11%	73	78,49%	27	79,41%	57	68,67%	107	65,64%
Mix	14	38,89%	19	20,43%	7	20,59%	23	27,71%	56	34,36%
Only Livestock	0	0,00%	1	1,08%	0	0,00%	3	3,61%	0	0,00%

Table 3.2.18: Percentage of the farm rented out by farm type

Rent Out	Type 1	Type 2	Type 3	Type 4	Type 5
Most Part	47,22%	24,73%	52,94%	27,71%	44,17%
Part	38,89%	20,43%	20,59%	22,89%	20,86%
Nothing	13,89%	54,84%	26,47%	49,40%	34,97%

As we can appreciate in Table 3.2.19, in all the farm types are dominants the tenants from the county.

Table 3.2.19: Kind of tenant by farm type

	Type 1	Type 2	Type 3	Type 4	Type 5
Out of the country	3,23%	0,00%	4,00%	2,38%	1,89%
Local Pool	0,00%	0,00%	0,00%	0,00%	0,94%
Someone-country	77,42%	66,67%	64,00%	69,05%	69,81%
Unknown	19,35%	33,33%	32,00%	28,57%	27,36%

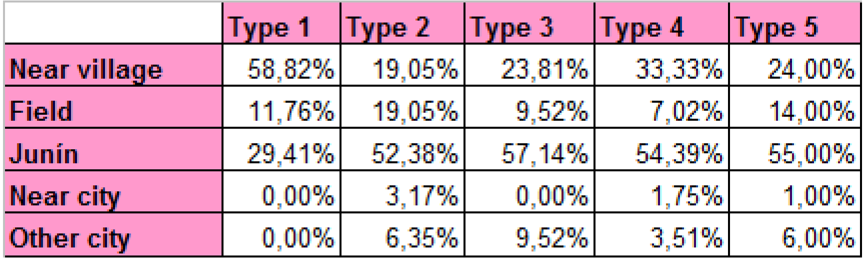
Also, we can consider the place of tenant residence in each type. In spite of the unknown cases, in all types, the tenant’s residence is at Junín or near there (Table 3.2.20)

Table 3.2.20: Percentage of tenancy versus residence

	Type 1	Type 2	Type 3	Type 4	Type 5
Junín	35,48%	25,58%	29,63%	27,91%	24,53%
Near field	6,45%	9,30%	11,11%	9,30%	12,26%
Near city	3,23%	2,33%	3,70%	2,33%	3,77%
Unknown	19,35%	34,88%	33,33%	30,23%	35,85%
Village	35,48%	27,91%	22,22%	30,23%	23,58%

Other important variable is the owner residency (Table 3.2.21). In type 1, the most number of cases the owner lives in a near village and, secondly, in Junín; while in the others types of farms, the owner lives in most cases in Junín and secondly in a village near the field.

Table 3.2.21: Percentage of Owner Residence



	Type 1	Type 2	Type 3	Type 4	Type 5
Near village	58,82%	19,05%	23,81%	33,33%	24,00%
Field	11,76%	19,05%	9,52%	7,02%	14,00%
Junín	29,41%	52,38%	57,14%	54,39%	55,00%
Near city	0,00%	3,17%	0,00%	1,75%	1,00%
Other city	0,00%	6,35%	9,52%	3,51%	6,00%

3.2.9 Typology of Plots of San Justo

Typological classification of the sample farms was about 8 types in function of the different variables we registered in our field work. We can see that Type 1, 2 and 7 are the ones with less number of cases but of larger farm sizes, followed by type 4 and 3, and the remaining cases were classified under the types 8, 5 and 6, showing in general a smaller media size (Table 3.2.22).

Table 3.2.22: Typology of plots of San Justo

	Farm Size				
Type	**Nº cases**	**Total ha**	**Min**	**Max**	**Average**
Type 1	53	16882	15	4034	318,52
Type 2	31	11631	10	7229	375,19
Type 3	63	9164	113	197	145,46
Type 4	55	14270	11	3742	259,45
Type 5	81	4648	13	70	57,38
Type 6	87	2122	10	40	24,39
Type 7	52	27689	201	2268	532,48
Type 8	73	6598	71	110	90,38

Another very important variable on this typology is the rent in/out variable (Table 3.3.23), being type 1 and 2 the only ones who rent in extra land. Keeping in mind what we mentioned above related to their larger size this would be showing us a land concentration trend on this two types. However, when we consider the rent out cases inside each type we can see an intrinsic diversity on them related to their renting out strategy. This concentration trend focuses on type 2 where there is less renting out (29.03% between those who rent all their land and partially) and more land tenants renting in extra land (74.97%). We would like to underline that concentration on this types is related to the fact that these are land owners who also rent in extra land.

Table 3.2.23: Rent in/rent out percentage

	Rent Out %			Rent In			
Type	**All**	**Part**	**Nothing**	**Yes**	**%**	**No**	**%**
Type 1	0,00%	96,23%	3,77%	6	11,32%	47	88,68%
Type 2	25,81%	3,23%	70,97%	23	74,19%	8	25,81%
Type 3	58,73%	1,59%	39,68%	0	0,00%	63	100,00%
Type 4	43,64%	3,64%	52,73%	0	0,00%	55	100,00%
Type 5	61,73%	0,00%	38,27%	0	0,00%	81	100,00%
Type 6	73,56%	0,00%	26,44%	0	0,00%	87	100,00%
Type 7	38,46%	0,00%	61,54%	0	0,00%	52	100,00%
Type 8	63,01%	0,00%	36,99%	0	0,00%	73	100,00%

On Table 3.2.24 we can see the productive orientation of each type. Thus, we can see type 6 and 5 show a predominance of crops producers while type 4 is the only one with a 100% livestock production. The remaining types have a mix composition, but we can distinguish type 1 and 2 for having some cases of only livestock production (though to a much lesser extent that crops and mix activities) from types 3, 7 and 8 without any cases of only livestock production.

Table 3.2.24: Productive orientation per type

	Crops		Mix		Livestock		Others	
Type	**Nº cases**	**%**	**Nº cases**	**%**	**Nº cases**	**%**	**Nº cases**	**%**
Type 1	21	39,62%	33	62,26%	1	1,89%	0	0,00%
Type 2	16	51,61%	8	25,81%	1	3,23%	8	25,81%
Type 3	38	60,32%	27	42,86%	0	0,00%	0	0,00%
Type 4	0	0,00%	0	0,00%	55	100,00%	0	0,00%
Type 5	62	76,54%	21	25,93%	0	0,00%	0	0,00%
Type 6	71	81,61%	18	20,69%	0	0,00%	0	0,00%
Type 7	25	48,08%	29	55,77%	0	0,00%	0	0,00%
Type 8	49	67,12%	26	35,62%	0	0,00%	0	0,00%

Productive Systems Summary

The modal size of the productive systems at each study sites vary, but in each site some common trends are observed. Balcarce features larger size farms. The average farm size at Balcarce is of 630 ha, while the average farm size for Junin and San Justo was of 177 and of 187 ha, respectively. At each site, there is a clear association between farm size, tenancy form, and production profile. Smaller plots are more frequently sown with annual crops by neighbors or local tenants, while medium and large-size farms tend to produce crops and beef and to be operated by their owners. Large nation-wide sowing pools do not usually rent land in any of the study sites.

The productive systems of each site were classified in a typology according to the characteristics such as size, percent of farmland rented out, and productive activities. We hypothesize that these characteristics will largely determine the farm’s adaptive capacity to climate changes.

3.3 Fire risk

3.3.1 Introduction

Fire is a major disturbance affecting worldwide ecosystems, and more particularly the tropics where drought and high temperature co-occur on highly flammable shrubs and grasslands and where fires are closely related to deforestation (van der Werf et al., 2003). Recent studies hypothesize that fires might play a more important role than any other processes in modifying the landscape dynamics at the regional level by three main causes: i) by resetting natural ecosystems to their early successional stages, ii) by favoring plant functional types adapted to recurrent disturbances and iii) by changing the land cover structure.

Inter-annual variability and seasonality of fires have been accurately related to climate and particularly drought periods. In general, shallow rooted grasslands get dry earlier in the dry season favoring high fire risk compared to the deep rooted forests, which can get access to water for a longer period. Concomitantly, aerial biomass structure determines flammability with a higher fire risk for fine branches compared to thick trunks. As a consequence, grassland/shrubland fires are highly recurrent with low inter-annual variability, while severe forest fire happens only during prolonged droughts mostly driven by El Niño events in the tropical forests. Indeed, modeling current and future fire regime at the global is based on available biomass and its water status (Thonicke et al. 2001). Beside this knowledge on climate influence on the fire regime, changes in fire regimes in the last century clearly illustrate how land cover changes, changes in fire policies or forest management strategies can significantly affect long term changes in fire regime, and in a more significant manner than any climate trend (Mouillot et al. 2005).

The La Plata Basin (LPB) (which spans over five countries: Argentina, Bolivia, Brazil, Paraguay and Uruguay) is highly important for the South American economy, biodiversity and food security. The LPB covers a wide range of “anthromes”, sensu Ellis and Ramankutty (2008) and Ellis et al. (2010), i.e. a diversity of biomes (Pantanal, Atlantic Rainforest, Cerrado, Chaco and Pampas ...) transformed by a multiplicity of land uses, from urban areas and forest plantations to crop and livestock activities.

We investigated here the Driver-Pressure-State-Impact-Response (DPSIR) chain that can lead to the different fire regimes in LPB and its potential changes under climate and socio economic changes based on analyzing recent fire history from 5 global remote sensing fire products, several land use/land cover datasets. This conceptual framework will be used to build fire regime scenarios for the 21th century based on climate and socio economic forecasts.

3.3.2 Material and methods

A. Fire datasets

Fires produce several signals such as heat and light, smoke, deposits of ash or alteration of vegetation structure, which can be observed from space and form the basis of remotely sensed fire datasets (Robinson, 1991). Even though several detection techniques as well as improved algorithms have been developed, evaluating a fire regime at the regional or local scale remains uncertain, despite observed convergences between products for generic signals (Schroeder et al. 2009). Fires are heterogeneous in time, in space, and in intensity, making detection methods subject to false-detections and missed observations (Qu et al., 2008), coupled with signal anomalies due to solar angle and day length variations across large areas (Schroeder et al. 2005). In addition, allowing a fire signal to a given land cover/land use at local scale are expected to be tough in the tropics because many tropical landscapes are complex mosaics of pastures, woodlands and croplands - mixing fire types – and because some mismatches between the scales of biomass burning and sensors used have been subject to less attention (Bradley and Millington, 2006). However, limited ground-based fire statistics across Latin America, make remotely sensed datasets sound alternatives for assessments of fire in the La Plata Basin (Chuvieco et al., 2008). Acknowledging that available fire datasets are limited in scope, our study combines several of them:

- Global VGT burnt area product (L3JRC, 2000 – 2006)

The Global burned area product is based on classification of SPOT VGT S1 data to burned areas. A single algorithm is used on pre-processed images (to remove cloud shadows and other unwanted data), using a temporal index in the near infrared channel. The output is then post-processed to remove over detections, mainly on the basis of the GLC2000 product (22 classes land cover map based on regional land cover analysis). It is assumed that a surface cannot be burned more than once in the same fire season and the product indicates julian date that a burned area was first detected and geographic coordinate of the center of each pixel (~0.00892° pixels).

- ATSR World Fire Atlas (1997 – 2009)

The ATSR night time data are based on a 1 km resolution instrument and 2 algorithms. Hot spots are detected if radioactive anomaly in the 3.7 micrometer channel exceed 312 K (Algorithm 1, referred as ATSR1) or 308 K (Algorithm 2, referred as ATSR2). Therefore the data based on algorithm 1 are to be more reliable (less commission errors) and the data based on algorithm 2 more sensitive. Among the known limits are overlapping ATSR frames (some fires can be detected twice), warm surface detection (with Algorithm 2) and global underestimation of the hot spot number (only night time detection).

- Burned area (BAE, Globcarbon product, 1999 – 2007)

The BAE product from the European Space Agency builds on methods and information from previous GLOBSCAR and GBA2000 assessments. The approach is to integrate the two processing chains and fire location information derived from existing but independent databases (ATSR products, TRMM, FireM3). Three algorithms (UTL, IFI and GLOBSCAR algorithm) are used independently and then merged along with the fire location information to provide a single product on a monthly time step. They are based on temporal differences of several signals, mainly reflectance value and red, near infrared and shortwave infrared, NDVI and NDWI indices. All pixels identified by one of the algorithms are retained in the final product at 1 km, with a separate band indicating how many algorithms detected a burned area and the earliest date of detection found among the three algorithms.

- MODIS Collection 5 Burned Area Product – MCD45 (2000- 2009)

MODIS algorithm detects the approximate date of burning at 500 m by locating the occurrence of rapid changes in daily surface reflectance time series data. It is specifically designed for detecting active fires, with a high band saturation brightness (500 K) and relatively high spatial resolution (1 km). In the MODIS design, the 3.75 µm channel used in AVHRR and TRMM was shifted to 3.96 µm to avoid the variable water vapor absorption and to reduce reflected solar radiation. The collection 5 has been improved through the use of a bidirectional reflectance model to deal with angular variations found in satellite data and the use of a statistical measure to detect change probability from a previously observed state.

MCD45 product is a subset from the standard MCD45A1 centered on South America. However, the bounding latitude does not extend to the entire South of the LPB, and therefore fire data is missing for the southern part of the Argentinean pampas in our study.

- NOAA AVHRR fire product (2000 – 2009)

The dataset is based on fire detection by the AVHRR sensor onboard of the NOAA's Polar Orbiting Environmental Satellites (NOAA-15, NOAA-16, NOAA-17, NOAA-18 and NOAA-19). It is made available by the Brazilian Instituto Nacional de Pesquisas Espaciais (INPE), being the reference product.

B. Land Use and Land Cover datasets

Fire distribution across the La Plata Basin was analyzed in regard to several land cover and land use databases. To minimize errors due to uncertainty in fire localization at the kilometer scale and the limits of single classification algorithm in complex tropical Landscapes, continuous databases were used. Mainly:

- Rural Population Density

The FGDD rural population density map is a global raster data-layer with a resolution of 5 arc-minutes. Each pixel classified as rural by the urban area boundaries map contains the number of persons per square kilometer, aggregated from the 30arc-second data-layer (Salvatore et al., 2005). Across the LPB, rural population densities range from 1 to 318 persons/km², with a mean density of 5.23 persons/km²

- Distance to Urban Centers

The distance to urban center map was calculated from the MODIS 500-m map of global urban extent (Schneider et al., 2009,2010) using the IDRISI software. The value of each pixel corresponds to the distance to the nearest urban center, in meters. For the LPB, mean distance to urban center is 45 km, and maximum distance is 115 km, in the wetlands of the Brazilian Pantanal.

- Cropland, Grassland and Forest densities

The International Institute for Applied System Analysis (IIASA), provides datasets of global forest cover, grass cover, urban cultivation, water, and bare ground, whose percentage are given at 5' resolution (1/12°) (Fischer et al., 2008). For each dataset, pixel value represents the percentage of the pixel occupied by this cover, which was assessed thanks to several other land cover datasets:
1) GLC2000 land cover database at 30 arc-sec;
2) IFPRI global land cover categorization with 17 land cover classes at 30 arc-seconds;
3) FAO's Global Forest Resources Assessment 2000 at 30 arc-seconds resolution;
4) Digital Global Map of Irrigated Areas at 5'×5' resolution;
5) IUCN-WCMC protected areas inventory at 30 arc-seconds;
6) FAO-SDRN population density inventory at 30 arc seconds.

C. Statistical analysis

All the fire databases were re-sampled at 1 km resolution , and further reframed to the La Plata Basin and projected to Sample Interrupted Goodes projection. To compare fire patterns observed in the different datasets, we chose the longest common time series available, i.e. the 2000 – 2006 period, by summing all the fires detected per 1 km pixel over this period. Data were then aggregated at10 km.

