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Social Methods for Assessing Agricultural Producers' Vulnerability to Climate Variability and Change based on the Notion of Sustainability

*Wehbe M.B, Seiler R.A, Vinocur M.R, Eakin H, Santos C and Civitaresi H.M

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*Direct correspondence to Monica Wehbe:
(mwehbe@eco.unrc.edu.ar)

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Social Methods for Assessing Agricultural Producers' Vulnerability to Climate Variability and Change based on the Notion of Sustainability

Authors: M.B. Wehbe, R.A. Seiler and M.G. Vinocur, H. Eakin, C. Santos and H.M. Civitaresi

Introduction

It is increasingly accepted that the vulnerability of agricultural populations to climatic conditions cannot be solely understood through the quantification of biophysical impacts. The degree to which climatic events affect an agricultural system depends on a wide variety of factors, including (among other things) the types of crops or livestock produced, the scale of the operation, the farm's orientation towards commercial or subsistence purposes, the quality of the natural resource base and specific human variables — education, risk tolerance, age — of the farm's managers. Vulnerability is also mediated by institutional factors: The rules, norms and policies that govern land tenure, markets, financial capital and insurance, support programs and technology development and distribution.

The diversity of social, economic, political and environmental conditions of agriculture in Latin America challenges the search for a methodology for vulnerability assessment that accurately captures the local specificities of production while allowing for a comparative discussion of vulnerability across systems. The tendency has been to use aggregate indicators —GDP, population growth rates, human welfare indicators — as proxies for the changing social context in which climate change is occurring. While these indicators may appropriately reflect general trends, they gloss over important differences in the relationships between particular economic actors and the societies in which they live.

In this paper, we present a conceptual approach for assessing vulnerability and adaptive capacity that we have adopted in the research project, "Integrated Assessment of Social Vulnerability and Adaptation to Climate Variability and Change Among Farmers in Mexico and Argentina" (AIACC/LA29). Rather than relying exclusively on national aggregated data and models of "average" production conditions, we have instead chosen a series of case studies to capture the contrasting responses to risk and uncertainty of different production systems under broadly similar political and economic trends. Given that small scale subsistence and semi-subsistence systems have already been the subject of study in the region (see for example Conde & Eakin, 2003; Eakin, 2000) we focused our research on small and large scale farmers oriented towards commercial markets. In Argentina, we worked with farmers (400 –500 has average) of rain fed grains, soybeans and peanuts in southern Cordoba. In Mexico, we focused on small-scale (< 5 ha) coffee farmers in central Veracruz and large-scale (20 – 200 has) farmers of rain fed and irrigated grains in southern Tamaulipas. Farmers in both countries are facing rapid changes in agricultural policies and institutions as each country struggles to maintain a foothold in global agricultural markets. Instead of identifying particular variables that can be used across each system of study, our aim was to define critical indicators that not only capture the present fragility of the systems to climatic risk, but also suggest the direction of the systems' future development and thus future vulnerability. In this aspect, we hope to contribute directly to national efforts to enhance the sustainability of particular agriculture populations in each country of study.

Following this introduction, the paper is divided into four sections. The first of these presents our analysis of the relationship between vulnerability and sustainability, as the overarching framework for both the methodological approach we are adopting as well as for the intended policy applications of our research. The second section focuses on the concept of social vulnerability and adaptive capacity and its relation

with sustainability. The third section explores the concept of social vulnerability in relation to general variables and attributes that we feel capture critical differences between the systems of study and explains how these general indicators are made operational through a series of variables specific to each case study. The forth section presents a case study as to show main results obtained from the application of the proposed methodology. In the conclusion, we again return to the issue of sustainable development in our discussion of how we hope that this approach will contribute to the formation of sector policies and programs that will enhance adaptive capacity and the resilience of the types of systems we are studying.

I. Vulnerability, Sustainability and Agriculture

Over the last century, advances in agricultural technology and new market opportunities dramatically changed the operating environment for farmers in many developing nations. Mexico was in many ways the birthplace of the green revolution that transformed the way in which agriculture was practiced and types of inputs used such that many developing countries saw enormous advances in yields and labor productivity (Jennings, 1988). Despite this long-term international effort to create more homogeneous production systems and promote the use of particular technology packages, the present diversity of production in Latin America is testament to the social complexity and environmental challenges of agriculture in the region. One of the key lessons of the green revolution has been that not all technology packages or policies are appropriate for all farmers (DeWalt, 1975; Feder & O'Mara, 1981; Wright, 1984). Another lesson is that geography and place matter in technology adoption, particularly in terms of the types of environmental risks faced by farmers and how these risks are addressed in their production strategies (Michaels, 1979; Yapa, 1996).

Although many advances have been made in climate change research so that now more subtle and not-so-subtle differences between farm systems are captured in vulnerability assessments, there is still a tendency to focus on technological solutions to vulnerability, rather than on the socioeconomic context in which farmers make strategic decisions. Furthermore, it is clear that not all practices or technologies are appropriate for reducing the vulnerability of farm systems. Indeed, it could also be argued that in some cases the type of technological packages and practices promoted through present agricultural policy may even exacerbate the sensitivity of the agricultural sector to longer-term environmental change.

In our project, our ambition is to identify some of the obstacles to adaptation in the regions of our case studies. Because we are interested in longer-term trends in climate averages and climatic variability, we are specifically interested in the implications of policy trends and technology development for the future resilience of the farm systems under study. This focus necessarily speaks to issues of agricultural and rural livelihoods sustainability. Although evaluating agricultural sustainability is not the goal of our project, we hope that our analysis of agricultural vulnerability and adaptive capacity to climatic variability and change can contribute to debates about sustainability in Mexico and Argentina by identifying ways in which policies and practices may inhibit effective responses to climatic conditions, and illustrating how inequities in resource access may be exacerbating the vulnerability of particular farm groups.

