

Exploring opportunities for diversification of specialized tobacco farms in the Northwest of Argentina

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**Exploring opportunities for diversification of specialized tobacco farms
in the Northwest of Argentina**

María Daniela Chavez

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Abstract

In the Northwest of Argentina tobacco (*Nicotiana tabacum* L.) is economically and socially important. Tobacco mono-cropping, excessive tillage and inadequate irrigation management cause soil degradation. This and also tobacco production dependence on government subsidies and concern about health damage from tobacco consumption calls for research on diversification. The aim of this thesis was to explore opportunities for diversification of specialized tobacco farms in the Northwest of Argentina.

The application of random and fixed effect econometric models to a pseudo-panel of data of soil analysis reports showed positive elasticity between SOM (soil organic matter) and Nitrogen (N), Phosphorus (P) and Potassium (K) availability. The evaluation of SOM improvement through the use of green manure in relation to N (the only significant elasticity) showed that costs and benefits of green manuring would be equal if SOM would increase from the current content of 1.55 % to 3.61 % which is barely achievable. By applying Principal Component Analysis and Cluster Analysis to Agricultural Census data, four clusters of tobacco farms were determined. The largest two clusters in terms of number of farms (90%) concerned highly specialized tobacco farms with 23-24 ha of tobacco. The Analytic Hierarchy Process (AHP) technique was used to get a ranking of farming activities for diversification. The final weights of farming activities showed that especially livestock activities and spring-summer crops are important alternatives for tobacco production. Following this ranking of activities a quadratic programming model including maximization of expected income minus risk was applied to a typical specialized tobacco farm. The model results for the current situation showed that all irrigated land was devoted to tobacco production while the rest was used for soybean production, irrespective of the level of risk aversion of farmers, resulting in continuous soil degradation. In the situation with the requirement of no further soil degradation, tobacco and soybean were replaced for an important part by beef bull production (including the production of alfalfa and maize for silage for feeding) and farm gross margin decreased by 35% compared to the current situation. In the situation of abolishment of governmental subsidies on tobacco, the production plan consisted of soybean, beef bulls and tobacco; soil degradation was reversed but the gross margin of the farm decreased by some 60%.

Key words: *Nicotiana tabacum*, specialized tobacco farms, tobacco diversification, soil degradation, bio-economic modeling, fixed and random effects, Analytical Hierarchical Process, quadratic risk programming, income risk, risk aversion.

*In memory of my former professor, and later colleague and work mate, Engineer
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Chapter 1

General introduction

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1.1 Background and scope

Tobacco (*Nicotiana tabacum* L.) is the non-food crop with the largest acreage in the world and is currently produced in almost 130 countries due to its performance under widely variable climatic and soil conditions. Tobacco is a controversial crop, not only for causing health problems to tobacco consumers, but also because its production causes environmental damage such as soil degradation, deforestation and water pollution (ITGA, 2012; Geist et al., 2009).

Virginia tobacco, the most grown tobacco type in the world, is a flue-cured tobacco variety that is dried in closed buildings with a heating system. Tobacco plant is grown as an annual crop consisting of a central stalk with 10 to 20 leaves, which are harvested to be transformed into the final tobacco product. The following steps are followed in Virginia tobacco production: seedling, planting, harvesting, curing and classifying (Chavez, 2010; ITGA, 2012).

Tobacco production in Argentina is concentrated in the northern part of the country and it has an economic and social relevance for the economy of this region (Giménez Monge et al., 2009). Salta province (Northwest of Argentina) produced 48.5 % of Virginia tobacco of the country in 2011. Tobacco is one of the main exported products in the province, in terms of monetary values and around 1700 farmers and more than 175,000 people rely on tobacco for living (MinAgri, 2012; MinAgri, 2011; Cámara del Tabaco de Salta, 2008). The Valle de Lerma is a region located in the province Salta and is the focus of this thesis.

Being socially and economically important for Valle de Lerma, tobacco production also presents negative environmental impacts, in particular for specialized tobacco farms. Specialized tobacco farms are farms that only grow tobacco or show low level of diversification. Almost seven decades of continuous mono-cropping, too much tillage and insufficient irrigation management caused a degradation of physical (structure and compaction and low infiltration rate), chemical (loss of organic matter and nutrient unbalance) and biological (decreasing microorganisms diversity) soil properties (Arzeno, 2009; Giménez Monge et al., 2009; Carmona et al., 2008; Guardo, 2002). In addition, tobacco farming involves production and price risk. Variations in temperature, precipitation and irrigation water availability affect tobacco yield and quality. Farmers get a subsidy from the national government in addition to the price paid by the industry. The increasing international pressure to reduce tobacco subsidies,

the increasing concern about health damage from tobacco consumption and soil degradation due to an intensive use, make tobacco production uncertain and call for diversification strategies (MinAgri, 2012; Fittipaldi, 2004; Guardo, 2002).

Farming activities that are technically feasible options for diversifying farms producing tobacco in the area include among others: dairy cows, feedlot, peach, nuts, blueberry, wheat, oat, onion, flowers, paprika, bean and aromatic crops (INTA, 2011; Chavez, 2007; Fittipaldi, 2004; Bazán et al., 1995). Criteria to evaluate diversification activities and the relative importance of diversification activities are missing for the Valle de Lerma. Moreover, what is missing is an assessment of the potential of existing and diversification activities to improve farm income and reduce risk, while accounting for their competition for farm resources (land, labor, irrigation water) and putting a halt to soil degradation.