Correlation matrix of both datasets (1 km and 10 km resolution) were computed with IDRISI. Analysis of fire distribution among the ecosystems (or bio-geographic communities) of the La Plata Basin is based on the Olson's et al (2001) Biomes. They were further subdivided by country (Argentina, Bolivia, Brazil, Paraguay and Uruguay), to take into account potential socio-political effects on fire distribution (Pyne, 2007).

Patterns of high fire activities, or "fire patches", were mapped by applying a fire density threshold to each 10 km resolution 2000-2006 fire dataset (Figure 3.3.1). The fire density threshold was chosen in order to have total fire patch surface (i.e. pixels superior to the threshold) account for less than 15% of the La Plata Basin while concentrating more than 80% of the total fire density. The possibility to set such a threshold for each fire dataset is the result of high aggregation of fire activity across the LPB (Table 3.3.1).

ATSR2 fire patches were chosen as reference. Their degree of accuracy was estimated by analyzing presence or absence of the patch in the other patch datasets (degree of certainty is therefore the number of time a patch was detected as fire disturbed, value between 1 and 6). Potential omissions in the ATSR2 dataset, were complemented by fire patches detected in a least 3 other datasets (complementary patches).

Fire disturbed patches were characterized by their mean cropland, forest and grassland density (GAEZ datasets; Fischer et al., 2008), population density (Salvatore et al., 2005) and average distance to urban centers (calculated from Schneider et al., 2009).

Agro-ecological landscape classification was established by clustering the patches on the basis of these 5 attributes using the Xmeans algorithm in WEKA. Quality of clustering was assessed by plotting clusters on the two first components of a Principal Component Analysis (R software), based on all patches (ATSR2 and complementary) characterized by their 5 attributes. The classification in agro-ecological landscapes is therefore based on land-use and land cover attributes and not on characteristics of the fire regime of patches. This choice was made because of the limits of the fire time series, that do not enable reliable identification of return interval, type of vegetation burnt, inter-annual variability. Their utilization is therefore restrained to the identification of high fire activity zones, whose state and dynamics are to be understood on the basis of their agro-ecological pathway (e.g. Deforestation, pasture management, cropland expansion).

D. DPSIR approach adapted to fire studies

The Driver-Pressure-State-Impact-Response approach (DPSIR) is a conceptual framework used to organize information about the state of the environment and the relations between human activities and possible environmental changes. This approach is based on the concept of causal links that start with the human activites (driving forces) exerting pressures on the state of the system, which then change the quality and the quantity of natural resources and finally leads to societal responses.

Integrated fire assessment, such as vulnerability of land systems to fire framework (Lavorel et al., 2007) could be adapted to fit DPSIR approach. We would interpret it as follows:

Driver: Broad driving forces leading to exposure of land use systems to fire. For example, climate and climate change, via their influence on fuel availability and flammability; Population Growth and need for increased agricultural lands, can trigger the use of fire for deforestation; or land abandonment of marginal areas, can lead to fuel accumulation and increased fire hazards. Here, identifying the drivers is to understand the broad distribution of fire patches across the La Plata Basin over the 2000-2006 period, as well as the phenomenon that could modify them.

Pressure: Direct controls of fire ignition and fire spread. As fires are mainly an anthropogenic practice in Latin America, therefore in the La Plata Basin (Lauk et al., 2009) pressures are mainly related to fire practices (ex. pasture management, deforestation, cropland cleaning, agricultural practices, hunting...) and to landscape features (fuel continuity, opened forests next to zones of fire use, loaded grasslands...). In our methodology, the pressure could be assessed by analyzing the different socio-economic settings of the fire patches identified, in order to understand why the “fire option” is the practice chosen (Mistry, 1998).

State: Fire regime embedded in a socio-ecological matrix. We propose to use the agro-ecological landscapes identified by the clustering of the fire patches on the basis of their 5 attributes. These landscapes can be conceived as a state as they account for a particular setting of land uses, human activities and landscape, interacting with fire. As Lambin puts it (quoted from Lavorel et al., 2007) “Where fires are mostly ignited by human activities, there is an inverted-U-shaped relationship between land use intensity and fire frequency: unoccupied ecosystems do not burn frequently; systems dominated by slash-and-burn agriculture or pastoralism favors fires as a land management tool and modify vegetation accordingly; and systems based on mechanized farming or intensively managed plantations have suppressed fires”.

Impact: Known consequences of fire in these agro-ecological landscapes. Fires impact socio-ecological systems in a broad range of ways, from soil structure to species composition, threat to infrastructures, to chronic human health diseases (Uriarte et al., 2009), in longer term ecosystems can be modified (Bond et al.,), and carbon stocks altered....

Response: Especially if fire is seen as a threat (e.g. respiratory diseases, carbon emissions; soil destruction; economic losses), than there might be societal responses to control its uses or modify its practices (controlled burning, fire bans, environmental laws). Capacity of a system to adapt fire uses in response to its impact is dependent on the existence of applicable alternatives (for example price of fencing to organize grazing, mechanization of harvest, access to mechanical treatments...). However, according to the complexity of fire ecology and our limited capacity to understand and control it so far (e.g. Yellowstone fires), responses should not be seen as the end of the causal link but as a new beginning, with uncertain effects over multiple time and spatial scales.

3.3.3 Results

A. Fire regime in LPB: General pattern and mismatches between fire products

The La Plata River Basin covers approximately one-fifth of the South American continent, extending over some 3 million km², composed of 40% of cultivated areas, 29% of forests, 31% of rangeland, shrubs and pastures. It is composed of contrasted biomes according to their climate, soil and topography (Figure 3.3.1).

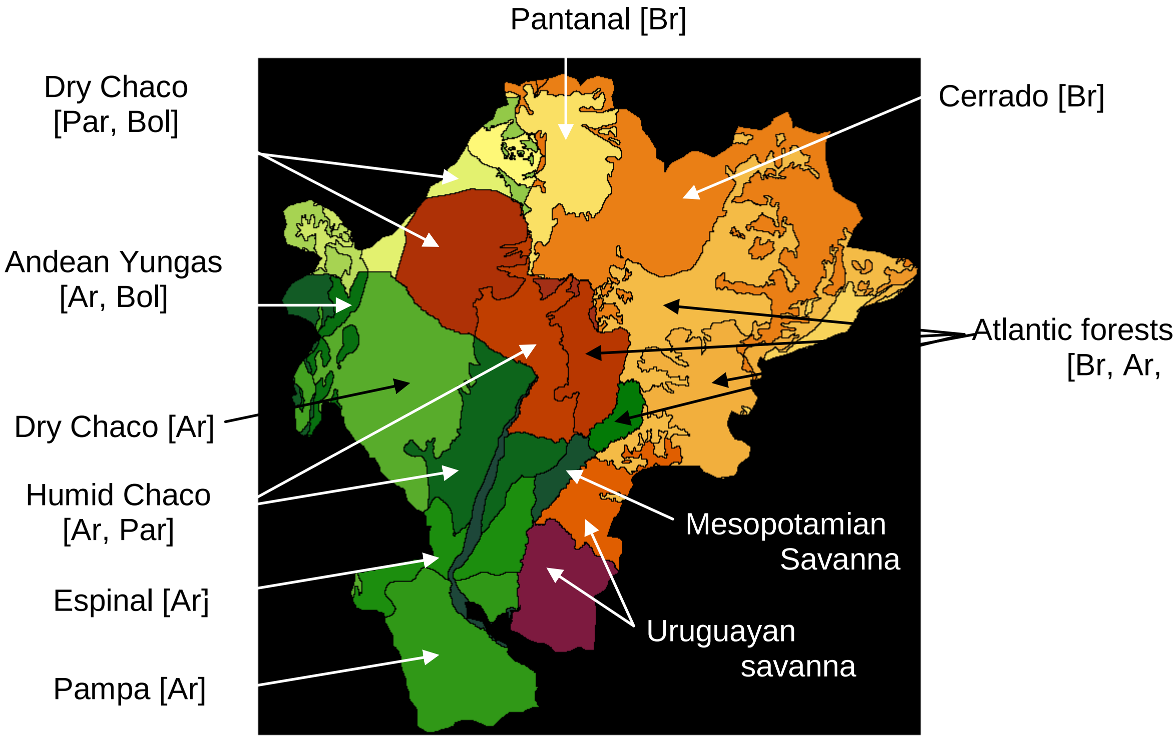
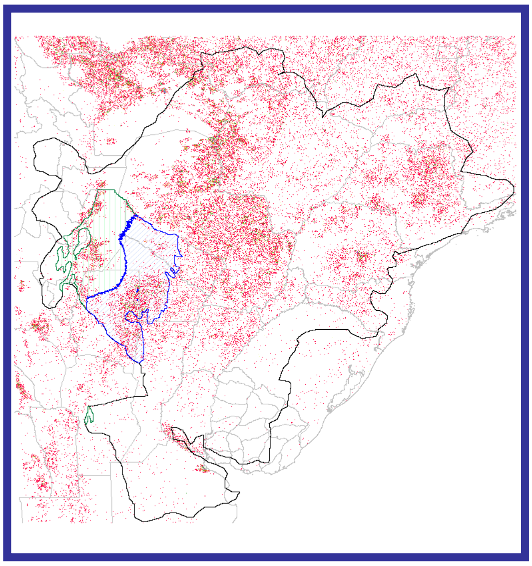
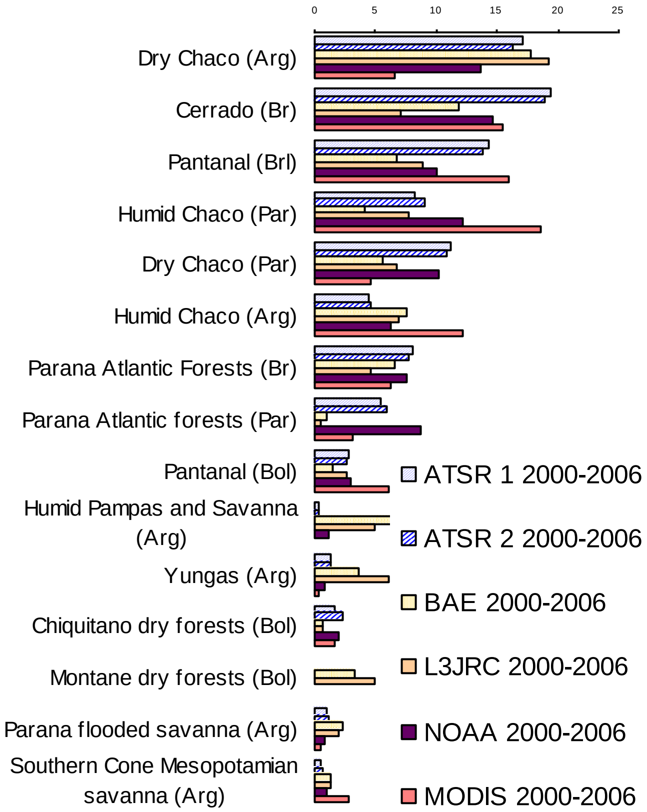


Figure 3.3.1: Major biomes in LPB

Within the region, fire hotspots affect between 2% and 73% of the total area depending on the fire database with a high spatial heterogeneity (Figure 3.3.2). Most biomes are affected by fires, including wildland (forests, shrublands and grasslands) but also land used for crops, pastures and the wildland-urban interface. Most fires are distributed in the Dry Chaco, the Humid Chaco, the Cerrado and the Pantanal over the 2000 – 2006 period. They account for more than two thirds of the fire activity, with a contribution of 22.5%, 17%, 14.5% and 13.5% each (average over all the fire databases).

Figure 3.3.2: Fire distribution in LPB from ATSR	Figure 3.3.3: Fire distribution among LPB biomes for each of the fire product.
	

The Temporal trend for fire activity across the region is somewhat highly variable by a factor of 2, with the 1998 and 2000, 2003 and 2008 being the highest fire years and 2001 and 2004 being the lowest. We can already observe some discrepancies between the datasets but the generic inter-annual variability is well depicted (Figure 3.3.4). General trends and patterns could then be identified at the regional scale, but several inconsistencies between the fire datasets are observed:

- Number of burnt pixels detected can vary from 61000 to over 200000, i.e. a 30 times variation according to the dataset;
- Spatial correlations are weak when used at 1km resolution and greatly improve when upscaling at 10km resolution;
- Few regions largely contribute to the discrepancy: flooded regions can be considered as fires for their high reflectance and grassland vs forest fires are not detected by the

same sensors according to their timing (night time vs day time) and their sensitivity to specific thresholds.

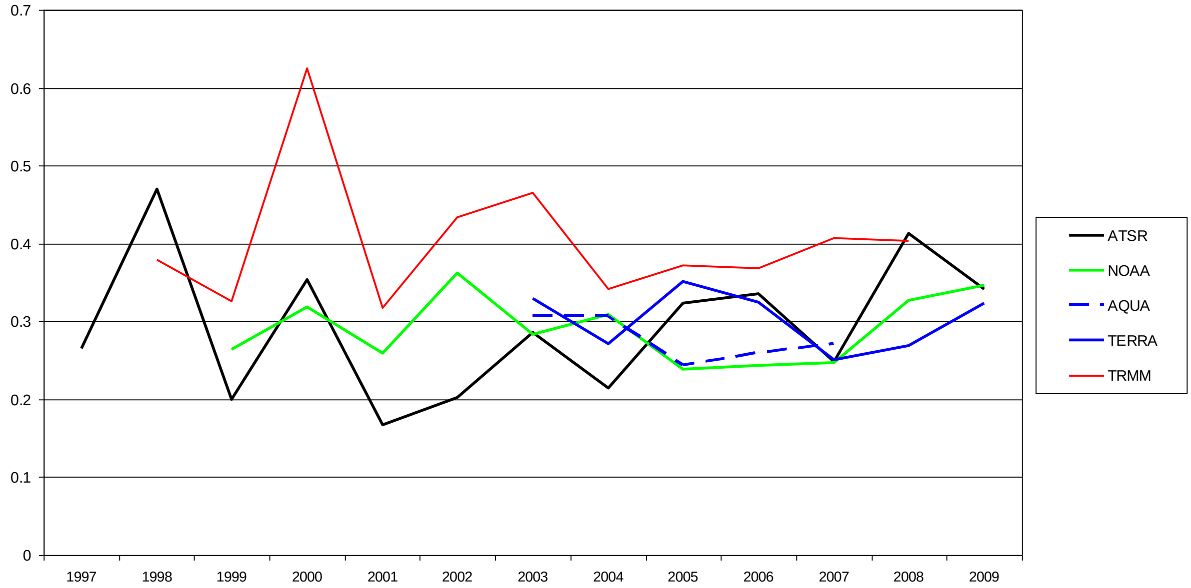


Figure 3.3.4: Inter-annual variability of fire hotspots in LPB between 2000 and 2006.

B: Fire regions in LPB: characterizing fire regimes

The fire patch Clustering led to the identification of six types of agro-ecological landscapes, characterized by different land-use and land cover associations (Table 3.3.1). We can discriminate the most forested areas (cluster 2, 1, and 3) compared to the most agricultural areas (6, 4), with and additional level of differentiation based on human pressure based on population density and distance to large urban centers. The spatial distribution of these clusters is presented in Figure 3.3.5.