II. Sustainability and Vulnerability

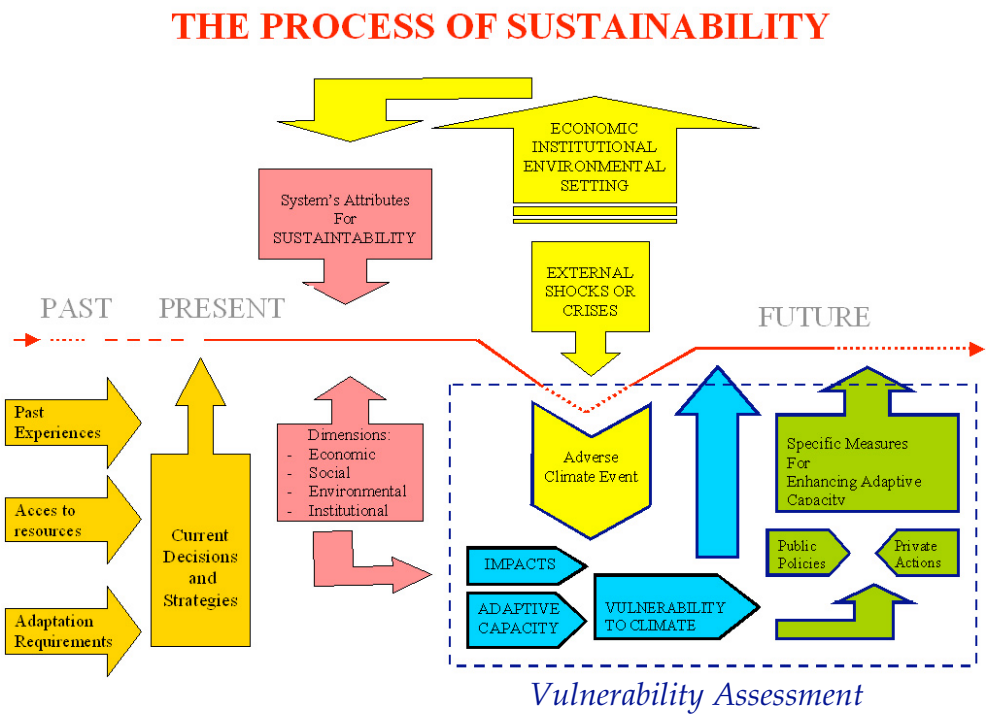
The concept of sustainable development began to be incorporated into theories on agricultural development in the early 1980s and throughout the 1990s, during a period in which a number of concerns appeared on the development agenda related to macroeconomic reforms, institutional change, food insecurity and poverty; and

specifically those issues related to pollution, environmental degradation and sustainable agriculture from the local to the global level (Eicher and Staatz, 1998). The possible impacts of global processes such as economic globalization or climate change on sustainable development became an issue for exploration, particularly with respect to the implications of economic growth for social equity and the efficient use of natural resources in the short and long run.

Our project has the ambition of contributing to the process of sustainable development in the study regions through our analysis of vulnerability. This objective was pursued through understanding the links between the strategies farmers are using to address structural changes in the economy and implications of those responses for their livelihoods, resource base and thus their sensitivity to climate impacts. International agencies such as the Department for International Development and the Food and Agriculture Organization (FAO, 1995), have defined sustainable systems, whether livelihoods, communities or national economies, as those that are able to cope with or recover from external shock or stress, while maintaining or improving its resource base. Thus, if agricultural populations are vulnerable to climate risks in the sense that they cannot cope with adverse climatic events, or lack appropriate mechanisms for doing so, the outcome might be a situation of vulnerability that undermines the resource base therefore sustainability in the medium and long term. If losses due to climatic events are repeated over time and aggregated across an entire sector (given that climate scenarios suggest greater variability and more intense extreme events), one can expect that such impacts will contribute negatively to the capacity of the system to maintain productivity and to assure stable or improving rural livelihoods. And, lack of adaptive capacity in agriculture may be indicative of a more general lack of sustainability of the system

This sustainability/vulnerability process is presented schematically in the following figure. In the figure the red line represents the "level" of sustainability of the unit of analysis; in our case, the agricultural household. At any given moment in time, this "level" of sustainability incorporates the accumulated past experiences of the household and the implications of that experience for present decisions and strategies. The social, environmental, or economic outcomes of these strategies in turn affect the future level of sustainability of the unit of analysis (household). This process is influenced by a number of factors, represented in the diagram by the series of boxes below (representing the micro-context of decision-making) and above (representing the global or exogenous context of decision-making) the red line. The boxes in dark yellow represent the factors affecting the decision-making at the household-level. The light yellow area above the red line represents the broader economic, institutional and environmental context of decision-making over which the individual household has little direct influence or control. These macro and micro factors affect households via sustainability attributes specific to the particular unit of analysis (illustrated in generic terms by the red boxes and as described by Masera and López-Ridaura 2000).

Figure1: The sustainability and Vulnerability of Agricultural Systems



The light yellow area is also a source of exogenous stressors that can affect the unit of analysis at any point in time, including adverse climate events. The dotted line in the lower right hand corner represents the scope of analysis of this project in which climate events and their impacts on the households are emphasized over other stressors in the sustainability analysis. The implications of the climate events for the vulnerability of the households are determined by the sensitivity of the system and its capacity to adapt. The resulting vulnerability of the system can have an important impact on the level of sustainability of the household, as well as on the broader production system to which it belongs, thus affecting the future trajectory of its development. Interventions, either on behalf of public or private actors, to either reduce the sensitivity of the system or improve the capacities of households to adapt can counter-act this impact on sustainability and thus also influence the system's future development.

With this framework in mind, we focused our project on the factors that affect agricultural adaptive capacity with the hope that some of the factors we identify as facilitating adaptation will help enhance the system's sustainability. Moreover, we argue that the structural characteristics of the system that appear to inhibit farmers' adaptation are likely to contribute to undermine the sustainability of the system over time. Thus, by identifying those structural characteristics (for example, agricultural support programs that may be encouraging particular practices that increase vulnerability) we may be able to involve policy makers more actively in debates about future vulnerability to climate change. Although we cannot pretend to address all aspects of sustainability, we do hope that in these ways our study's findings may contribute to the development debates in each country.

III. The vulnerability function

The project conceived vulnerability as a function of *sensitivity* (S) on a system generated by the characteristics of a system in relation to different climatic events; and, *adaptive*

capacity (AC), or the ability of a system to cope with, recover from and adjust to changing climatic conditions and extreme events. We explicitly recognized that vulnerability is spatially and socially differentiated. In other words, sensitivity and adaptive capacity are related specifically to the type of climatic threat affecting a population, the type of farmer or farm system affected, the location of production or livelihood activity (Bohle et al, 1994). It is also important to clarify if one is assessing the adaptive capacity of the agricultural productive unit or, as in the case of this project, also the livelihood strategy that rests on it. Formally, we expressed vulnerability as a function of both variables as follows:

$$ {}^{i}_{j}V^{c}_{k} = F \left\lfloor {}^{i}_{j}S_{k} ;\ {}^{i}_{j}AC^{c}_{k} \right\rfloor $$

Where,

i = 1, 2,...,n represents different climatic events that can have a negative impacts.
j = 1, 2,..,m and represents different type of producers.
k = 1,2,...,w and represents particular geographical zones to be considered.
c = whether an agricultural productive unit or an agricultural producer's livelihood strategy.