Table 3.3.1: Average coordinates and standard deviation for each cluster

	nb de patch	Culture	Forest	Grassland	Population	Distance to cities
Cluster 1	150	18 ± 6	35 ± 10	41 ± 11	8 ± 5	15556 ± 10604
Cluster 2	173	2 ± 3	70 ± 8	26 ± 7	2 ± 3	26244 ± 18298
Cluster 3	270	5 ± 4	46 ± 8	45 ± 7	2 ± 2	22225 ± 13485
Cluster 4	83	29 ± 9	18 ± 11	49 ± 11	25 ± 7	9338 ± 5754
Cluster 5	254	7 ± 6	20 ± 8	70 ± 10	4 ± 3	28770 ± 21431
Cluster 6	214	31 ± 7	10 ± 6	55 ± 8	8 ± 5	15077 ± 10225

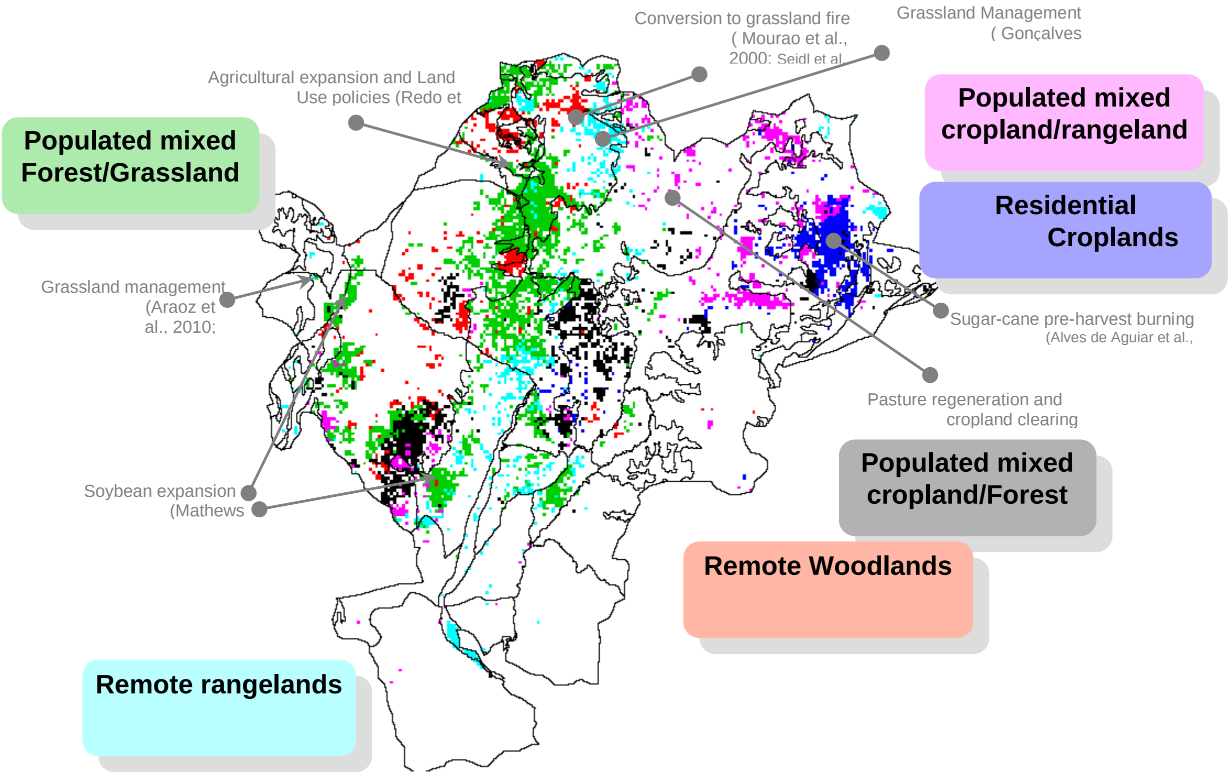


Figure 3.3.5: Spatial distribution of fire related cluster of vegetation and human pressure.

The fire occurrence and its seasonal distribution across the LPB for each cluster were assessed on the basis of the ATSR2 data (Figure 3.3.6). Majority of the fire activity of the LPB occurs during the months of August, September and October, representing more than 68% of the annual fire distribution. However we observe differences in the seasonal fire distribution in these different clusters. These differences were used as the basis for interpreting climatic and human drivers of fire regime and associated with a bibliographical review of fire practices in theses regions.

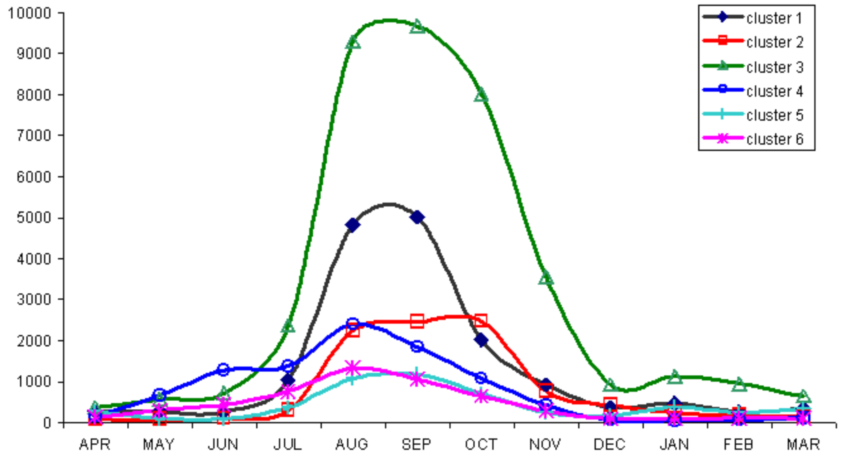


Figure 3.3.6: Monthly seasonal fire distribution for each regional land cover cluster from ATSR2 dataset.

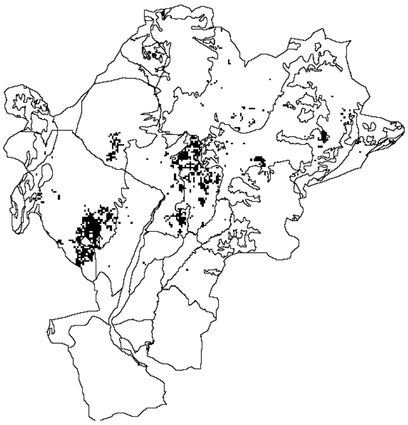
Cluster 3 is the most fire affected area in LPB. Its fire season is July to November, corresponding to the end of the dry season and the beginning of increasing temperature. This cluster actually covers a wide range of climate and natural vegetation types from Brazil to Argentina. It appears that September to November fires are more distributed in the Cerrado and Mata Atlantica forest, while the Pampa region is more burnt earlier in the season in August. Grasslands actually tend to get dryer much earlier in the season compared to deep-rooted ecosystems. Cluster 2, composed of remote woodlands follow the same fire seasonality, but with lower fire activity. Cluster 4 composed of sugar cane cultivation areas follows a much earlier and longer fire season starting in May and ending in September. This pattern clearly follows the cultivation cycle where sugar cane is burn before harvest for harvest facilitation and residues are burnt for soil preparation. Clusters 5 and 6 are affected by regional variations according to climate.

Conclusion on fire analysis: We could identify that LPB is composed of contrasted regions according to their climate, their land cover/land use and in turn fire regime. The fire occurrence and its seasonality give some answers on the hierarchy of climatic and human driving forces for fire regimes in LPB for predicting future fire regimes. This analysis was then confronted to a bibliographical review of fire practices in the region to accurately identify drivers and impacts for each of these contrasted regions. We then built six DPSIR based on this analysis to identify potential changes as a consequence of climate and socio economic changes in the region.

C: Identifying fire drivers in LPB

We proposed here to describe the fire drivers in each region of LPB, with the main pressures described in the bibliography with the aim to establish the DPSIR for each region.

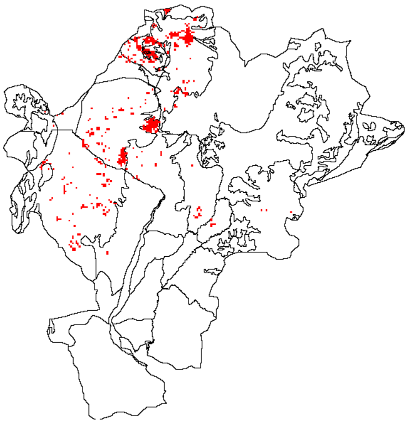
Cluster 1: Populated mixed cropland forest.



The fire patches classified as Cluster 1 are mainly in the South-East of Paraguay – atlantic forest region and eastern part of the dry Chaco - and in Argentina, in the transition from humid to dry Chaco (Chaco and Santiago del Estero Provinces), with a high fire occurrence. The highest fire detections in the Paraguayan Atlantic Forest are related to deforestation processes associated with the reduction of the tree cover observed from 73.4% in 1973, to 40.7% in 1989 and further down to 24.9% in 2000 (Huang et al., 2007, Catterson et al., 2004). Land cover change, and therefore fire use, are both driven by settlers and large private owner's strategies, stemming from widespread land disputes and preference for agricultural production over forest products (Huang et al., 2007). Similar land clearing affects the southern margin of the great chaco, were soybean expansion has lead to major changes in fire regimes, both by increasing it's uses for deforestation and reducing it's practice to control woody and herbaceous species within grassland management (Grau et al., 2008a, 2008b; Kunst et al., 2009). More than 1.2 million ha of Chaco forest would have been cleared over the past thirty years (Zak et al., 2004). As dense forest are less fire-prone because closed canopy induce moist microclimatic conditions in the understory, they are slashed, dried, and burned in the end of the dry season (Souchaud, 2002). Fires following forest felling are repeated for several years, in order to make land clearance as complete as possible. This could explain both the restricted fire season (mainly august and September, at the very end of the dry season) as well as the size of the fire patches (repeated fire uses leading to wide area of perturbation as whole landscape is progressively transformed by the process).

Drivers of the fire patterns identified as Cluster 1 are therefore expected to be drivers of agricultural expansion, from infrastructure and development projects, such as the Paraguayan Western Corridors (Catterson et al., 2004) to national biofuels market-creating initiatives (Mathews et Goldsztein, 2009). Increased **pressures** are created as fire uses expand, in a flammable landscape of grasslands and croplands, interspersed among fragmented forests. Both components of these populated open forest mosaics are highly vulnerable to fire. However, impacts of modified fire regimes seem to have been overlooked, as main concerns have been centered on biodiversity conservation and creation of protected areas. While the fire factor is left behind (no national program to control forest fires in Paraguay; little funding for fire management in Argentina) fire risks are likely to increase with densification of population and infrastructures.

Cluster 2: Remote Woodlands.



The regions classified as cluster 2, are located in the Paraguayan and Argentinean dry chaco (near the interface with the humid chaco and further West), in the Bolivian's lowlands (Santa Cruz Department) and across the Northern and Southern parts of the Pantanal. If the pressures are expected to be rather uniform among these patches – fire being set late in the dry season to maximize combustion of felled trees (leading to delayed fire season with greatest occurrence in October), drivers seem different across the region.

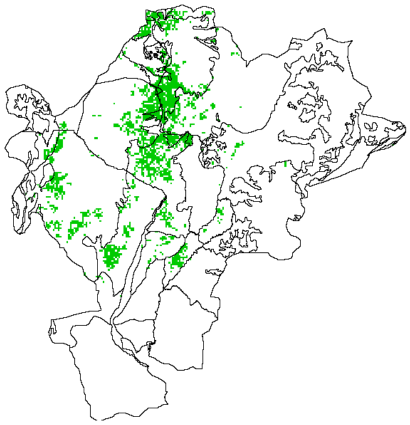
In Paraguay, although current soya plantations in the Alto Paraguay and the Wetlands bordering the Pantanal are limited, they are expected to increase strongly in the upcoming years (Dros, 2004). Drivers of the Paraguayan cluster 2 patches would therefore be similar to cluster 1, namely agricultural expansion drivers, but with peripheral settings modulating fire practices and their impacts.

In Bolivia, the lowlands have been experiencing high rates of forest clearance, up to 100 000 ha.year-1 in the late 1990s' (Steininger et al., 2001). According to Redo et al. (2011) a combination of neoliberal and post-neoliberal policies, especially land reform and burning regulations, are unintended driving forest losses.

In the Pantanal, Cluster 2 patches detected could correspond to deforestation for artificial pasture, as this land use is increasing in its eastern border (Seidl et al., 2000; M744m, 2009). As livestock breeding capacity of the Pantanal is constrained by the magnitude and duration of the annual floods, flood-free areas, naturally occupied by forests, are preferential areas for artificial pasture implantation and ranching intensification (Silva et al., 1999): climate changes could significantly modify these boundaries of flooded/non flooded areas. Also, land speculation and capture of governmental fiscal incentives rather than beef production would be the underlying drivers of fire uses (Fearnside, 2002).

Drivers of fire uses in the remote woodlands regions of Cluster 2 would therefore be the result of a multiplicity of policies: from pasture intensification to incentives for oil crop production in Argentina (Mathews and Goldsztein, 2009) including agricultural colonization in Bolivia as well as Plantations of *Pinus* and *Eucalyptus* in Misiones' Atlantic forests (Izquierdo et al., 2008). Policies further interacting with a diversity of local settings (land tenure, rural institutions, ecological constraints...) leading to unintended fire patterns and forest losses. All the more, as population and infrastructure densities are low in these regions, exposure and consequently fire risk are lower. Therefore fire uses are less likely to capture attention and trigger a specific consideration in the framing of land use policies, which could increase their unexpected feedbacks.

Cluster 3: Populated Mixed Forest and Grassland.



Cluster 3 is spanning a wide area across the LPB, from the North of the Pantanal to the Argentinean Humid Chaco (Santa Fe province), including the Southern cone mesopotamia Savannas (Corrientes), the Atlantic Forests of Misiones; as well as the Andean margins of the Dry Chaco (Salta and Jujuy provinces), and includes the largest amount of fires. According to the landscape structure in these regions, grasslands in a forested matrix, fire is expected to be used for pasture management, as well as eventual deforestation for agricultural/livestock expansion. Local case studies tend to confirm these fire practices:

- As noted for Pantanal regions classified in cluster 2, the Northern part of the Pantanal is subject to deforestation for pasture implantation as well as grassland management fires (Silva et al., 1999). Fires along the Bolivian border would be attributed to illegal acquisition of lands (Redo et al., 2011) and ranching activities;
- In the margins of the Dry Chaco, several processes would interact to shape the fire regime (Izquierdo and Grau, 2009). In the Andean highlands decreasing sheep grazing and increase precipitations, would favor accumulation of fuels and maintain fire activity (Carilla and Grau, 2009). In the low lands, at the interface between the Yungas and the Chaco, an expansion of mechanized agriculture would lead to fire uses for deforestation. The production being constrained by precipitation, would lead to increasing deforestation and fire uses with annual precipitation (Grau, 2005);

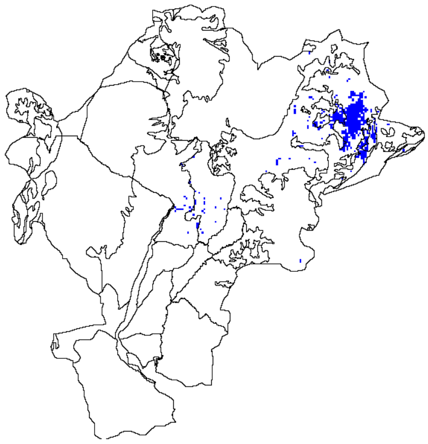
In the eastern border of the Dry Chaco, climatic, technological and socioeconomic factors, converge towards conversion of other land covers to cropland (Gasparri et al., 2008). Recent increase in annual rainfall has improved the agricultural potential of the region on the eastern plain and deforestation has been accelerated (Zak et al., 2004).

The process is sustained by the Biodiesel projects launched after the Argentinean Biofuels Law in 2006/2007 (Mathews and Goldsztein, 2009), and reinforced in these areas by the easy access to Argentina's major waterway, the Parana river;
- In Paraguay, grassland management and agricultural practices represent the main and widespread fire uses leading to identification of a large fire disturbed patch. Fires are ignited every one or two years to reinvigorate grass seed and diminish weedy growth not suitable for cattle grazing. Although fire has been recognized part of the natural disturbance regimes of many Paraguayan grasslands, the frequency and extent of burning have increased beyond natural occurrences. Limited understanding of fire uses' dynamics as hindered ability to propose management strategies and allocate means to diminish fire risks. As a result, 2007 witness a mega fire that destroyed nearly 2.5 million acres of pastures and other land covers, leading to a declaration of National Emergency and the displacement of thousands of inhabitants (FS, 2007).

In regards to previously described clusters, regions identified by cluster 3 seem to rely on fire uses more deeply rooted in the land use systems, mainly in the grassland management options. Grasslands are highly flammable ecosystems, extremely sensitive to climate. They can become water stressed and ignite after only few rainless days. These regions are therefore characterized by the association of highly flammable covers and sensible opened forests, in a landscape of widespread fire use. Therefore they are expected to be highly sensitive to climatic drivers: A drought period can turn an escaped fire into a non-selective herbivore spreading across uninterrupted fuel-loads. The vulnerability is all the more increased as the connectivity between these regions is high across the La Plata Basin.

Possible impacts of such event seem to have been taken into national fire policies (e.g. National Fire Management Plan in Argentina, 1996). However, technical means seem limited in regards to mega fires that could stem from these structural settings.

Cluster 4: rural sugar cane activity

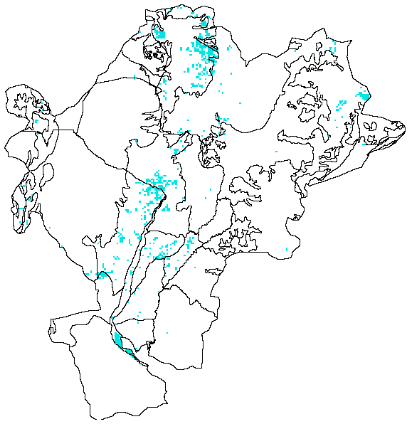


Cluster 4 is mainly distributed across Sao Paulo, the South of Minas Gerais and the North of Parana, in what appears has a continuous highly populated fire disturbed patch. High fire activity in this zone is attributed to sugarcane burning before harvesting, a practice used to facilitate the manual harvest and repel dangerous animals, such as spiders and snakes (Ripoli and Ripoli, 2009). The State of Sao Paulo accounts for 60% of the Brazilian production, of both Sugar and Ethanol, and in recent years, renewed interest in alternative energy sources has forced an expansion of biofuels, that increased from 2.57 million ha un 2003 to 4.45 million ha in 2008 (Rudorff et al., 2010). Cane is harvested continuously during the dry season, from May to October, which could explain the anticipated fire season observed for this cluster. However, fires observed in the region could also be caused by an interaction of anthropization and land management. Study of land uses around 81 cerrado remnants in the State of Sao Paulo, showed an interaction between invasive grasses and pastures near roads and urban centers, that would increase their exposure to fire (Durigan et al., 2007).

The harvesting method of burning sugarcane has produced negative impacts, in terms of risks to infrastructures (railways, highways, forest reserves...), respiratory diseases, and pollution (Arbex et al., 2000; Uriarte et al., 2009). As a result, the harvesting burning practices are being phased out. In 2002, the governor of the state of Sao Paulo set a timetable for progressive elimination of manual harvesting in the state up to 2031. In 2007, the Sao Paulo Secretariat for the Environment and UNICA (Brazilian Sugarcane Industry Association) signed an environmental agreement to anticipate the timetable for sugarcane burning phase-out. In the State of Minas Gerais, the Secretariat for the Environment is preparing similar legislation. Therefore, alternative strategies to burning are likely to diminish the ignition pressure on these land use systems. However, the drivers of the sugar-cane related fire practices go beyond the harvesting technique. With the planned expansion of the sugar-cane sector and the creation of an international biofuel market, areas allocated to sugar-cane are expected to increase in the incoming years. These new areas are subject to a zoning (Zoneamento Agroecologico de Cana-de-Açucar, 2009) that intends to limit the negative effects, especially by limiting direct deforestation and favouring reconversion of land previously used as pasture and croplands. Therefore fire uses related to cropland expansion should be limited. However it might trigger indirect land use changes, leading to displaced fire as the previous land uses move into forested land covers (FOEE, 2010).

Sugarcane regions spanned by Cluster 4 seem to have completed an entire DPSIR: from increased fire uses in the sugarcane production system, driven by productivity needs (Ripoli and Ripoli, 2009), to negative impacts on human health and the environment; leading to fire policies phasing out burning and to the adaptation of agricultural practices. Over the long term, fire activity is expected to locally decline. However, on the medium term cropland expansion might lead to peripheral fire activity in the state of Parana, Mians Gerais and Mato Grosso do Sul. Fire uses may also be delocalized, as a result of the displacement of previous land uses. The maintenance, increase or decrease of this production system will be related to climate stability/instability that has to be studied more closely in terms of sugar cane yield, maturation quality, and sprouting.

Cluster 5: Remote Rangelands.



Cluster 5 covers a great diversity of grasslands and wetlands, from the borders of the Pantanal, to the plains of the Parana River in Paraguay and Argentina, and the North of the Pampas. Cluster's specificity of high pasture density (70% on average) combined with an important fire activity, clearly stated for drivers related to grassland management fire practices.

In the Pantanal, cattle ranchers make use of controlled burning annually for cleaning and renewal of native pasture, usually in the open grassland area. However, overgrazing and overuse of fire can lead to a substantial loss of forage quality, and increased fire uses to promote re-growth. This feedback loop eventually triggers the formation of extensive areas of "macegas" that constitute a great amount of fibrous and highly inflammable fuel biomass, sensitive to climatic conditions (Onigemo et al., 2007). Therefore human practices, vegetation dynamics and climate strongly interact in shaping the fire regime of the Pantanal's grazed grasslands. Understanding of these retroactions seems yet limited, for example, the introduction of burning permits reduced fire use and increased fuel loads, contributing to widespread fire events in 2001 (Rodrigues and Rodrigues, 2002). As the Pantanal is at 95% under private property and at 80% composed of cattle ranches (Seidl et al., 2001), ranchers and their drivers (be it land speculation, cattle production or resource preservation...) will probably be shaping the future fire regime of the Pantanal.

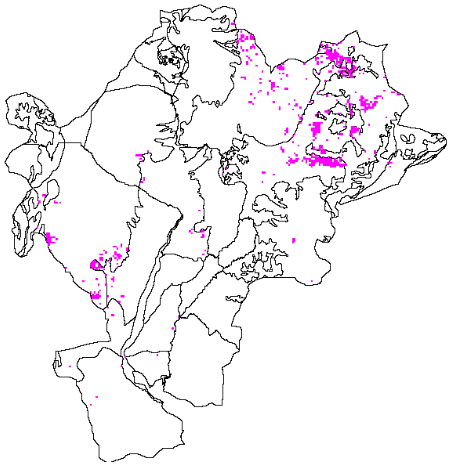
In the Cerrado fire is commonly used to promote pasture re-growth and eliminate undesirable species during the dry season, and clear land for cultivation in the wet season (Wilcox, 1993; Mistry, 1998). In the Southern grasslands, such as in Empedrado (South of Corrientes), grasslands would be burned when not grazed to diminish fuel accumulation to prevent large fires hard to control and hazardous for human habitats and infrastructures (Kurtz et al., 2010). In the Chaco's grassland, fire is used to promote new grass growth and prevent grassland's encroachment.

This wide geographical spanning as well as diversity of pasture managements could explain diversity of fire seasonality across this cluster. Regions to the South (Chaco and Pampa) with a somewhat temperate climate would experience early fire events in March and April at the end of the dry season as humidity is low and fuel highly flammable. In the Northern wetlands with more of a tropical climate, fire season would not start before August because of the hydrology of the Pantanal, 80% of the 1000-1400 mm yearly rainfall occurring from November to March (Hamilton, 2002). Floods would limit the flammability of vegetation and the fire activity during these months.

Fire affected grasslands of the La Plata Basin are shaped by a diversity of pasture management practices. Drivers of fire use are likely to be expressed through pressures on ranching activity. Negative impacts on ecological processes have been highlighted (Wilcox; 1993), but understanding of the institutional setting and of the feasibility of alternatives to burning appear essential to escape the downward fire spiral. For example, Mistry (1998) identifies two main factors leading farmers to the fire option in the Cerrado: time and income constraint as well as lack of other feasible options. The costs, both financial and time wise from setting a fence around a planted grass area to provide cattle feed, and from clearing fields manually or using a tractor, reduced choice to the option of burning. Without explicit targetting of these constraints, policies such as burning permits are deemed to unexpected results.

Interactions between climatic drivers, human activities and ecosystems processes also appear particularly important in shaping the fire regimes of these grasslands at different scales. For example, small variations in precipitation distribution can modify fire seasonality (Macédo et al., 2009) and fire induced land cover changes could shift water recharge and discharge of these grasslands (Jackson et al., 2009).

Cluster 6: Populated Mixed Cropland Rangeland.



Cluster 6 is located in the Cerrado and in the Brazilian Atlantic Forests, around the areas of sugarcane production; as well as in the Argentinean Dry Chaco, near the soybean expansion zones. As the cluster 6 regions are characterized by landscapes of mixed grasslands, croplands and forests, at the interface with agricultural intensification areas, their fire activity could be the result of peripheral land use changes induced by the core intensifying areas.

As sugarcane production increases in Sao Paulo, agricultural and livestock production could be displaced to the states of Goias, Mato Grosso do Sul and Mato Grosso (FOEE, 2010). Sugarcane areas also increase in the neighbouring states of Sao Paulo. For example in Parana, area in sugarcane increased over 75% between 2005 and 2009 (da Silva et al., 2010). Therefore the fire activity of these regions would be indirectly driven by the drivers of the “core regions” combined to local factors.

Though driven by different processes, these regions could be characterized by similar fire practices such as clearing of remnants for mechanized agriculture, field cleaning before sowing, or intensification of livestock grazing. Policy responses to the impacts induced by increased fire uses do not seem of have been subject of major attention yet. But they may stem quickly from adaptation of fire policies adopted nearby.

3.3.4 The DPSIR Framework for fire risk in LPB

Our analysis of fire regime in LPB from global remote sensing products could illustrate the high variability in both fire occurrence and seasonality, due to different climate conditions and related drought period, but also different fire practices and human pressure in the region. Fire is often said to be deeply rooted in the culture, society and traditions of most countries of South America. However our analysis pictured the fire embedded in agro-industrial landscapes and processes, responding to modern drivers rather than traditional uses. We propose here a synthesis of our analysis in six DPSIR related to the six regions identified as homogeneous according to their land cover types and human pressure.

Multiple scale embedded factors appear to drive fire regimes across the La Plata Basin, from international commodity prices to national policies or regional historical settings, such as struggles for land in Paraguay or colonization processes in Bolivia. Fire appears to be largely un-thought, i.e. fire activity was neither explicitly dealt with, nor problematized in a broad framework. If considered, the “fire problem” is often narrowly defined as a threat to forest conservation, with potentially global repercussions for the global climate system (Sorrensen, 2009). As such, it’s the outcome of a local land use practice, and policies should aim at limiting and controlling individual fire uses. This leads to politics of access regulation (e.g. permits to burn), creation of conservation units, fire fighting forces, education (e.g. Training)... yet this can be disconnected from the reasons for fire use practices such as historical inconsistencies of land policy over time that produced rural institutions limiting possibility to find alternative practices.

	Cluster 1 population mixed cropland forest	Cluster 2 Remote woodland	Cluster 3 Populated mixed forest and grassland	Cluster 4: sugar cane	Cluster 5 Remote rangeland	Cluster 6: populated mixed cropland rangeland
D	Agricultural policies. Market prices Land Use conflicts	-Mixed of inter-twinned policies -Climate	-Biodiesel policies -climate grassland -land management	Biofuel prices Environmental Laws	-Climate -Cattle density	Local settings and drivers from core regions of intensification
P	LU intensification, Land clearing	-Slash and burn deforestation in low populated areas -Drought and extreme fire risks years	- Grassland fires - forest clearing - Highly flammable fuel biomass	Mechanization possibility	-Grassland management -Fuel amount and dryness	Diversity of uses, land clearing, field cleaning...
S	Populated mixed cropland forest with soybean expansion and managed pastures	-Remote woodlands affected by soybean projects and deforestation for pasture -natural fire regime mainly driven by drought	Populated mixed Forest Grassland with fire events linked to cropland expansion, pasture management -burnt area limited by biomass amount and length of the drought period.	Sugar cane burnings for pre harvesting and post harvest land clearing	-fires for pasture management and expansion in remote rangelands	Pasture management and cropland expansion, mainly in the Cerrado, the Dry Chaco and the Atlantic Forests.
I	Deforestation Changes in regional Water and carbon cycle	-Rapid loss of forest covers in unintended patterns - regional carbon and water cycle	-Mega uncontrolled fires - infrastructure loss - livestock mortality - smoke and particle emissions in atmosphere	-Health respiratory diseases in surrounding megacities - smoke and particle emissions in atmosphere. - potential spread out in to conservation units	-Possibility of soil degradation, nutriments depletion, and erosion. - threat to infrastructures	- vegetation reset to early successional stages - regional water and carbon cycle -smoke and particles in atmosphere
R	No response yet: fire control policies to be developed.	-Other land use policies - fire fighting policies	Limited political responses to structural vulnerability	Timetable to phase out sugar cane burning	Controlled burning	-laws on quotas for burning and expanding crops

As a conclusion, it appears that there are no simple causal loop leading to fire use and fire risk. Rather, there are embedded policies and political discourses at different scales triggering fire uses, shaping fire patterns and trying to curb the “access” to fire. For example, in Mato Grosso do Sul, Brazil, fire has been considered as a tool for grassland management, a natural disturbance, essential to the maintenance of the ecosystem as well as its native cattle ranching activities (Rodrigues and Rodrigues, 2002). Historical grounds of ranching in Mato Grosso (Wilcox, 1993), as well as political power of cattle ranchers, are likely to shape this vision of fire as a natural disturbance, in order to maintain a practice central to low cost extensive grazing. In the Sate of Sao Paulo, heavy use of fire for pre-harvest burning of sugarcane has led to environmental laws to progressively phase out the burning to 2031. Unsatisfied by this far away deadline, municipalities have ceized the sugarcane sector and the state to diminish the deadline against what is pictured as an harmful practice to health, nature and future generations. Firms already ready for mechanized harvests are pressuring the sector for reducing the terms, thereby demonstrating their sustainable visions of bio-ethanol markets, and eventually putting stress on the less adaptable concurrent producers. In Minas Gerais, were plantations of Pinus and Eucalyptus have been repulping the landscape for over three decades, forest engineers have been charged of fire management, as elsewhere, their identity is sustained by their success in keeping trees alive. Therefore they tend to drive fire policies towards protection of Conservation Units were it is to be excluded. They double it by training of firefighters and investment in equipment as well as burning permits to control the uses, a brilliant demonstration of their devotion to fire fighting.

Such diversified views on fire in just three neighboring states are likely to shape fire regimes in different ways in the forthcoming years, though the exact consequences remain poorly predictable. This inter-twinning of global drivers that can be common across the LPB with more local settings make more difficult the construction of a simple and/or general model to assess present and future fire risks on the basis of climate, land use, and ignitions. Simply because most human decisions related to ignition involve non-necessary and non-sufficient causal relations that are poorly captured by causal loops that can, on the other side, describe efficiently physical relations such as combustion or evaporation. What does this mean? That our study can provide an image of fire patterns but will perform poor for future, except a conservative scenario, that is no more probable than any other alternative that could be imagined. However, it is a first step to understand the present fire use systems, and maybe to understand their link to climate drivers and other issues as changes in livestock or crop cultivation strategies.

3.4 Pastures

3.4.1 Background – Recent Land Use Changes in Uruguay

Before introducing the DPSIR framework used for the analysis of pasture based systems in Uruguay, a general overview of recent changes in land use and land tenure in the country is required. Such changes are key to the understanding of the global and national context within which the pasture based cattle production systems have recently evolved.