In order to assess the adaptive capacity of farmers to climatic variability and change, our project is basing its methodology on the MESMIS framework (Masera & López-Ridaura, 2000) and on recent research on social vulnerability in central Mexico. The MESMIS framework was originally developed to evaluate the sustainability of natural resource management in rural areas. Analytically, we consider that adaptive capacity is determined by the interaction of social, economic, institutional and environmental processes that combine to affect farmers' decisions at the moment that they face climatic risk and change.

Adaptive capacity (AC) refers to farmers' ability to recognize present and future climatic risks, respond to and cope with risk (through reorganization of activities, investments, resource allocation, etc.) in order to minimize risk of future negative consequences. Such capacity has been defined as being related to specific sustainability attributes of that system, and for our project we are using the following: a) access to resources that are critical to preparing for and recovering from climatic events, and are identified together with stakeholder; b) flexibility, which reflects the capacity of a system to maintain its functioning after being affected by a stressor, and depends partly on access to resources and system diversity; and c) stability, includes the frequency of both climatic and non-climatic shocks and the degree of uncertainty affecting the decision-making environment of the system and the system. Both consistent resource access and flexibility contribute to system stability, a property which refers to the system's ability to sustain itself.

Methodologically, assessing agricultural producers' adaptive capacity to adverse climatic events is challenged by the problem that no single set of indicators can be determined in advance for analyzing any of capacity attributes, but rather that the indicators need to be defined through both an analysis of existing literature on the systems of study and collaborative research with actors in the system to determine the critical points that characterize each attribute of capacity specific to the system. In our case, this means extensive consultations both with sector experts and with different classes of farmers in order to identify the appropriate variables that best represent the attributes of interest for each group and sector. Therefore while the attributes of adaptive capacity we chose can be considered relevant for any development setting, the indicators were determined as a function of particularities in the agricultural setting. Many of the indicators identified in the project (see table below) may also be considered indicators of rural sustainability, and as such, we hope that although we cannot address all aspects of sustainability in our vulnerability research, we will provide a basis from which necessary connections between future social development and future vulnerability can be made.

Table 1. Attributes and Indicators of Adaptive Capacity

ATTRIBUTES	INDICATORS
1. Flexibility (FL)	
• Diversity of agricultural system	Diversity of seeds available and used; number of crops planted
• Income diversity	Diversity of income sources (agriculture, livestock, off-farm and non-farm)
• Resource base (endowments) (biological, physical, human, social, financial)	Water supply; soil quality and diversity; land tenure, size, distribution; financial capital; education and age; material equipment and machinery; animals
Tendencies and changes in the above	
2. Stability (ST)	
• Exposure to/ impact of market risk	Variability in input and output prices and availability
• Exposure to/ impact of climatic risk	Main climatic impacts; agriculture and cattle losses
• Degree of variability/change in rural economy	Migration; land sales, land rental
Tendencies and changes in the above	
3. Resource Access (AR)	
• Access to financial resources	Formal and informal credit
• Participation in social programs	Emergency welfare programs, social services
• Participation in support programs	Technology transfer; technical assistance
Tendencies and changes in the above	

The general idea is to combine both qualitative (interviews, group discussions, review of primary literature) with quantitative approaches (analysis of production data, trends, etc., survey, climate analysis) within an effort to link an analysis of climatic data with social variables such that each component of the study is constantly reinforcing the other and neither socio economic nor climate are simply the "context" in which the other occurs.

IV. A case study

The main objective of this section is to apply the described analytical framework to a specific case study in the Argentinean research area of the AIACC Project LA-29. To assess vulnerability of agricultural producers to climatic variability and change, two approaches can be used: To start from a real climatic event or phenomenon and, consequently, from its impact on the productive system; or to start from a decision taken by agricultural producers which certainly hides one or more of the perturbation factors that affects the system. In the first approach, once the perturbation is identified, then the following activity is to assess the system's capacity to adapt to that impact. On the other hand, in the second approach, it is necessary to determine whether there was a climatic phenomenon driving the decision and evaluate the consequences of the decision in terms of vulnerability and sustainability. We use the second approach to analyze a case study of the peanut production and producers of the south and center of Cordoba Province, Argentina.

Argentina: From peanuts to soybeans

Peanut is cropped in the south and center of the Cordoba Province since the beginning of XXth century. The peanut production locates the Province in the level of the major producer nationwide, accounting for the 95% of the primary and processed production of the Country. The crop has traditionally been an important

source of economic welfare for the region. The area planted with peanut increased until 1978 when peanuts began to be replaced by soybeans (Figures 2, 3 and 4). The peanut production system is mostly rain-fed. Weather and climate conditions generate inter-annual variability in yields, due mainly to the shortage of water during critical periods of the crop's development (Vinocur et al, 2000). Peanut producers involved in the study were medium- and small-size independent farmers from the central part of the region who have changed to soybean crop. The objective of the study was to assess the possible factors determinant of the change, focusing the attention in the climate and soil conditions (the bio-physical environment) together with other factors related to markets, technologies and sector policies (the socio-economic environment). In this research we sought to answer questions like, what were the driver(s) of the decision to replace peanut with soybean?; how much of the decision was due to the climatic factors involved?; was the crop change an adaptation to the actual climate scenario?

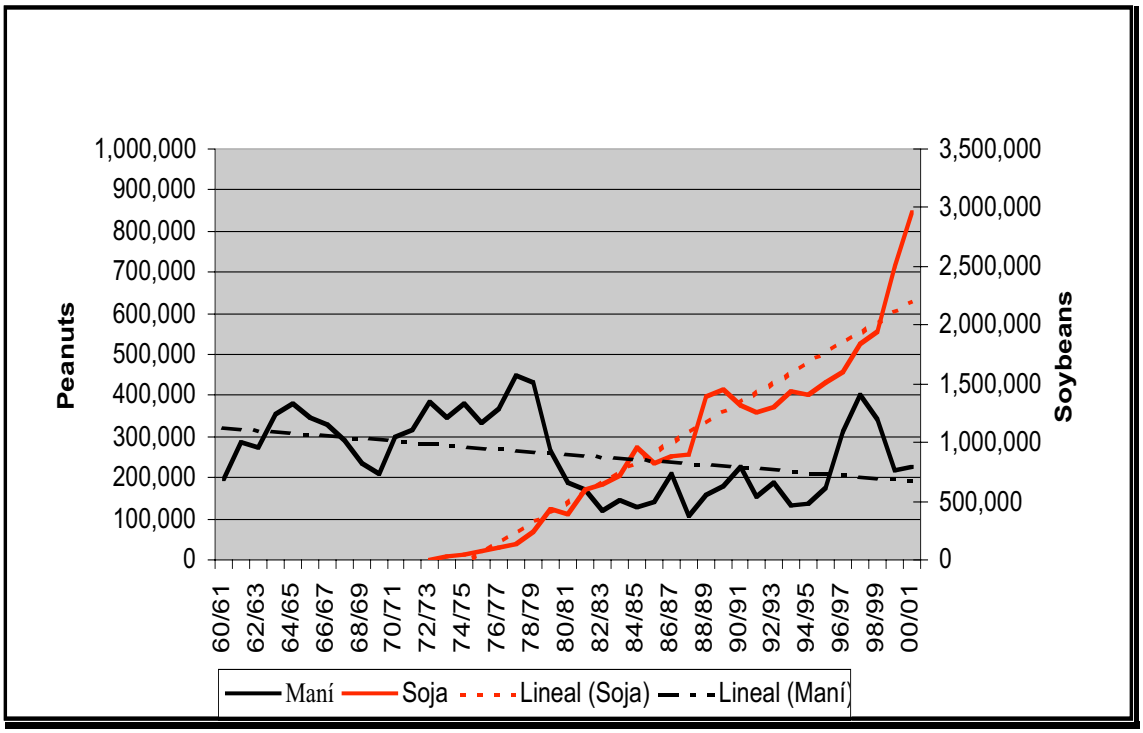


Figure 2. Evolution of peanut and soybean planted area (has) in Cordoba province-Argentina
Source: SAGyRR, Cordoba, 2002

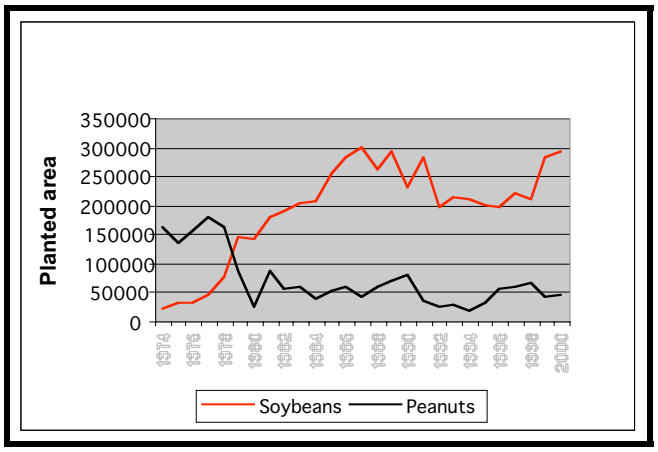


Figure 3. Evolution of the planted area (ha) with peanuts

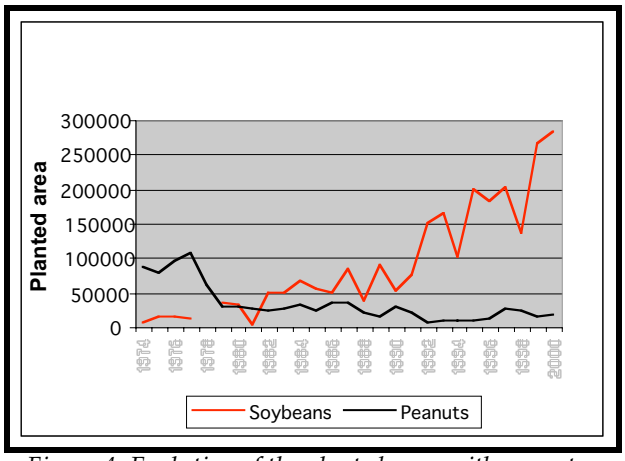


Figure 4. Evolution of the planted area with peanuts

and soybeans in Tercero Arriba Department
Source: SAGyRR, Cordoba, 2002

and soybeans in Rio Segundo Department
Source: SAGyRR, Cordoba, 2002

4.1 The bio-physical environment

i) Impacts of climate variability and climate change on peanut yield and production

The whole Cordoba province, including the study region, showed changes in the mean values of precipitation and temperature over the last century. Mean monthly values of precipitation and temperature were higher for the period 1961/90 compared to those in the 1931/60 series (Seiler and Vinocur, 2005, Technical Report, 2005). Along these changes, inter decadal climate variability was also observed. De la Casa and Seiler (2003) comparing every ten years average of temperature and precipitation from 1941 to 1990, found that the climatic variability affected the grass development and the aptitude for livestock production in the province of Cordoba. In a precipitation trend analysis for Cordoba from 1931 to 2000, Ravelo et al (2002) showed precipitation increases of 0.2 to 4 mm per year according to the year seasons.

Peanut crop yield and production is affected by climate change and climate variability. The effect of changes in the mean and in the daily and inter annual variability of the temperature and precipitation were significant on simulated yields of peanut (Vinocur et al, 2002). The increase of the temperature variability substantially decreased mean peanut yields and increased their variability. This is mainly due to the high frequency of crop failure as the crop season was extended. Such decrease of the mean yields is not so evident when the variability of the peanut yields through the yield series is analyzed at the department level in Cordoba. Yield diminutions due to temperature increments may be compensated by changes in the precipitation. In fact, peanut yield series for the departments of Rio Segundo and Tercero Arriba have shown positive trend in both cases (Figure 5).