Cattle breeding has long been the dominant activity in the Uruguayan extensive pastures, mainly for the production of beef. However, several other productions systems (dairy farms, agriculture, and forestry) have greatly developed during the past two decades exerting a competition for the land, especially for the most fertile soils. During the 1990s, agriculture (mainly rice since area of other crops actual decreased during that decade) and forestry -which received tax incentives from the government- gained approximately 10% of the area to livestock production (Figure 3.4.1).

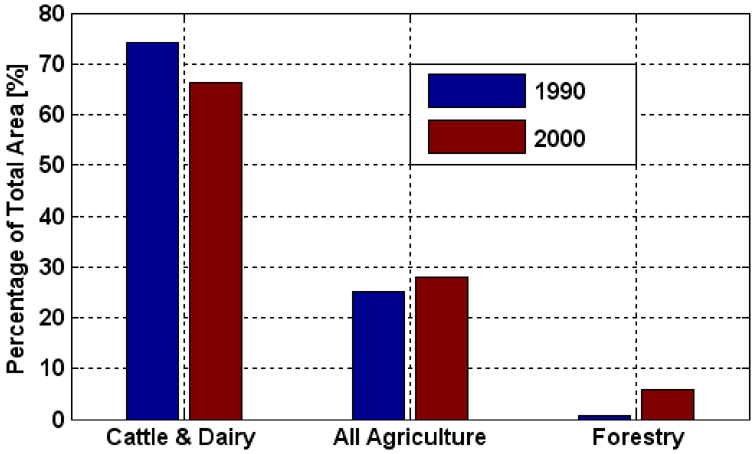


Figure 3.4.1: Evolution of area coverage of different productions systems in Uruguay from 1990 to 2000.
From DIEA: Department of Agriculture Statistics, Secretary of Agriculture, http://www.mgap.gub.uy/

This tendency greatly accelerated during the first decade of the XXI century. The agriculture area expanded five-fold, pushing the agriculture frontier to levels not known since the peek during the mid XX century (Figure 3.4.2).

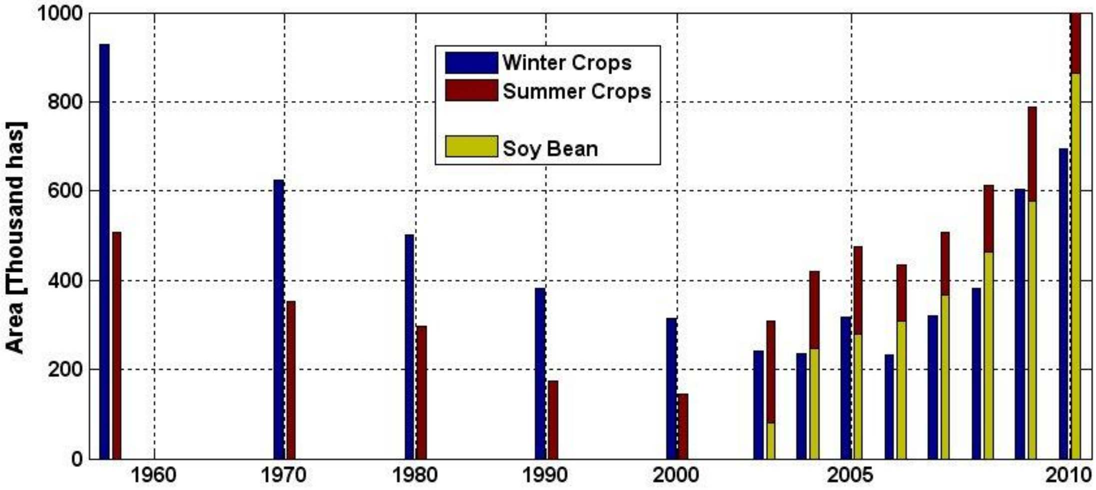


Figure 3.4.2: Evolution of area coverage of winter and summer crops (excluding rice) in Uruguay, in particular soy bean.
From DIEA: Department of Agriculture Statistics, Secretary of Agriculture, http://www.mgap.gub.uy/

However, important differences should be point out: the recent advance of agriculture was driven by summer crops –mainly soy bean- as opposed to winter crops (predominantly wheat). Also, no tillage practices are currently generalized with almost any exception, in contrast with the dominant traditional practices of the past. In addition, the intensification coefficient, measured as the summer crops plus winter crops area divided by the total area, has evolved from 1.1 in 2000 to 1.5 in 2010.

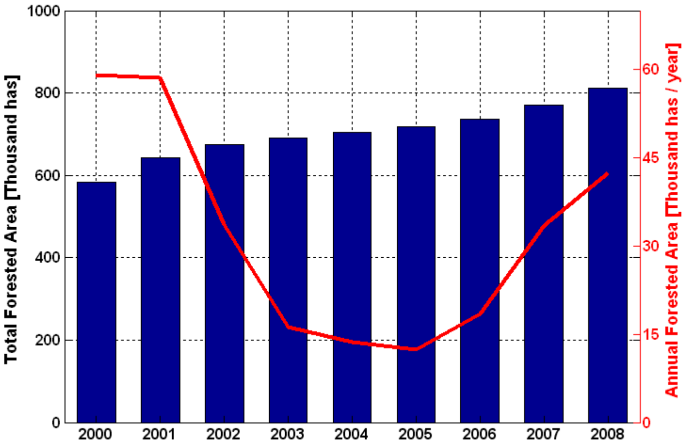


Figure 3.4.3: Growth of forested area in Uruguay during the past decade.
From DIEA: Department of Agriculture Statistics, Secretary of Agriculture, http://www.mgap.gub.uy/

Forestation maintained, with some oscillations, the pace of development that carried from the 1990s (Figure 3.4.3). During the last decade, the area increased by approximately 50%, again mainly at the expense of pastures previously dedicated to livestock production.

The reduction in land area dedicated to cattle production, however, has not resulted in a decrease in the activity of the sector, as shown in Figure 3.4.4. On the contrary, the number of cattle heads slaughtered in the last 5 years is approximately 27% higher than the five year period ending before 2001, when a financial crisis and an outburst of foot and mouth disease severely affected the sector and the economy of Uruguay as a whole (other interannual variations in the stock and slaughter evolution are generally caused by climate). Moreover, the increase in production is significantly higher that the increase in stock, indicating a reduction in the mean age at slaughter; still another sign of the intensification of the system.

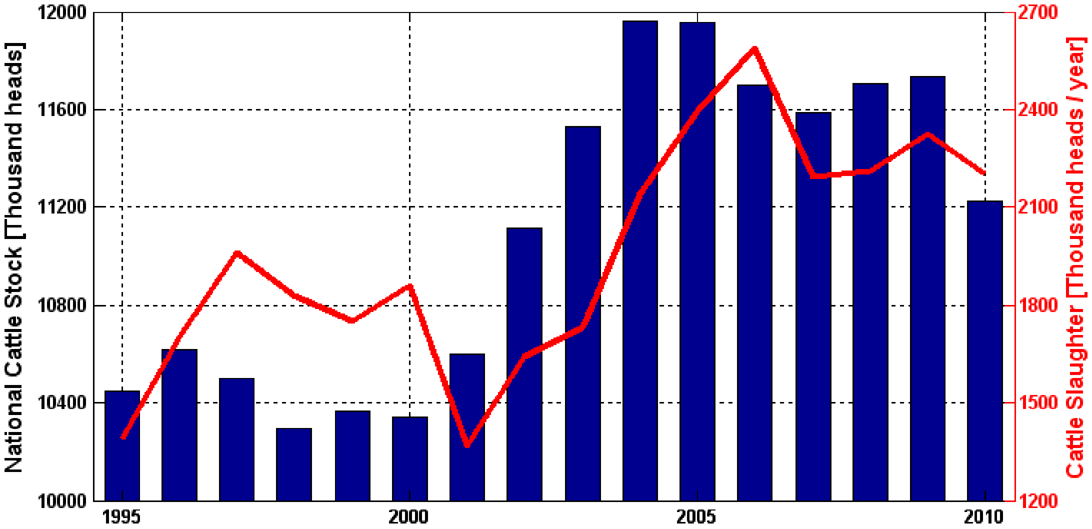


Figure 3.4.4: National cattle stock and slaughter evolution in Uruguay during the past 25 years.
From INAC: National Beef Institute, http://www.inac.gub.uy/

Such intensification is only possible with large investments in the production process which, in turn, has been made viable by the spectacular increase of the price of beef (Figure 3.4.5) in the international markets, following the tendency of other commodities.

Figure 3.4.5: Evolution of the price of beef in Uruguay during the past decade.
From INAC: National Beef Institute http://www.inac.gub.uy/

These major changes in the production systems and the market value of the produce have inevitably generated an enormous upward pressure on land price, triggering a spectacular four-fold increase in the price of land in half a decade (Figure 3.5.6).

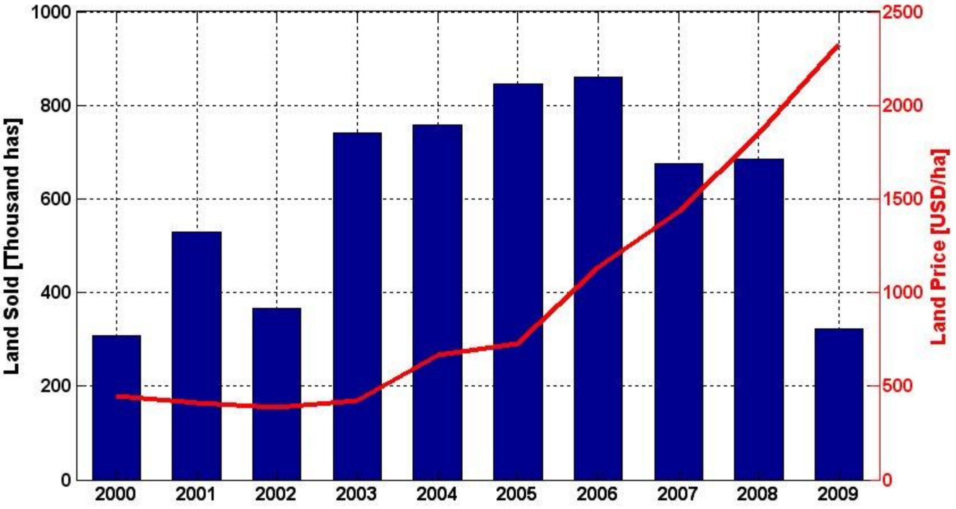


Figure 3.5.6: Area of land that changed tenure (with repetitions) and land price in Uruguay in the past decade.
From DIEA: Department of Agriculture Statistics, Secretary of Agriculture, http://www.mgap.gub.uy/

Associated with the changes in value and in production systems, there was an unprecedented change in land tenure. Figure 3.4.6 shows the area of land that switched hands (counting repeats of the same plots) per year during the last decade, while Figure 3.4.7 shows the percentage of area in each state that was sold (again, counting repeats) during the entire period. The national average in the same period (2000-2009) is approximately 34%, which evidently reflects a major socio-economic shift which is beyond the scope of this analysis.

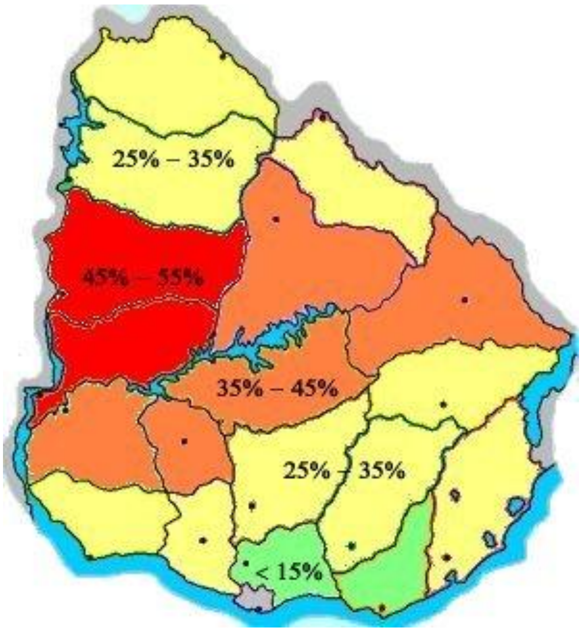


Figure 3.4.7: Percentage of the area that changed tenure (with repetitions) in Uruguay during the period 2000-2009.
From DIEA: Department of Agriculture Statistics, Secretary of Agriculture, http://www.mgap.gub.uy/

3.4.2 DPSIR Framework

The DPSIR Framework adopted to analyze the pastured based systems in Uruguay is presented in Figure 3.4.8.

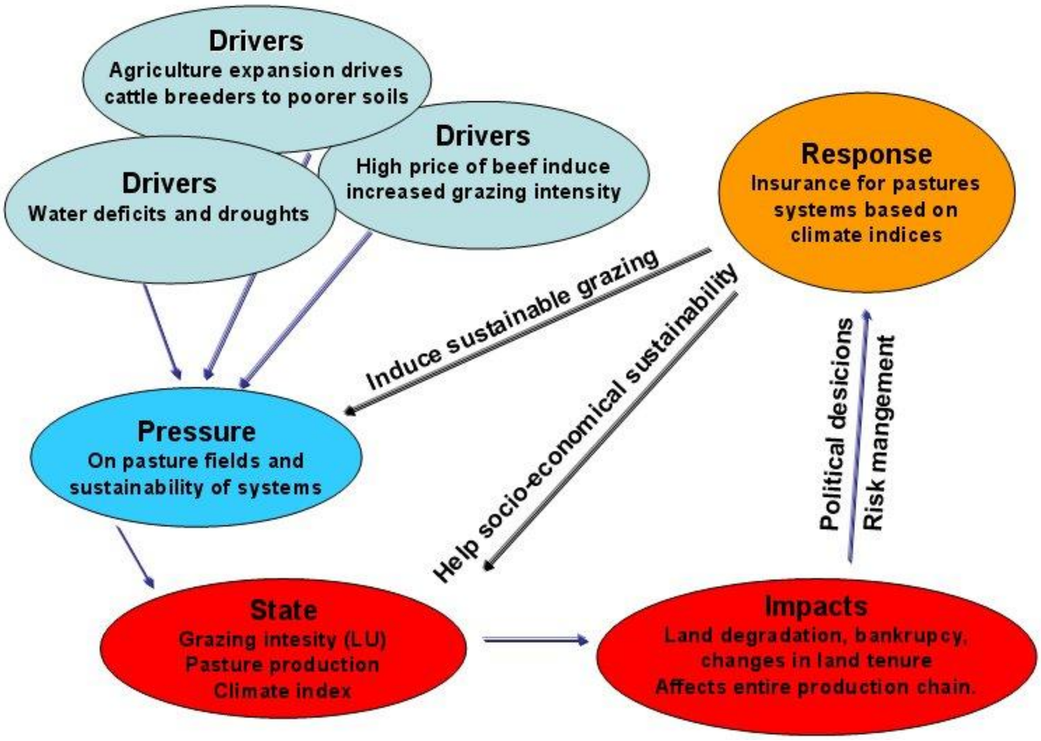


Figure 3.4.8: DPSIR framework for the analysis of pastured based systems in Uruguay

<u>Drivers:</u>

Major recent land use and tenure changes were described in the background section. Several drivers are already evident in that analysis which can be traced back, in one way or another, to the increase in commodity prices. On the one hand this tendency drives the expansion of agriculture and forestry that, in turn, relegates the cattle breeding sector to poorer and shallower soils in a reduced area, thus increasing its vulnerability to climate variations. On the other hand, the rise in the price of beef induces farmers to increase the grazing intensity, further pressuring the pasture based systems. These drivers stress the system increasing its vulnerability to climate risk. It is on this background that the climate change driver should be considered. Of particular importance is the climate risk associated to water deficits and droughts. One of the most vulnerable regions in Uruguay is the northwest, with the highest temperatures on the shallow basalt soils. The Figure 3.4.9 shows the variability of precipitation in the peak of the growing season for pastures during late spring to early summer at Salto. The very large inter-annual variability during the last decade is evident and has been the cause of multiple forage crises, some of which were severe and had major socio-economic impacts. In summary, the economic and climate drivers act in a synergistic way, the former increasing the vulnerability of the system to the risk associated with the latter.