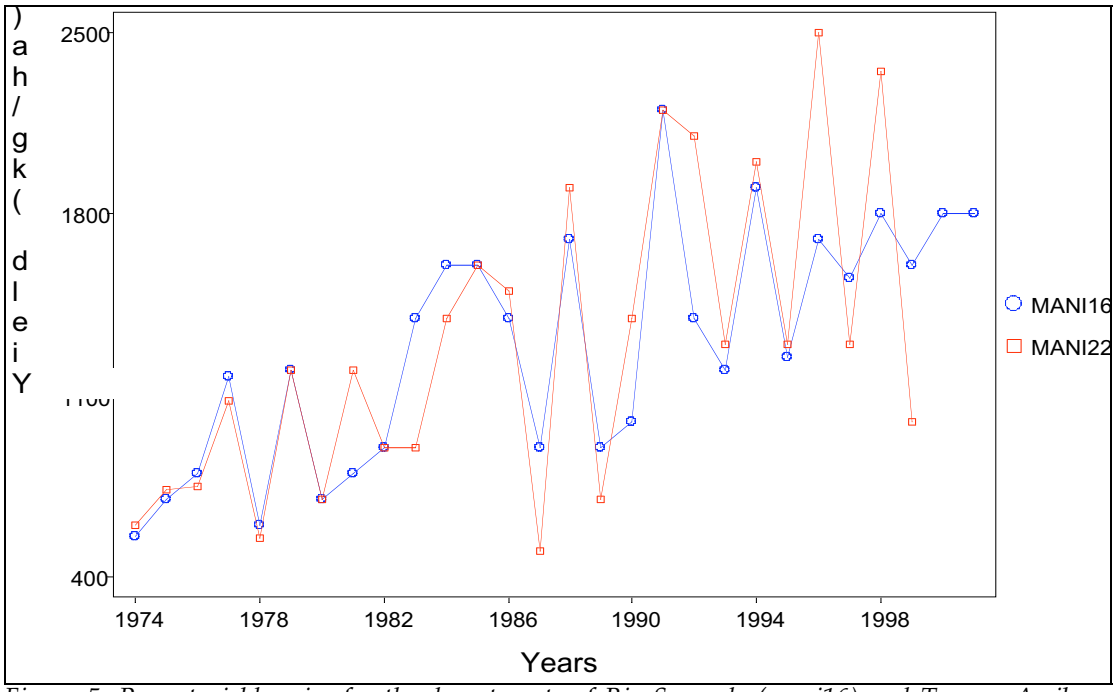


Figure 5. Peanut yield series for the departments of Rio Segundo (mani16) and Tercero Arriba (mani22) in the Province of Cordoba

The inter annual variability of the soybean yields in the same period of time (1974-2000) and for the same departments, presents the same pattern of variability than the peanut yield, although the mean yield of soybean is higher. Figure 6 depicts the variability of the yields for both crops for the department of Rio Segundo. Average yield of peanut in both departments is about 1300 kg/ha, while for soybean is 2000 kg/ha and 1700 kg/ha in the departments of Rio Segundo and Tercero Arriba, respectively.

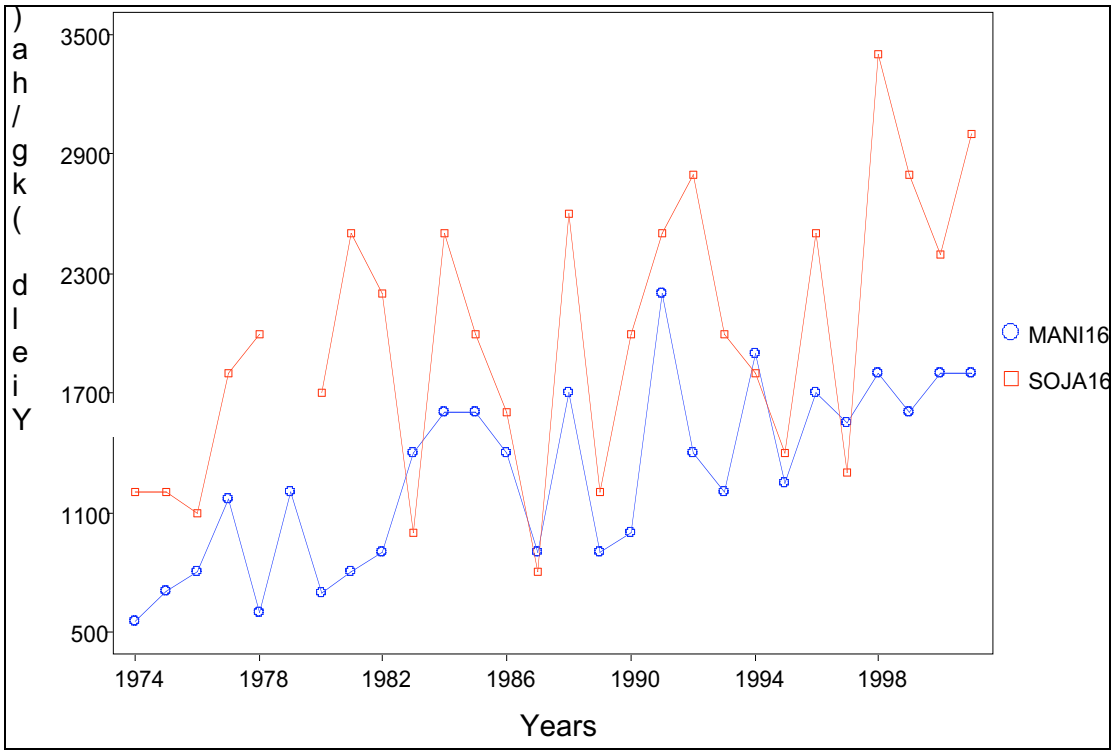


Figure 6. Peanut (MANI16) and soybean (SOJA16) yield variability for the department of Rio Segundo

The similar pattern of response in the variability of the yields of these two crops (peanut and soybean) with close bio-climatic requirements indicates that climate change and variability impacts, at least by the direct effects, are not enough reasons to support the substitution of peanut for soybean in the area. Moreover, peanut yield series shows a fewer number of occurrences of low yields than soybean. For example, comparing frequencies of yields of both crops, as deviations from the trend in percentage, yields lower than 70% happened in 10% and 18 % of the times for peanut in Rio Segundo and Tercero Arriba, respectively, while for soybean were 29% and 23% of the times, respectively (Figure 7).