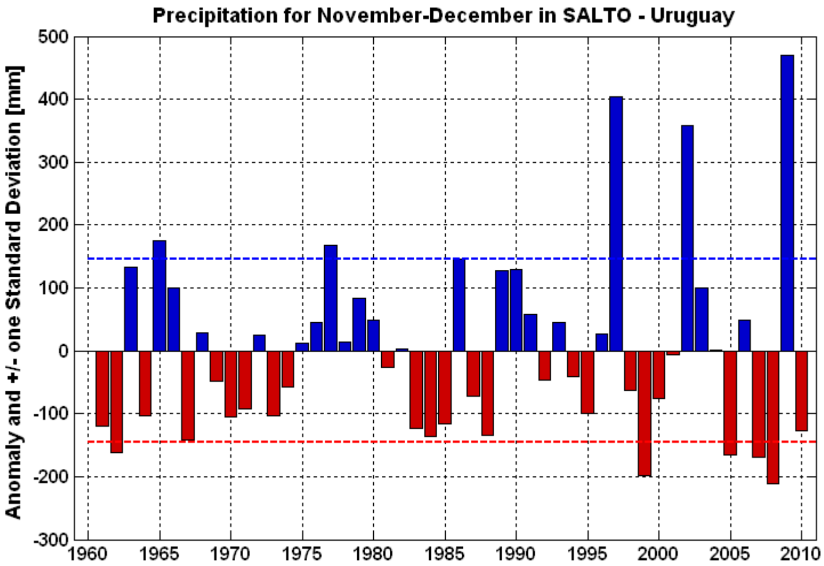


Figure 3.4.9: Anomaly of November-December accumulated precipitation in Salto with respect to the mean (bars). Plus and minus one standard deviation is indicated in dashed lines.

Pressure:

The drivers described above exert pressure on the pasture system inducing an increase in the grazing intensity beyond sustainable levels, making it more vulnerable to climatic risk. Sustainability should be considered not only regarding the physical basis (land degradation) but also in a socio-economic point of view. The increase in the price of commodities and land, and associated intensification of the production systems, are pressuring and even compromising the sustainability of the small scale cattle farmers that are becoming more vulnerable to climate variations which, in turn, are expected to become more intense in the future.

State:

Of the many variables germane to the description of the pasture based systems and identification of its state, we are most interested in those related to the vulnerability to climate risks, in particular droughts. Three key elements are considered: (i) grazing intensity measured in Livestock Units gives a succinct view of the stress imposed on (ii) the physical production of the pastures measured in kilograms of dry matter per hectare which, in turn, depends on genetic and edaphic resources and (iii) climate which will be measured by a climate index to be defined so that it best captures the climatic events to which the system is most vulnerable. A critical recent development in Uruguay consists of the real time availability by the government of the cattle grazing intensity (measured in livestock units) at each individual farm. This is a by-product of the beef cattle traceability system that is mandatory since 2007. This allows the design of policies (i.e. insurance) that could eventually depend of grazing intensity at the level of each production unit. This helps overcome a major obstacle in the implementation of insurance for pasture based systems, namely the monitoring of grazing practices.

Impact:

Besides the environmental degradation of an overgrazed pasture and the evident socioeconomic impact (bankruptcy, changes in land tenure), there’s a recent recognition that the country’s cattle breeding sector may have trouble keeping up with the feeding and finishing sectors, in particular the growth of the feedlot industry, which has flourished in conjunction with the agriculture expansion. Uruguay is in the midst of a fast changing rearrangement of its agriculture activities and in particular the beef sector. However, the entire production chain is based on the breeding sub-sector that provides the calves every year, precisely the sub sector that most depends on natural pasture production. Therefore, the vulnerability of the breeding sector affects the entire production chain as can be recognized in the annual national slaughter figures where main droughts can be easily identified.

Response:

As it was clearly established in the introduction, the agriculture sector in Uruguay is rapidly adjusting to the fast changing global drivers. Both the private and public sector are struggling to find responses to groundbreaking shifts in prices and land tenure. One common element to any sensible response is the need to better manage climate risk in the intensified environment resulting from the pressure exerted by the economic drivers. In this context, the Office for Planning and Policy (OPyPA) from the Secretary of Agriculture, Livestock and Fisheries is working on the development of an insurance product for pasture systems, in particular to analyze the possibility of a climate index insurance. We will thus focus on the generation of the information required to the design of such a product, evaluating climate risk based on simulated pasture production for different grazing intensities. The information generated should also be useful for the development of other risk management strategies which are inevitable in a system dependent on natural resources so exposed to climate variability.

4. DISCUSSION

Originally, the DPSIR framework has been set up to be used in environmental management, due its power as a “conceptual model for promoting dialogue between different disciplines that must work together” (Holman et al., 2008) to deal with complex ‘wicked situations’. This is also one of the reasons why the DPSIR framework has been adapted to CLARIS LPB conditions, a project where scientists from different disciplines and backgrounds come together to analyze impacts on ecosystems and society and to develop climate change adaptation strategies.

To avoid the emergence of large differences among the project partners in their understandings, the DPSIR of WP8 presented in Figure 2.2.2 was defined in a participative way as a joint framework of analysis. The DPSIR study cases described here (land use, agro-systems and rural development, fire risk, and pastures) resulted therefore from the process of generating a common understanding, taking into account, at the same time, the differences and specific characteristics reflecting the local contexts, backgrounds and capacities of WP8 partners.

Therefore, the results presented in this deliverable can be discussed from two different but complementary perspectives: from the perspective of the *adoption* of DPSIR as a tool to structure a causal understanding of processes (climate change scenarios and induced anthropogenic reactions) taking place within the LPB, and from the perspective of the *results* achieved with the adoption of the DPSIR framework in the specific case studies, concerning the dynamics of agricultural land use and tenure, the adoption of adaptation strategies, fire risks within LPB, pastures, etc., and their importance for further work on vulnerability and the design of adaptation strategies to climate change.

4.1 DPSIR as a tool

As described on section 2.2 and considering the size of LPB, the available resources and capacities, and following the discussions on DPSIR in Curitiba (WP8-WP9 M1 meeting), Rome (M18 meeting) and Florianópolis (M26 meeting), it was decided to set up DPSIR case studies covering different but interrelated research subjects carried out by different WP8 partners.

As already discussed on section 2.1, DPSIR is cited in the Fourth Assessment Report of the IPCC (AR4) as a research method for impact assessment. Beyond this reason, the adoption of a common framework to harmonize problem-oriented analyses was a major aim within WP8. However, as can be read in sections 3.1 to 3.4, its adoption was not restricted solely to the impacts of climate change on land use, but also of other sensitive drivers as price relations and population growth. The DPSIR framework was easily contextualized to the different specific situations analyzed in this deliverable, attending to the claim made by Ison (2010) (for further details see please section 2.1).

Although being organized as a logical chain, some problems in terms of adopting the DPSIR framework have been identified. One of the main difficulties associated with the adoption of DPSIR as a framework for impact assessment and the identification of causal relationships is the different interpretations of each DPSIR component. This occasionally caused not only a disagreement among researchers, but also made difficult for some researchers to understand the point of view of other colleagues. Similar difficulties have been reported by Holman et al. (2008), in particular the need to resolve the differences of interpretations and to develop a consensus. Despite the joint participative process carried out at WP8-WP9 M1 meeting in Curitiba, which was an important step to overcome some of the difficulties, a few differences in understanding still persisted, especially detailed interpretation of issues and its classification into the DPSIR categories as well as the definition of system boundaries, what might be controversial.

4.2 Comparative analysis of the DPSIR case studies

All DPSIR case studies presented in this deliverable were based on Figure 2.2.2 and are summarized on Table 4.1. Although all DPSIRs are related with agricultural land use or agricultural problem-situations, a direct comparison among the DPSIR case studies and its single elements is not possible, because the individual DPSIRs presented in Figures 3.1.1, 3.1.21, 3.2.1 and 3.4.8 were developed by different WP8 partners working under different contexts. This also applies for the DPSIR of “fire risks” although a figure is not presented. Nevertheless, under the influence of similar drivers, these DPSIR case studies allowed the identification of some common trends in the dynamics of land use for different regions within LPB, which will be discussed here. On Table 4.2 is presented the summary of the major characteristics of each DPSIR case study.

Changes in land use in some regions within LPB were observed due the pressures exerted by climate. In Anchieta, Brazil, small farmers were pushed to adopt landrace seeds as a strategy to keep agricultural production in water shortage conditions. In Argentinean sites, the below-average rainfalls and the periods with abundant rainfalls followed soon after by periods of intensive droughts were responsible for the observed changes in agricultural production systems. The case study about fire risk pointed that the variability and seasonality of fires have been related to climate and drought periods, since the dry grasslands are more vulnerable to be burnt.

Table 4.1: Overview of the DPSIR elements of the case studies for CLARIS LPB

DPSIR elements	Case study "land use"		Case study "agro-systems and rural development"	Case study "fire risk"	Case study "pasture"
	Brazilian LPB	Anchieta		Cluster 1: populated mixed cropland forests Cluster 2: remote woodlands Cluster 3: populated mixed forest and grassland Cluster 4: rural sugarcane activity Cluster 5: remote rangelands Cluster 6: populated mixed cropland rangeland	
D	Population growth, demand for agricultural products	Drought	Climate change, price relationships	Cluster 1: agricultural policies, market prices, land use conflicts Cluster 2: mixed of inter-twinned policies, climate Cluster 3: biodiesel policies, climate grassland, land management Cluster 4: biofuel prices, environmental Laws Cluster 5: climate, cattle density Cluster 6: local settings and drivers from core regions of intensification	Agricultural expansion drivers cattle breeders to poorer soils, water deficits and droughts, high price of beef induce increased grazing intensity
P	Land use	Territory/agrosystems of Anchieta	On production systems, on the local agrarian system	Cluster 1: land use intensification, land clearing Cluster 2: slash and burn deforestation in low populated areas, droughts and extreme fire risk years Cluster 3: grassland fires, forest clearing, highly flammable fuel biomass Cluster 4: mechanization possibility Cluster 5: grassland management, fuel amount and dryness Cluster 6: diversity of uses, land clearing, field clearing	On pasture fields and sustainability of systems
S	Land cover change	Social context and vulnerability of agricultural family farms	Characterization of the systems, use/tenancy of farmland, dynamics of the territory	Cluster 1: populated mixed cropland forest with soybean expansion and managed pastures Cluster 2: remote woodlands affected by soybean projects and deforestation for pastures, natural fire regime mainly driven by drought Cluster 3: populated mixed forest grassland with fire events linked to cropland expansion, pasture management, burnt area limited by biomass amount and length of the drought period. Cluster 4: Sugar cane burnings for pre harvesting and post harvest land clearing Cluster 5: fires for pasture management and expansion in remote rangelands Cluster 6: Pasture management and cropland expansion, mainly in the Cerrado, the Dry Chaco and the Atlantic Forests	Grazing intensity (LU), pasture production, climate index
I	Land use change	Decrease in food security, poverty and	Impact on main crop yields in the Pampa	Cluster 1: deforestation, changes in regional water and carbon cycle Cluster 2: rapid loss of forest covers in unintended patterns, regional carbon and water	Land degradation, bankruptcy, changes in land tenure affects

		decrease of agricultural production	conditions	cycle Cluster 3: mega uncontrolled fires, infrastructure loss, livestock mortality, smoke and particle emissions in atmosphere Cluster 4: health respiratory diseases in surrounding megacities, smoke and particle emissions in atmosphere, potential spread out in to conservation units Cluster 5: possibility of soil degradation, nutriments depletion, and erosion, threat to infrastructures Cluster 6: vegetation reset to early successional stages regional water and carbon cycle, smoke and particles in atmosphere	entire production chain
R	Environmental laws enforcement, agroecological zoning	Local crop breeding	Insurance/weather derivatives development, loans to alleviate specific impacts, incentives for soil conservation practices and specific productions, individual informal actor’s response to mitigate impacts	Cluster 1: no response yet: fire control policies to be developed Cluster 2: other land use policies, fire fighting policies Cluster 3: limited political responses to structural vulnerability Cluster 4: timetable to phase out sugar cane burning Cluster 5: laws on quotas for burning and expanding crops	Insure for pastures systems based on climate indices

Table 4.2: Synthesis of the major characteristic of the DPSIR case studies for CLARIS LPB

	Case study “land use”		Case study “agro-systems and rural development”	Case study “fire risk”	Case study “pasture”
	Brazilian LPB	Anchieta			
Stakeholder group	Large scale/small scale farmers	Small scale farmers; decision makers	Large scale/small scale farmers	Energy Company of Minas Gerais State; Fire Prevention Group on Forestry Institute of Minas Gerais; Association of Municipalities of Furnas Lake	Office for Planning and Policy from the Secretary of Agriculture, Livestock and Fisheries
Issue (“problem situation”)	Land use/land cover change	Drought as a threat for agricultural production and subsistence	Land use change, types of production systems	Fire plays an important role in modifying the landscape dynamics at regional level. Variability and seasonality of fires have been related to climate and drought periods	Expansion of dairy farms, agriculture and forestry over cattle breeding
Indicators	Population, agricultural area, animal production	Agricultural productivity, labor, availability of water, temperature, precipitation	Agricultural area, soil water holding capacity, precipitation, water deficit, farm sizes, prices of agricultural products, rent of land, tenancy of land	Heat and light, smoke, deposits of ash, alteration of vegetation structure, rural population density	Area used for cattle and dairy, agriculture and forestry, precipitation, prices and land tenure
Methodology	A survey was done by using a database of Brazilian Institute of Geography and Statistics for a specific period of time (1996-2008)	Questionnaires were applied to the farmers and decision makers in order to evaluate their perceptions about climate change and also to assess some adaptation strategies suggested by specialists	Use of data from several governmental institutions to characterize the productive systems in Balcarce, Junín, and San Justo, in Argentina	Fire datasets were combined in order to assess the fire regimes in LPB. Land use and land cover datasets were employed to characterize the rural population density, to calculate the distance to urban centers, and to evaluate cropland, grassland and forest densities	Data from governmental institutions were evaluated in order to characterize the changes in land use and in land tenure in Uruguay
Outcomes	The changes in land use/land cover were observed especially regarding to temporary crops and animal production, evidencing the need for policies to assure the food production in the region	The farmers’ perceptions pointed the intensification of droughts as an evidence of climate change. The local plant breeding can be understood as an adaptation strategy to guarantee agricultural production	The characterization of the production systems may determine the farm’s adaptive capacity to climate change	The fire occurrence and its seasonality in LPB give some answers on the hierarchy of climate and human driving forces for fire regimes in LPB for predicting future fire regimes	The generation of the information required to design an insurance product for pasture systems, in particular to analyze the possibility of a climate index insurance

Analyzing the dynamics of land use change in Brazilian LPB (section 3.1.1.3), it is very clear that the expansion of agricultural land use occurred within the traditional climatic regions for the considered crops in the study, and how some input less intensive land uses, as pastures, gave place to input intensive crops, mainly for exportation and to feed the increased poultry and swine productions, also observed in the case study. Extreme climate events have not influenced agricultural land use yet, and the verified land use changes reflect mainly the increased demand for agricultural commodities at the world market.

The DPSIR for the Argentinean case study (Figure 3.2.1) put its focus on the State element, and shows how complex might be the influence of the considered drivers on land use change and the characteristics of the productive systems, the two dimensions of the State element being analyzed. The results illustrate the interdependencies among an extreme climate event (drought), the international price relationships and land use, determining not only the extent of area cultivated with a certain crop, or which crops are being cultivated but also land tenure relationships. The significance of extreme climate events for the dynamics of land use change (the causal relationship between climate and land use change) is evident, at least during certain time periods, as can be seen in Figures 3.2.2, 3.2.3, 3.2.4 and 3.2.5. Moreover, a clear association among farm size, tenancy form and production profile could be verified. Although in the Brazilian case study the dynamics of the agrarian production structure has not been analyzed in detail at regional level, similar relationships can be expected, since the expansion of agricultural land normally is associated with changes in farm size and tenancy form.

A similar trend in the dynamics of land use change and land tenure, as described for Argentina and Brazil, can be also verified in Uruguay (section 3.4). A distinctive characteristic is, however, that the recent increase of agricultural land use (expansion of soybean production) has substituted the extensive pastures, which was used for cattle breeding as the dominant activity in these land use systems. The DPSIR for the Uruguayan pastures systems (Figure 3.4.8) makes very clear how climate risks as water deficits and droughts associated with economic drivers (price of beef) affects their vulnerability, since the expansion of agricultural land use has displaced these pasture systems to poorer and shallower soils. These edaphic resources together with an increasing grazing intensity are particularly important for the vulnerability of these pasture systems to current climate risks and to climate change.

In the DPSIR for Anchieta (Figure 3.1.21), the importance of farmers’ perceptions is emphasized. The results reveal the importance of adequate perception to ‘act’ for better adaptation to extreme climate event as drought, but also the manner how perception may influence institutional responses to develop adaptation strategies using the example of developing maize landraces. By comparing local adaptation strategies to drought strategies, it was observed that each activity should be tailored to the regional needs.

Therefore strategies differ among regions and the scopes of analysis as well. Whereas the case of Anchieta analyses predominantly the farmers' perceptions, the Uruguay case poses insurances to stabilize livelihoods as the most important objective.

The importance of the dynamics of land use change, and its significance for land cover, is also considered by the case study which analyses the "fire risks". According to the results presented here, changes in fire regime in the last century clearly illustrates how land cover changes can significantly affect fire use and fire risk in a more significant manner than any climate trend (e.g. increase of droughts). The region considered in this case study is characterized by a high variability in both fire occurrence and seasonality due the different climate conditions and related drought period. Beyond that, the fire practices and human pressure is highly variable within the region. Therefore, six DPSIR analyses related to the six regions identified as homogeneous according to their land cover types and human pressure were proposed and discussed.

5. CONCLUSIONS

The presented DPSIR case studies revealed important causal relationships that might be taken into consideration for vulnerability assessment and the design of adaptation strategies to climate change in agricultural land use for LPB. These case studies allow for understanding how certain elements of the current situation being addressed are linked, and to which extent they might contribute in the magnitude of the climate change impact. The case studies are not based, however, on different climate change scenarios as suggested by the title of the deliverable, but on current climate extreme events, and other drivers.

Despite of the value of DPSIR as a tool to foster communication among researchers with different backgrounds, which is an important goal achieved with the case studies presented here, some of DPSIR's shortcomings should not be forgotten particularly when considering the issues addressed by CLARIS LPB. So, although the iterative way of DPSIR normally includes responses and feedback among its elements, these processes were in general poorly addressed in the case studies. This example goes along with the general criticism of the DPSIR, suggesting that the application of the framework might be too systematic, and less systemic. As a result, unintended consequences and unforeseen effects may not appear in the foreground when adopting this sort of linear thinking or "chain reaction" assumed by DPSIR. The argument of this criticism is even more evident if the causal structures are not entirely known, with the consequence that some important aspects might be not considered. So, the fact that "most human decisions related to ignition (leading to fire outbreaks) involve non-necessary and non-sufficient causal relations that are poorly captured by causal loops (chains)" can be considered as a good example of the above argument.

However, the DPSIR framework allows for identifying some important factors affecting the vulnerability [to climate change] of the most important agricultural land use systems of LPB. But vulnerability itself may be the result of the interconnectedness (actually not considered) of the DPSIR's elements. This will not be recognized by a systematic understanding of the situation. Nevertheless, the DPSIR case studies showed how similar agricultural productive systems may have different vulnerabilities. Furthermore, the results show how vulnerability to climate change might be affected by some concrete aspects like land tenure and land use, as well as by more intangible dimensions, like the perception that stakeholders have about climate and climate events.

Although agricultural systems are already adapting to changes in climate and climate variability, the results presented in this deliverable show that in the major agricultural production areas of LPB agricultural systems are currently responding to other drivers (like the world market for agricultural commodities) than climate change or extreme climate events. These extreme climate events have had only local effect on agricultural land use, and mostly only during a short time period. What can be perceived is that farmer's decision on land use still depends on economic variables, which have had similar effects over the whole LPB.

The DPSIR analysis of the case studies suggest also that the local context, which includes local vulnerability, might be more relevant in determining the extent to which a driver, which under certain circumstances might be a threat as climate change and its extreme climate events, influences the whole situation being considered. In other words, local vulnerability might contribute to a higher extent to “impacts” than a driver itself.

6. FURTHER RESEARCH NEEDS

In complex “wicked situations”, influenced by human-induced global warming and climate change, multiple causal factors are involved and determining the dynamics of land use change. The presented DPSIR case studies illustrate this very clearly. However, the understanding of causal relationships among single DPSIR elements may not be sufficient to address issues like vulnerability of land use systems to climate change and the design of adaptation strategies. Therefore, it is necessary to investigate possible feedback processes among different DPSIR elements and their significance for vulnerability assessment, taking into consideration the specific characteristics of the case studies.

As has been discussed, local vulnerability might contribute to a higher extent to the magnitude of the “impacts” of a given driver than the driver itself. Therefore, the regional sensitivity of driver impacts should be carefully analyzed. Vulnerability might be tested by modeling impact assessment in adequate scenario design. These simulations might help to rank driver contributions and to set priorities when it comes to decision making on most adequate adaptation strategies.

The study being reported here could also be complemented by the identification of the set of indicators related to each case study and its DPSIR components, as briefly presented on Table 4.2., in order to assess the vulnerability state of the interested system. These indicators should be traceable and easily available, to produce objective results with comprehensive meaning. For vulnerability assessment, it is necessary to identify and delimitate the problem situation and to define a possible change for it. The participation of different categories of stakeholders in this assessment process is fundamental to evaluate the effectiveness of the measures to be implemented in the system that is being considered.

7. REFERENCES

ABEF 2010. Associação Brasileira dos Produtores e Exportadores de Frango. Available at: http://www.abef.com.br/portal/_clientes/abef/cat/Abef%20RA_4021.pdf. Accessed in June 18, 2010.

ABRAF 2009. Anuário estatístico da ABRAF. Ano base 2008. ABRAF: Brasília. 129p.

Altieri M. A. 2004. Linking ecologists and traditional farmers in the search for sustainable agriculture. Frontiers in Ecology and the Environment. 2(1):35-42.

Antle J. M., Capalbo S. M. 2002. Agriculture as a managed ecosystem: Policy implications. Journal of Agricultural and Resource Economics. 27(1):1-15.

Arbex M. A., Gyorgy B. M., Saldiva P. H. N., Conceicao G. M. S., Pope A. C., Braga A. L. 2000. Assessment of the effects of sugarcane plantation burning on daily counts of inhalation therapy. Journal of the Air & Waste Management Association. 50(10): 1745-1749.

Assad E. D., Pinto H. S. 2008. Aquecimento global e cenários futuros da agricultura brasileira. São Paulo: EMBRAPA/UNICAMP. 84p.

Baldi G., Paruelo J. M. 2008. Land use and land cover dynamics in South American temperate grasslands. Ecology and Society. 13(2):6. [online] URL: http://www.ecologyandsociety.org/vol13/iss2/art6/

Bonatti M. 2009. Cambios climáticos. percepciones humanas y desarrollo rural. Buenos Aires. 177p. Dissertação (Mestrado). Universidade de Buenos Aires. Programa de Pós-Graduação em Desenvolvimento Rural.

Bond W. J., Keeley J. E. 2005. Fire as a global 'herbivore': the ecology and evolution of flammable ecosystems. Trends in Ecology and Evolution. 20(7): 387-394.

Bouma J., Droogers P. 2007. Translating soil science into environmental policy: A case study on implementing the EU soil protection strategy in The Netherlands. Environmental Science & Policy, 10:454-463.

Bradley A. V., Millington A. C. 2006. Spatial and temporal scale issues in determining biomass burning regimes in Bolivia and Peru. International Journal of Remote Sensing. 27(11): 2221–2253.

Bürgi M., Hersperger A. M., Schneeberger N. 2004. Driving forces of landscape change - current and new directions. Landscape Ecology. 19: 857-868.

Burton I., Lim B. 2005. Achieving adequate adaptation in agriculture. Climatic Change 70: 191-200.

CA. Comprehensive Assessment of Water Management in Agriculture. 2007. Water for Food. Water for Life: A Comprehensive Assessment of Water Management in Agriculture. London: Earthscan. and Colombo: International Water Management Institute. 48p.

Campelo E., Michels I. 2009. A expansão da agroindústria canavieira em Mato Grosso do Sul. Revista de Política Agrícola. 3: 25-38.

Campos A.V. 2007. Milho Crioulo: sementes da vida. Pesquisa, melhoramento e propriedade intelectual. Frederico Westphalen: URI, Brasil. 15p.

Campos C. G. C., Braga H. J., Alves R. 2006. Mudanças climáticas e seus impactos no Estado de Santa Catarina. Revista Agropecuária Catarinense. 19(3): 31-35.

Canci A. 2004. A diversidade das espécies crioulas em Anchieta-SC: Diagnóstico resultado de pesquisa e outros apontamentos da agrobiodiversidade. São Miguel do Oeste: Mclee. 112p.

Cardona O. 2001. La necesidad de repensar de manera holística los conceptos de vulnerabilidad y riesgo. Una crítica y una revisión necesaria para la gestión. Red de Estudios Sociales en Prevención de Desastres en América Latina. Universidad de Los Andes. Bogotá. 18p. Avaliable at http://www.desenredando.org/public/articulos/2001/repvuln/index.html. Accessed in 24 feb. 2011.

Carilla J., Grau H. R. 2010. 150 Years of Tree Establishment, Land Use and Climate Change in Montane Grasslands, Northwest Argentina. Biotropica. 42(1): 49-58.

Carr, E. R.; Wingard, P. M; Yorty, S. C.; Thompson, M. C.; Jensen, N. K.; Roberson, J. 2007. Applying DPSIR to sustainable development. International Journal of Sustainable Development & World Ecology. 14: 543-555.

Carter, T. R., Jones R. N., Lu X., Bhadwal S., Conde C., Mearns L. O., O'Neill B. C., Rounsevell M. D. A., Zurek M. B. 2007. New Assessment Methods and the Characterization of Future Conditions. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth

Assessment Report of the Intergovernmental Panel on Climate Change, Parry M. L., Canziani O. F., Palutikof J. P., van der Linden P.J., Hanson C. E. (Eds.) Cambridge University Press, Cambridge, UK, 133-171pp.

Catterson T. M., Fragano F. V. 2004. Tropical Forestry and Biodiversity Conservation in Paraguay. Final Report of a Section 118/119 Assessment EPIQ II Task Order N°.1

CEPA 2009. Síntese Anual da Agricultura de Santa Catarina. Florianópolis: Epagri/Cepa. Available at: http://cepa.epagri.sc.gov.br/Publicacoes/sintese_2009/sintese_2009.pdf. Accessed in December 22, 2010.

Cerri C. C., Bernoux M., Cerri C. E. P., Feller C. 2004. Carbon cycling and sequestration opportunities in South America: the case of Brazil. Soil Use and Management. 20:248-254.

Choudhury A. T. M. A., Kennedy I. R. 2004. Prospects and potentials for systems of biological nitrogen fixation in sustainable rice production. Biology and Fertility of Soils. 39: 219-227.

Chuvieco, E., Opazo S., Sione W., del Valle H., Anaya J., Di Bella C., Cruz I., Manzo L., López G., Mari N., González-Alonso F., Morelli F., Setzer A., Csiszar I., Kanpandegi J. A., Bastarrika A., Libonati R. 2008. Global burned-land estimation in Latin America using MODIS composite data. Ecological Applications 18:64–79.

Coutinho H. L. C., Noellemeyer E., Jobbagy E., Jonathan M., Paruelo J. 2009. Impacts of land use change on ecosystems and society in the Rio de La Plata Basin. In: Tiessen H., Stewart J. W. B. (Eds.) 2009. Applying Ecological Knowledge to Land Use Decisions. SCOPE. Scientific Committee on Problems of the Environment. IAI Inter-American Institute for Global Change Research. and IICA Inter-American Institute for Cooperation on Agriculture. 159p.

Coutinho H. L. C., Noellemeyer E., Jobbagy E., Jonathan M., Paruelo J. 2006. Societal and Environmental Impacts of Land Use Change in the Rio de La Plata River Basin. IAI Scope Meeting. San Jose. Available at http://platabasin.unsl.edu.ar. Accessed in May 5. 2010.

Da Silva W. F., Alves A. D., Rudorff, B. F. T., Sugawara, L. M. 2010 – CANASAT project: Monitoring of the sugarcane cultivation area in south central Brazil. In:

Wagner W., Székely, B. (Eds.) ISPRS TC VII Symposium – 100 Years ISPRS, Vienna: IAPRS, Vol. XXXVIII, Part 7B.

Dros, J. M. 2004. Managing the Soy Boom: Two scenarios of soy production expansion in South America. Amsterdam: AIDEnvironment, 65p.

Durigan G., Siqueira M. F., Franco G. A. D. C. 2007. Threats to the Cerrado remnants of the State of Sao Paulo, Brazil. Scientia Agricola. 64(4): 355-363.

Ellis E. C., Ramankutty N. 2008. Putting people in the map: anthropogenic biomes of the world. Frontiers in Ecology and Environment. 6(8): 439–447.

Ellis E. C., Goldewijk K. K., Siebert S., Lightman D., Ramankutty N. 2010. Anthropogenic transformation of the biomes, 1700 to 2000. Global Ecology and Biogeography. 19(5): 589-606.

EMBRAPA. Empresa Brasileira de Pesquisa Agropecuária. 2005. A realidade bioeconômica do médio pecuarista: um estudo de caso em Mato Grosso do Sul. Campo Grande: Embrapa Gado de Corte. Available at: http://www.cnpgc.embrapa.br/publicacoes/doc/doc_pdf/Doc154.pdf. Accessed in December 22, 2010.

EPAGRI/CEPA. Síntese Anual da Agricultura de Santa Catarina 2007. Available at http://cepa.epagri.sc.gov.br/Publicacoes/sintese_2008/Sintese_2008.pdf. Accessed in September 17, 2009.

Fagan B. 2009. O aquecimento global: a influência do clima no apogeu e declínio das civilizações. São Paulo: Larousse do Brasil. 303p.

FAO. Food and Agricultural Organization. 2006. World agriculture: Towards 2030/2050. Prospects for food, nutrition, agriculture, and major commodity groups. Interim Report Global Prospect, Studies Unit. FAO: Rome. 78p.

FAO. Food and Agricultural Organization 2004. Fertilizer requirements in 2015 and 2030 revisited. Land and Plant Nutrition Management Service. Land and Water Development Division. FAO: Rome. 56p.

Fearnside, P. M. 2002. Can Pasture intensification discourage deforestation in the Amazon and pantanal regions of Brazil. In: Wood C. H., Porro R. (Eds.) Deforestation and land use in the Amazon. Gainsville: University Press of Florida, 299-314pp.

Fischer G., Nachtergaele F., Prieler S., van Velthuizen H. T., Verelst L., Wiberg D., 2008. Global Agro-ecological Zones Assessment for Agriculture (GAEZ 2008). IIASA: Laxenburg and FAO: Rome.

FOEE. Friends of the Earth Europe. 2010. Sugar cane and land use change in Brazil, Biofuel crops, indirect land use change and emissions. Available at: http://www.foe.co.uk/resource/briefings/sugar_cane_and_land_use_ch.pdf. Accessed in April 26, 2011.