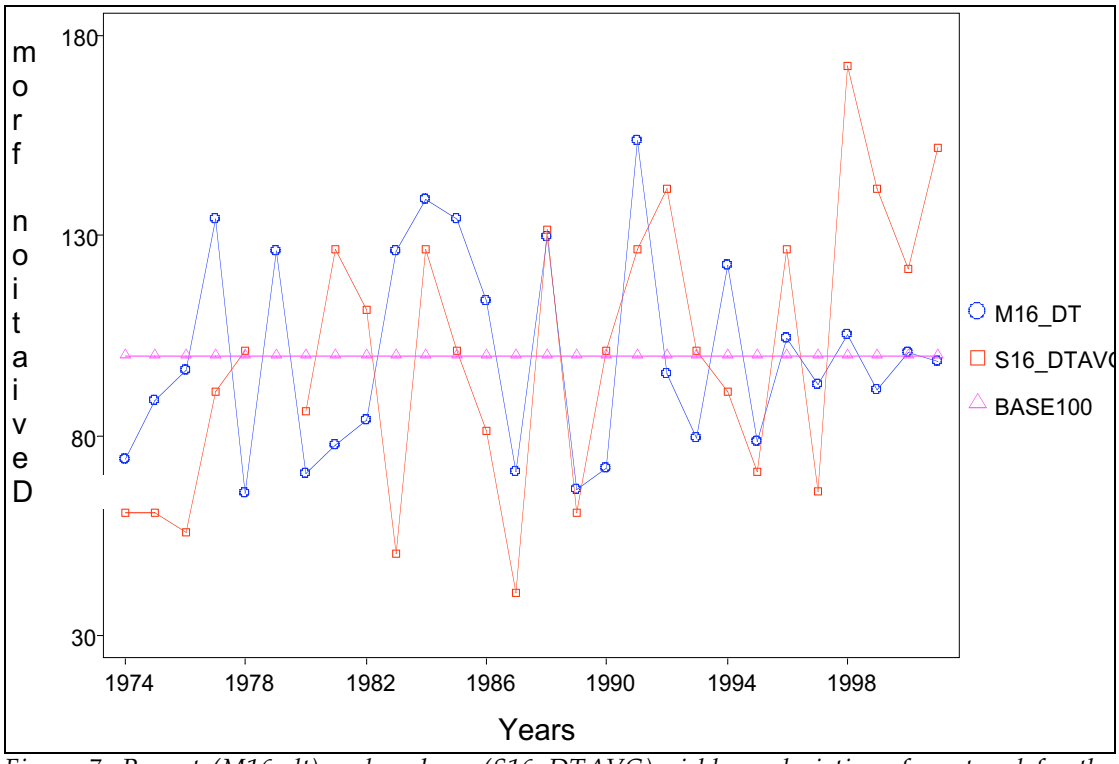


Figure 7. Peanut (M16_dt) and soybean (S16_DTAVG) yields as deviations from trend for the department of Rio Segundo

ii) Impacts from climate change and climate variability on pests and diseases

In addition to the direct effects of the climate variability and climate change on peanut yields and production, it is important to consider also their effects on the incidence of pests and diseases. They are responsible of major yield losses in the peanut crops and as they may require frequent chemical application, they increase crop production costs reducing farmers' incomes. The threat posed by the diseases depends significantly on the temperature and humidity conditions within the crop canopy and the presence of free water on the leaves (Jensen and Boyle, 1966; Klingauf, 1981; Phipps et al, 1997). In the peanut crop study area, March et al (1993) and, March and Marinelli (1995), found that local environmental conditions which favor pathogenic development were also associated to air temperature and humidity measured inside the crop canopy. Considering the relationship between climate variables and the appearance and development of diseases in peanut, disease prediction models were developed (e.g. Johnson et al., 1986, Wu, et al., 1996). For example, a peanut leaf spot (Cercospora sp) disease prediction model for the region (Llames et al, 1999) is based on the weekly duration of relative humidity above 80% and the weekly precipitation, both accumulated along the crop season. Although there are not known specific studies that analyzed the increment in the percentage of peanut diseases due to climate variability and climate change in the Cordoba

province, it is evident their increase in the traditional peanut growing area (Marinelli, 2003 personal communication). This disease increment appears not only in those diseases highly demanding of humidity and temperature but also on those that are favored by drought conditions. Climate variability towards both extremes might favor the appearance and development of different pathogenic groups that negatively influence peanut production and yield.

iii) Soil conditions

Under peanut monoculture, soils change the physical and biochemical conditions which diminished soil fertility and increased soil degradation. Monoculture also increase the amount of pathogenic microorganisms in the soil associated to the crop, causing a rise in production costs for the disease control or for developing new peanut cultivars with genetic resistance to diseases to avoid indirect peanut yields losses (La Nación, 2003).

A lack of crop rotation has also had an effect on the sustainability of the peanut production system. Although no-tillage or reduced tillage systems have been employed to conserve soils, reduce soil erosion , optimize soil water use and diminishes costs, these practices also induce changes in the diseases epidemiology. These changes are determinant of the increased incidence of some diseases (La Nación, 2003; INTA, 1998).

Peanut producers have been practicing peanut monoculture for a long time. The continuous use of this type of cropping system, with all the drawbacks already mentioned, constitutes a fundamental factor to be considered in the analysis of the sustainability of these particular farmers, that is, in their capacity to produce and reproduce the system in the medium and long term.

4.2. Socio-economic and institutional environment

i) International issues

Argentina is the fifth grain producer at the global scale and the third in world grain exports (Bolsa de Comercio de Córdoba, 2002). Destination markets are the European Union (70%), Canada and other American countries (30%). Therefore, circumstances of international markets, including production trends and production commercial policies, strongly affect internal markets. Some of these circumstances are described below:

- Agricultural policies in the United States (US), European Union (EU) and China that support primary production (e.g. providing high subsides for peanuts producers) and apply import taxes on processed products (exchange rate regimes, tariff barriers), distort international prices.
- The concentration of agro industry through mergers of European grain buyers and processors of grain and grain by-products diminishes the competitiveness of the international market structure.
- The relatively high allocation of financial resources to technological and biotechnological developments, contrasting to the Argentinean case.
- High and increasingly rising requirements for meeting quality standards, effectively operating as non-tariff trade barriers.
- Decreasing trends in international prices of peanut grains, oils and pellets.

It can be argue that main economic variables in Argentina –those depending on agricultural and agro industrial production- are directly affected by a number of

foreign policies, whether from countries, regions or trading blocks, making those related activities or sectors exposed to them.

ii) National issues

The main factors that characterize peanut production at the national level are related to the articulation of the commodity chain domestically, the relative complexity of the crop production system and the absence of sector policies (Instituto de Desarrollo Regional, 2003). The following are the main issues describing the economic structure of peanut production:

- Asymmetry is a characteristic in the relationships among agents. The nucleus is the industrial sector constituted by 25 enterprises with high level of investment in technology and infrastructure –8 of them concentrate around 70% of peanut processing. These firms fix commercial rules for independent producers (e.g. sanitary conditions of grains and prices) while at the time, they develop a process of vertical articulation towards the primary sector through buying and renting land, and contract farming. This implies the absence of transparent markets and of reference prices that together with highly variable prices constitute an obstacle for independent producers to plan production and crop rotations.
- High planting costs and high complexity in the primary production process.
- Changing strategies from peanut processors (e.g. the industry has moved from demanding crushing varieties to human consumption varieties of peanuts).
- Absence of sector policies towards: a) overcoming financial problems, mainly related to capital requirements for planting; b) producing technological developments –specifically those to solve producers' problems, instead of for meeting demand requirements; and c) developing alternative insurance markets -mainly those related to highly variable and adverse climatic events.

iii) Producers issues

Recent research (Aguero et al, 1997; Instituto de Desarrollo Regional, 2003) has determined that the result of these international and domestic circumstances of production has caused principally small size farmers to disappear from the market by selling or hiring their land to bigger and well-provided producers who were less vulnerable to different stresses and able to sustain peanut production over time. It was during the 1990's that production scale became one of the main determinants of competitiveness in the new context of free-market policies.