Frederiksen P., Kristensen P. 2008. A Framework for indicator selection to analyze sustainability impacts of land use changes. In: Helming K., Perez-Soba M., Tabbush P. (Eds.) Sustainability Impact Assessment of Land Use Changes. Berlin Heidelberg: Springer. 293-304 pp.

FS. Forest Service. 2007. Available at: http://www.fs.fed.us/pnw/fera/research/targeted/international/index.shtml. Accessed in April 26, 2011.

Gaspari N. I., Grau H. R., Manghi E. 2008. Carbon Pools and Emissions from Deforestation in Extra-Tropical Forests of Northern Argentina Between 1900 and 2005. Ecosystems 11: 1247-1261.

Giddens A. 2009. The politics of climate change. Cambridge: Polity Press. 264p.

Gonçalves R. G., Palmeira E. M. 2006. Suinocultura Brasileira. Observatorio de La Economia Latinoamericana. Available at: http://www.eumed.net/cursecon/ecolat/br. Accessed in June 22, 2010.

Grau H. R., Gasparri N.I., Aide T.M. 2005. Agriculture expansion and deforestation in seasonally dry forests of northwest Argentina. Environmental Conservation. 32:140–148.

Grau H. R., Mitchell A. T. 2008a. Globalization and Land-Use Transitions in Latin America. Ecology and Society. 13(2): 16.

Grau H. R., Gasparri N. I., Mitchell A. T. 2008b. Balancing food production and nature conservation in the Neotropical dry forests of northern Argentina. Global Change Biology 14: 985–997.

Hamilton S. K. 2002. Hydrological controls of ecological structure and function in the Pantanal Wetland (Brazil).The Ecohydrology of South American Rivers and Wetlands. IAHS Special Publication no. 6.

HDR. Human Development Report. 2006. Beyond scarcity: Power, poverty and the global water crisis. New York: UNDP. 440p.

Helming K., Diehl K., Kuhlman T., Jansson T., Verburg P., Bakker M., Perez-Soba M., Jones L., Verkerk P., Tabbush P., Morris J., Drillet Z., Farrington F., LeMouël P., Zagame P., Stuczynski T., Siebielec G., Sieber S., Wiggering H. 2011. Ex ante impact assessment of policies affecting land use, application of the analytical framework. Ecology and Society. Special Feature: Landscape Scenarios and Multifunctionality - Making Land Use Assessment Operational, 16(1).

Hernández V. 2007. El fenómeno económico y cultural del boom de la soja y el empresariado innovador. Desarrollo Económico. Revista de Ciencias. Sociales. Buenos Aires. 47(187): 331-365.

Holman I. P., Rounsevell M. D. A., Cojacaru G., Shackleyy S., McLachlan C., Audsley E., Berry P. M., Fontaine C., Harrison P. A., Henriques C., Mokrech M., Nicholls R. J., Pearn K. R., Richards J. A. 2008. The concepts and development of a participatory regional integrated assessment tool. Climatic Change. 90:5-30.

Huang C., Kim S., Altstatt A., Townshend J. R. G., Davis P., Song K., Tucker C. J., Rodas O., Yanosky A., Clay R., Musinsky J. 2007. Rapid loss of Paraguay's Atlantic forest and the status of protected areas – A Landsat assessment. Remote Sensing of the Environment. 106(4): 460-466.

IBGE. Instituto Brasileiro de Geografia e Estatística. 2009. Available at: http://www.sidra.ibge.gov.br. Accessed in August 3, 2009.

IBGE. Instituto Brasileiro de Geografia e Estatística. 2006. Manuais técnicos em geociências. Manual técnico de uso da terra, n.7. Rio de Janeiro: IBGE, 91p.

IPCC. Intergovernmental Panel on Climate Change. 2007. Summary for policy makers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge United Kingdom and New York: University Press. 18p.

Ison R. Systems practice: how to act in a climate-change world. London: Springer – Verlag, 2010. 344p.

Izquierdo, A. E., De Angelo C. D., Aide T. M. 2008. Thirty years of human demography and land-use change in the Atlantic Forest of Misiones, Argentina: an evaluation of the forest transition model. Ecology and Society 13(2): 3. [online] URL: http://www.ecologyandsociety.org/vol13/iss2/art3/

Izquierdo A. E., Grau. H. R. 2009. Agricultural adjustment, land use transition and protected areas in Northwestern Argentina. Journal of Environmental Management. 90(2): 858-865.

Jackson R. B., Jobbagy E. G., Nosetto M. D. 2009. Ecohydrology in a human-dominated landscape. Ecohydrology Bearings. 2(3): 383-389.

Kang Y, Khan S, Ma X. 2009. Climate change impacts on crop yield, crop water productivity and food security – a review. Progress in Natural Science. 19:1665-1674.

Kunst C., Ledesma R., Bravo S., Albanesi A., Anriquez A., Godoy J. 2009. Fire as a tool for rangeland improvement in Northwestern Argentina. Fire Paradox, 1st South American Symposium on Fire Ecology and Management. Puerto Madryn. 5p.

Kurtz D. B., Schellberg J., Braun M. 2010. Ground and satellite based assessment of rangeland management in sub-tropical Argentina. Applied Geography. 30: 210-220.

Lauk C., Erb K. H. 2009. Biomass consumed in anthropogenic vegetation fires: Global patterns and processes. Ecological Economics. 69: 301-309.

Lavorel S., Flannigan M. D., Lambin E. F., Scholes M. S. 2007. Vulnerability of land systems to fire interactions among humans, climate, the atmosphere, and ecosystems. Mitigation and adaptation strategies for global change. 12(1): 33-53.

Macedo H. A., Silva A., Silva Neves S. M. A., Neves R. J. 2009. Avaliação das queimadas no Pantanal do Paraguai na região de Corumbá e Ladario, MS no período de maio de 2009. Anais 2º Simpósio de Geotecnologias no Pantanal, Corumbá, Embrapa Informática Agropecuária/INPE. 452-459 p.

Mathews J. A., Goldsztein H. 2009. Capturing latecomer advantages in the adoption of biofuels: the case of Argentina. Energy policy. 37: 326-337.

McIntyre B. D., Herren H. R., Wakhungu J., Watson R. T. 2009. International assessment of agricultural knowledge, science and technology for development (IAASTD): global report. Washington: Island Press. 606p.

Mistry J. 1998. Decision-making for fire use among farmers in savannas: an exploratory study in the Distrito Federal, Central Brazil. Journal of Environmental Management. 54: 321-334.

Mouillot F., Field C. B. 2005. Fire history and the global carbon budget: a 1° x 1° fire history reconstruction for the 20th century. Global Change Biology. 11(3): 398-420.

M744m. 2009. Monitoramento das alterações da cobertura vegetal e uso do Solona Bacia do Alto Paraguai – Porção Brasileira – Período de Análise: 2002 a 2008. Iniciativa: CI – Conservação Internacional, ECOA - Ecologia e Ação, Fundación AVINA, Instituto SOS Pantanal, WWF- Brasil. Brasília, 2009. Available at: http://www.wwf.org.br/informacoes/?uNewsID=25181. Accessed in April 26, 2011.

Olson D. M., Dinerstein E., Eric D., Wikramanaya K. E., Neil D., Burgess, G., Pow E. L. L., Emma C., Underwo O. D., Jennifer A., D'amico, I. I., Holly E. S., Morrison J. C., Colby J., Loucks, T. 2001. Terrestrial Ecoregions of the World: A New Map of Life on Earth. BioScience. 51(11): 933-938.

Onigemo A. E., Santos S. A., Pellegrin L. A., Abreu U. G. P, Silva E. T. J. B., Soriano B. M. A., Crispim S. M. A. 2007. Application of Vegetation index to assess fire risk in open grasslands with predominance of cespitous grasses in the Nhecolandia sub-region of the Pantanal. Anais XIII Simpósio Brasileiro de Sensoriamento Remoto, Florianópolis: INPE. 4493-4500p.

PNMC. Política Nacional de Mudanças Climáticas. Lei nº 12.187. December 29. 2009. Available at: http://www.planalto.gov.br/ccivil_03/_Ato2007-2010/2009/Lei/L12187.htm. Accessed in December 9, 2010.

Pyne S. J. 2007. Burning Border. Environmental History. 12(4): 959-965.

Qu J. J. ,Wang W., Dasgupta S., Hao X. 2008. Active fire monitoring and fire danger potential detection from space. A review. Frontiers of Earth Science in China. 2(4): 479-486.

Redo D., Millingto, A. C., Hindery D. 2011. Deforestation dynamics and policy changes in Bolivia's post-neoliberal era. Land Use Policy. 28: 227 -241.

República Federativa do Brasil. (s.d.). Região Centro-Oeste rodoviário, político, regional e turístico. São Paulo: Trieste, 1 map (120 x 90 cm). Scale: 1:2.000.000.

República Federativa do Brasil. (s.d.). Região Sul rodoviário, político, regional e turístico. São Paulo: Trieste, 1 map (120 x 90 cm). Scale: 1:2.000.000.

República Federativa do Brasil. (s.d.). Região Sudeste rodoviário, político, regional e turístico. São Paulo: Trieste, 1 map (120 x 90 cm). Scale: 1:2.000.000.

Ripoli T. C. C., Ripoli M. L. C. 2009. Biomassa de cana de açúcar: colheita, energia e ambiente. Piracicaba: FUNEP. 333p.

Rittel, H. W. J., Webber, M. M. 1973. Dilemmas in a general theory of planning. Policy Sciences. 4: 155-169.

Robinson, J. 1991. Fire from space – global fire evaluation using infrared remote sensing. International Journal of Remote Sensing. 12: 3-24.

Rodrigues, C. A. G., Rodrigues, S. M. A. C. 2002. Queima controlada no Pantanal. Corumbá: EMBRAPA Pantanal. Documentos 35, 23p.

Rodríguez-Labajos B, Binimelis B R, Monterroso I (2009) Multi-level driving forces of biological invasions. Ecological Economics. 69: 63-75.

Rudorff B. F. T., Aguiar D. A., Silva F. W., Sugawara L. M., Adami M., Moreira M. A. 2010. Studies on the Rapid Expansion of Sugarcane for Ethanol Production in Sao Paulo State (Brazil) Using Landsat Data. Remote Sensing. 2(4): 1057-1076.

Salvatore, M., Pozzi F., Ataman E., Huddleston B., Bloise M. 2005. Mapping global urban and rural population distributions. Environment and Natural Resources. Working Paper 24. FAO: Rome.

Sanginga N. 2003. Role of biological nitrogen fixation in legume based cropping systems; a case study of West Africa farming systems. Plant and Soil. 252: 25-39.

Schneider, A., Friedl M. A., Potere D. 2009. A new map of global urban extent from MODIS data. Environmental Research Letters, volume 4, article 044003.

Schneider, A., Friedl M. A., Potere D. 2010. Monitoring urban areas globally using MODIS 500m data: New methods and datasets based on urban ecoregions. Remote Sensing of Environment. In review.

Schroeder W., Morisette J. T., Csiszar I., Giglio L., Morton D., Justice C. O. 2005. Characterizing vegetation fire dynamics in Brazil through multisatellite data: common trends and practical issues. Earth interactions. 9(13): 1-26.

Schroeder, W., Alencar, A., Arima, E., Setzer, A. 2009. The spatial distribution and inter-annual variability of fire in Amazonia. In: Keller M., Bustamante M., Gash J., Dias P. S. (Eds.). Amazonia and Global Change, American Geophysical Union. Washington: AGU. 43-60pp.

Seidl A. F., Silva J. V., Moraes A. S. 2000. Cattle Ranching and deforestation in the Brazilian Pantanal. Ecological Economics. 36: 413-425.

Seo S. N., Mendelsohn R. 2008. An analysis of crop choice: Adapting to climate change in South American farms. Ecological Economics. 67: 109-116.

Silva M. P., Mauro R., Mourão G., Coutinho M. 1999. Conversion of forests and woodlands to cultivated pastures in the wetland of Brazil. Ecotropicos 12(2): 101 – 108.

Smith P., Martino D., Cai Z., Gwary D., Janzen H., Kumar P., McCarl B., Ogle S., O'Mara F., Rice C., Scholes B., Sirotenko O., Howden M., Mcalister T., Pan G., Romanenkov W., Schneider U., Towprayoon S., Wattenbach M., Smith J. 2008. Greenhouse gas mitigation in the agriculture, Philosophical Transactions of the Royal Society Biological Sciences. 363: 789-813.

Smeets E., Weterings R. 1999. Environmental indicators: Typology and overview. Technical Report 25. European Environmental Agency: Copenhagen. 19p.

Sorrensen C. 2008. Potential hazards of land policy: Conservation, rural development and fire use in the Brazilian Amazon. Land Use Policy. 26: 782-791.

Souchaud S. 2002. Migrations et mutations des systèmes agraires: la culture brésilienne du soja au Paraguay. Migrations et environnement. 18(2): 105-137.

Steininger M. K., Tucker C. J., Ersts P., Killeen T. J., Villegas Z., Hecht S. B. 2001. Clearance and fragmentation of Tropical deciduous Forest in the Tierras Bajas, Santa Cruz, Bolivia. Conservation Biology. 15(4): 856-866.

Tauber F. 2000. Reflexiones y datos para una estrategia de desarrollo. Junín: Universidad Nacional de La Plata, 420p.

Thonicke K., Venevsky S., Sitch S., Cramer W. 2001. The role of fire disturbance for global vegetation dynamics: coupling fire into a Dynamic Global Vegetation Model. Global Ecology and Biogeography. 10(6): 661-667.

Tisdell C. 2006. Sustainable Agriculture. In: Atkinson G., Dietz S., Neumayer E. (eds.) Handbook of sustainable development. Massachusetts: Edward Elgar Publishing. 506p.

Tisdell C. 2003. Socioeconomic causes of loss of animal genetic diversity: analysis and assessment. Ecological Economics. 45: 365-376.

Uriarte M., Yackulic C. B., Cooper T., Flynn D., Cortes M., Crk T., Cullman G., McGinty M., Sircely J. 2009. Expansion of sugarcane production in Sao Paulo, Brazil: Implication for fire occurrence and respiratory health. Agricultue, Ecosystems and Environment. 132: 48-56.

Van der Werf G.R., Randerson G., Collatz G.J., Giglio L. 2003. - Carbon emissions from fires in tropical and subtropical ecosystems. Global Change Biology. 9: 547-562.

Vasques A. G., Nogueira A. S., Kirchner F. F., Berger R. 2007. Uma síntese da contribuição do gênero *Pinus* para o desenvolvimento sustentável no sul do Brasil. Floresta. 37: 445-450.

Wiebe K. 2003. Linking land quality, agricultural productivity, and food security. Agricultural Economic Report 823, Economic Research Service. Washington: USDA. 63p.

Wilcox R. W. 1999. The Law of the Least Effort, Cattle Ranching and the Environment in the Savanna of Mato Grosso, Brazil 1900-1980. Environmental History. 4(3): 338-368.

World Water Assessment Programme. 2007. La Plata Basin Case Study, UN-Water/WWAP. Available at: http://www.unesco.org/water/wwap/case_studies/index.shtml#plata. Accessed in: July 31, 2009.

Zak C. M., Hodgson J. G. 2004. Do subtropical seasonal forests in the Gran Chaco, Argentina, have a future? Biological Conservation. 120(4):589-598.

Zoneamento agroecológico da cana-de-açucar. 2009. Manzatto C. V. (Org). Rio de Janeiro: Embrapa Solos. 55 p.

Zuchiwschi E. 2008. Florestas nativas na agricultura familiar de Anchieta. Oeste de Santa Catarina: conhecimentos, usos e importância. Florianópolis. 178p. Dissertação (Mestrado). Universidade Federal de Santa Catarina. Centro de Ciências Agrárias. Programa de Pós-Graduação em Recursos Genéticos Vegetais.

Zullo Jr. J., Pinto H. S., Assad E. D. 2006. Impact assessment study of climate change on agricultural zoning. Meteorological Applications. 13: 69-80.

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