Medium-size and large-scale peanut producers, although vulnerable to pressures not to continue with peanuts, have had other options – principally the option to shift to soybean. As for any decision within a socio-economic unit, it is certainly not possible to identify a unique cause for this decision. However it is important to determine the role of climate in these decisions if one is to view the shift in crop as an adaptation measure. Moreover, it is important to identify the main factors that inhibited these producers to adapt to the changing situation within the peanut production system.

As it has been stated, there is an evident relationship between climatic conditions and peanut yields. However, if as a consequence of climate, yields were reduced by 20% (as an assumption) for both peanuts and soybeans, from a simple calculus it is easily noticed that – with every thing else held constant- impacts on gross margins for soybeans are higher than for peanuts as it is shown in Table 2, below.

Table 2: Impacts from less yields over gross margins (estimation 2000/01)

Item	PEANUTS	PEANUTS (80% average yields)	SOYBEANS	SOYBEANS (80% average yields)
Average prices/qq ($Arg.)	38,00	38,00	14,7	14,7
Yields (qq./ha.)	15,00	12,00	25,00	20,00
Gross Income	**570**	**456**	**367,5**	**294**
Direct Costs	**(351)**	**(351)**	**(244)**	**(244)**
Commercialization	(*)	(*)	70	70
Harvest	71	71	36	36
Planting and protection	280	280	138	138
Gross Margin	**219**	**105**	**123,5**	**50**

Source: *Instituto de Desarrollo Regional, 2003.*
(*) *Commercialization costs for peanuts are already deducted from average prices*

Based on this analysis, impacts from climatic conditions appear to be more costly to soybean production than for peanuts. It can be argued from this hypothetical climatic impact on yields that the risk of climate impacts for farm income is unlikely to have been determinant for agricultural producers' decision to change crops.

On the other hand, if instead of considering impacts from climate on crop yields we consider impacts on prices the result may be rather different. The sensitivity of prices to climatic conditions is higher for peanuts than for soybeans. If there are climate factor(s) that contribute to a reduction in commodity prices either indirectly or directly, then perhaps climate conditions can be shown to have affected crop choice. The analysis of prices revealed that yes, climate has affected the behavior of commodity prices, and the explanation for this influence rests on two particular characteristics of peanut production: biophysical conditions in the region under study and the market structure in which peanuts are produced and commercialized.

Peanuts mono-cropping in this region has contributed to the proliferation of pests and diseases that affect the crop, together with appropriate climatic conditions that favor their development. Moreover, incorporation of new longer cycle varieties (mainly since the incorporation of varieties for human consumption) has tended to increase time of exposure of crop to diseases and to periods with higher moisture implying higher drying cost and the consequent lost of quality (drying processes affect peanuts flavor)(Marinelli 2003, personal communication).

It is precisely through issues of quality (specifically quality criteria established by processors) that climatic conditions affect the prices received by farmers, inducing them to change to another crop. Quality is the main determinant of the final price received by unit. Quality criteria are mediating between climate and soil conditions, crop management practices and production decisions taken by the economic agents.

But what other factors could link climate conditions to decisions to switch crops in the studied region? Even though pests and diseases are a direct consequence of climate, peanuts are not the only crop being affected. Combinations of climatic, agronomic and economic particularities play an important role in that decision. Lower grain quality in a context of a highly concentrated industrial structure with no reference prices and lack of transparency in the criteria that determine quality at the

moment product is received, converge to signal the importance of climate in farmers' crop choices. Moreover, these conditions are accompanied by an industrial production strategy which promoted the substitution of peanut oil processing and demanded peanuts for human consumption with increasing quality requirements. Together, these factors illustrate how the result of a climatic stress is translated into an economic issue and from there becomes a determinant factor in the decision making process.

There is certainly no better way to understand why peanut producers decided to change to soybeans but asking farmers directly. The following are some conclusions from a recent survey (Instituto de Desarrollo Regional, 2003). Again even it is difficult to find climate conditions as directly affecting farmers' decisions to change from peanuts to soybeans, there exist some relationships between climate and their decisions. The farmers surveyed reported decisions based on crop pests and diseases and the lack of transparency in the peanuts commercialization process (see Figure 9). The role of climate is not directly recognized as a causal factor but it is intrinsic to the adduced causes and had affected peanut producers differently depending on their economic and productive structure.

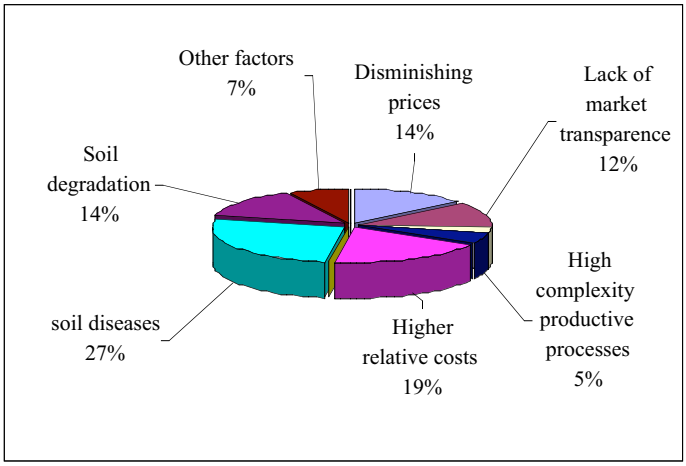


Figure 8. Main factors affecting producers' decisions to leave peanut production.
Source: Survey to ex peanut producers done in 2003, Instituto de Desarrollo Regional (2003).

4.3 Attributes and indicators of adaptive capacity

Despite sensitivity of peanut cultivation to the increased rainfall in the region, farmers work with different soil conditions and have different exposure to crop diseases. These and other factors affect farmers' adaptive capacities. It can be argued that vulnerability of peanut producers in the studied region was the result of highly unstable incomes derived from peanut production due to climatic and market impacts. The lack of flexibility at the farm level prevented farmers from overcoming this sensitivity (e.g., through crop rotations or experimenting with other varieties that might be less sensitive to climate), and this lack of flexibility was a consequence of the absence of reference prices that would help farmers strategically plan their crop mix, as well as the lack of public sector support programs or efficient insurance mechanisms. All these implied farmers lower coping capacity to remain as peanut producers; however some of them had the required adaptive capacity to change to soybean production.

Small farmers in the area of study, the same as for the whole *pampas* region, found themselves in a highly vulnerable situation, mainly in terms of the new macro economic setting that characterized the Argentinean economy since the end of the 1980s. A great number of them abandoned not only peanut production but also

agriculture activities, facing the impossibility to overcome accumulated indebtedness. Those who managed to survive the 1990s benefited from the new exchange rate after the economic crisis and the high international prices for soybeans, permitting them to change to soybean production. This crop shift did not completely resolve the economic situation for some farmers, and those small landholdings of limited access to resources were forced to depend on other sources of income as a livelihood strategy.

Medium size family farmers proved to be more flexible to the new scenario changing to soybean production and enlarging their landholdings through renting land. Although they still cultivate peanuts (mainly varieties for human consumption) because they have both the equipment and knowledge for doing it, the proportion of this crop in relation to soybeans has been constantly decreasing. This has been certainly affecting farmers' income since the economic gross margin per hectare is higher for peanuts than it is for soybeans (as shown in Table 2). Moreover, the expansion of soybean mono- cropping in the *pampas* is considered by some analysts to have negative impacts on the environment in terms of soil degradation and soil erosion. The strong dependence of farmers on marketed inputs (specifically the whole technological package of Round Up Ready Monsanto's soy seeds), the loss of agriculture system diversity and the increasing concentration of land in few large landholdings are also trends of social and environmental concern (Geymonat et al., 2002). These trends are evaluated in terms of the adaptive capacity attributes – flexibility, stability and access to resources- in Table 3.

Large landholdings (even those who have begun soybean cultivation) continue to be engaged in peanut production; however they have moved cultivation onto drier areas by renting land. Peanut processors now face an excess production capacity.

Table 3. Attributes and Indicators of Adaptive Capacity. Medium size peanut producers

ATTRIBUTES	**INDICATORS**	**EVIDENCE**
1. Flexibility		
• Diversity of the agricultural system	*Diversity of seeds available and used, number of planted crops*	*Change to varieties adequate to human consumption*(+) *Incorporating soybean production*(+)
• Resource base (biological, physical, human, social, financial)	*Soil quality and diversity* *Land tenure* *Size* *Financial capital* *Education and age* *Equipment and machinery*	*Degradation* (-) *Owners*(+)/*renters* (+-) *Medium size family farms*(+) *Limited* (-) *Mainly young, with technical education (speculative)* (+) *Appropriate to crop complexity* (+)
2. Stability		
• Exposure to/ impact of market risk	*Variability in output prices*	*Decreasing and highly variable, depending on internal policies and foreign markets* (-)
• Exposure to/ impact of climatic risk	*Main climatic impacts*	*Diminishing yields* (-) *Lower quality due to pest and diseases* (-)
3. Resource Access		
• Access to financial resources	*Formal and informal credit*	*Lack (high interest rates since 1990's)* (-)
• Participation in support programs	*Technology transfer* *Technical assistance*	*New varieties toward human consumption* (+-) *Agrochemical and processing*

		industry (+-)

V. Discussion and conclusions

Given the above analysis of the factors driving the social vulnerability of peanut producers and the motivations for the shift from peanuts to soy in the *pampas*, the question remains as to the extent to which farmers who have switched to soybean were able to overcome climate vulnerability.

Recent research (Technical Report, 2005) indicates that there still exists a high degree of vulnerability to climate impacts among small and medium size family farmers in the studied area relative to farmers in the broader region. This vulnerability is associated with the farmers' high sensitivity to droughts and hail storms and their low indicators of adaptive capacity. Farmers in the studied area (survey 2002/2003) face increasing problems of soil quality, a decreasing number of crops and cattle rising activities. More than 50% (average) of worked area is rented, which oblige farmers to pay a rent (more of the times in advance) even under harvest failure. And only 50 percent of farmers contract insurance against hail risk, while those no contracting insurance adduce to different reasons like the cost of the insurance among others.

A second question relates to the extent to which this process of crop substitution is affecting sustainability at the farm and regional (community) level. The notion of sustainability presented in this paper sustains the vulnerability of farmers to climate variability and change on the availability of (ownership or access) resources that allow them to cope with adverse climatic events. The case study on peanut producers shows that farmers were in general not able to adjust by *themselves* to the combined impacts from climate conditions and changes in the commercial structure of the peanut industry. Instead, those with sufficient capacities (e.g., medium and large-scale producers) have switched from peanut to soybean as an adaptation measure. However, our studies (Wehbe et al., 2005; Technical Report, 2005; Geymonat et al, 2002; IDR, 2003) showed that even though farmers act as rational economic agents when making production decisions, these are often made for a short-term planning horizon. Since cash crop production and soybean mono-cropping have increased in the region, the reliability, stability and resilience of the current crop systems have been put into doubt. At the farm level, productivity growth in the region has not reached the level of other countries because of physical constraints and, sometimes, the lack of full adoption of the whole technological package for soybean production by smaller producers. The process of soil degradation has continued, diminishing soils nutrients availability and degrading its physical and biological properties. At local or community level, unemployment was intensified as a consequence of increasing labor productivity, the use of no tillage production systems and land concentration in larger landholdings. Altogether these processes depressed local economic activity, especially in the small towns which once developed as service suppliers to the agriculture sector. Emigration has now increased from these areas. In a region characterized by the preeminence of family farmers, the strong dependence of them on a highly specialized and external input based production system was translated into fewer production alternatives. These alternatives – more diversified and less input dependent production systems - were before the basis for coping with potential risks. The loss of these alternatives will likely increase farmers' vulnerability to market and climate variability. Specifically, climate events in the area (e.g. droughts, hail storms, flood, and late frosts) imply serious production risks which will have more effect on small landholders with lower capacity to get the required resources to overcome these circumstances.

The peanut case study illustrates the complex motivations that driven individual farmers' decisions, the implications for their own vulnerability and the sensitivity of their productive resources to economic and climate stresses. The close

linkage between sustainability and vulnerability stated in this paper will possible help in orienting local actions and public policies to enhance farmers' capacities to adapt to climate in a coherent way with all dimensions of sustainability, both individually and collectively.

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