1.2 Diversification and risk in agriculture

Diversification in agriculture refers to a reallocation of farm resources into new agricultural and non-agricultural products or services on and off the farm (López-i-Gelats et al., 2011; Barry et al., 2000). For this study, diversification is defined as the adoption of farming activities different from tobacco production that use farm assets (land, labor, capital) to produce agricultural products (crops and animals) on specialized tobacco farms. This definition of diversification excludes off-farm employment and off-farm investments (Barbieri et al., 2008).

Diversification is frequently referred to as a risk-reducing strategy (Barry et al., 2000; Hardaker et al., 1997), where risk is defined as the uncertain consequences of an action. Tobacco production is carried out in open air and is exposed to risk due to uncertainty about the weather, water availability, incidence of pests and diseases, prices of inputs and outputs and uncertainty about the government subsidy (Fittipaldi, 2004; Barry et al., 2000; Hardaker et al., 1997). Risk can be reduced by including activities with a low correlation in income (Barry et al., 2000).

In addition to the presence of risk in tobacco production, farmers' attitudes to risk are important. Risk aversion means that a farmer requires a compensation for taking risk as the level of risk aversion increases. A farmer who is risk averse is willing to sacrifice some expected income for a reduction in risk (Acs et al., 2009; Barry et al., 2000).

Existing and potential diversification is studied using different methods. Existing diversification is analyzed by empirical methods to evaluate the impact of diversification on farmers' income, to assess the variables that contribute to diversification decisions and to identify types of farmers regarding diversification practices (Kasem and Tapa, 2011; López-i-Gelats et al., 2011; Démurger et al., 2010; Bravo-Ureta et al., 2006; Benin et al., 2004; Birthal et al., 2006). Potential diversification is investigated by optimization, multicriteria analysis and simulation models to study impacts of diversification alternatives on different factors like income, employment and environment including different levels of risk aversion (Manos et al., 2009; Hengsdijk et al., 2007; Guvele, 2001).

1.3 Bio-economic modelling

Bio-economic modelling is a quantitative methodology that combines knowledge from biophysical and socio-economic sciences to promote interdisciplinary analysis and policy debates. Bio-economic modelling can be applied to different aggregation levels, like field/plot, farm, watershed, region, sector, nation and for past and present, near and far future time periods (Louhichi et al., 2010; Kruseman, 2000).

Bio-economic modelling includes both positive and normative approaches. Positive approaches describe reality using empirical evidence whereas normative approaches prescribe results given decision rules and constraints (Kruseman, 2000, Hazell and Norton, 1986). Positive approaches are defined in this study as statistical representations of farm-level systems that allow for analysing economic and/or technical relationships. Prominent among the positive approaches are econometric models that examine factors influencing a dependent variable, reduce multivariate data dimension and categorize them (Acs et al., 2005; Shuhao, 2005; Lattin et al., 2003; Clay et al., 1998; Byiringiro and Reardon, 1996; Mausolff and Farber, 1995). Normative approaches include, among others, optimization models and multi-criteria analysis. Optimization models allow getting the best combination of farm activities to maximize or minimize one or more objectives, given farm constraints. Optimization models require the specification of a behavioural assumption like profit maximization and risk aversion. Multi-criteria analysis provides a tool to simultaneously consider economic, social and biophysical issues in a subjective way (Saadok et al., 2008; Van Kalker,

2006; Weersink et al., 2002; Kruseman, 2000; Foltz et al., 1995; Hazell and Norton, 1986).

Farm models have been largely developed for farm planning and extension, research planning and evaluation and for policy analysis. Farm models help to understand the conditions under which farmers operate and the effects of different management practices on farmer income and the environment, they analyse how inputs combinations and constraints impact on the farm result and they aim to clarify the effect of policy instruments on management decisions and also on economics and environment indicators (Belhouchette et al., 2011; Acs et al., 2005; Kruseman, 2000; Klein and Narayanan, 1992).

Bio-economic modelling is a challenging approach for analysing the problem of soil degradation due to intensive tobacco cultivation and for exploring opportunities for diversification at farm level. By applying different positive and normative bio-economic models, this study contributes to an understanding of the relations between biophysical and economic aspects of diversification in specialized tobacco farms, in the context of the Valle de Lerma farming systems.

1.4 Description of the study area

This research is carried out in the central part of the Valle de Lerma (24° 30' and 25° 38' Southern latitude and 65° 22' and 65° 37' Western longitude). The landscape consists of an extended plain between mountains at 1200 m of altitude; the rainfall is concentrated in summer time from November to April and it can vary from 400 to 1000 mm. The average temperature in the hottest months (December-January) is around 20 °C and in the coldest months (June-July) is around 11°C (Píccolo et al., 2008; Yañez, 2003). The area is characterized by the use of irrigation to compensate winter and spring water deficits. Next to tobacco, vegetables, bean, beef and milk cattle are products of the area (Píccolo et al., 2008; Bravo et al., 1999).

The central part of the Valle de Lerma includes the departments of Cerrillos, Chicoana and Rosario de Lerma (see figure 1.1). The total area of the three departments is 6781 km² and the population consists of 94,766 habitants (Laboratorio de Teledetección y SIG, 2012; INDEC, 2010). These three departments produce more than 70 % of the total production of tobacco in Salta province (MinAgri, 2008). Because of

the relevance in the total production of tobacco and availability of data, this research will focus on Cerrillos, Chicoana and Rosario de Lerma departments.

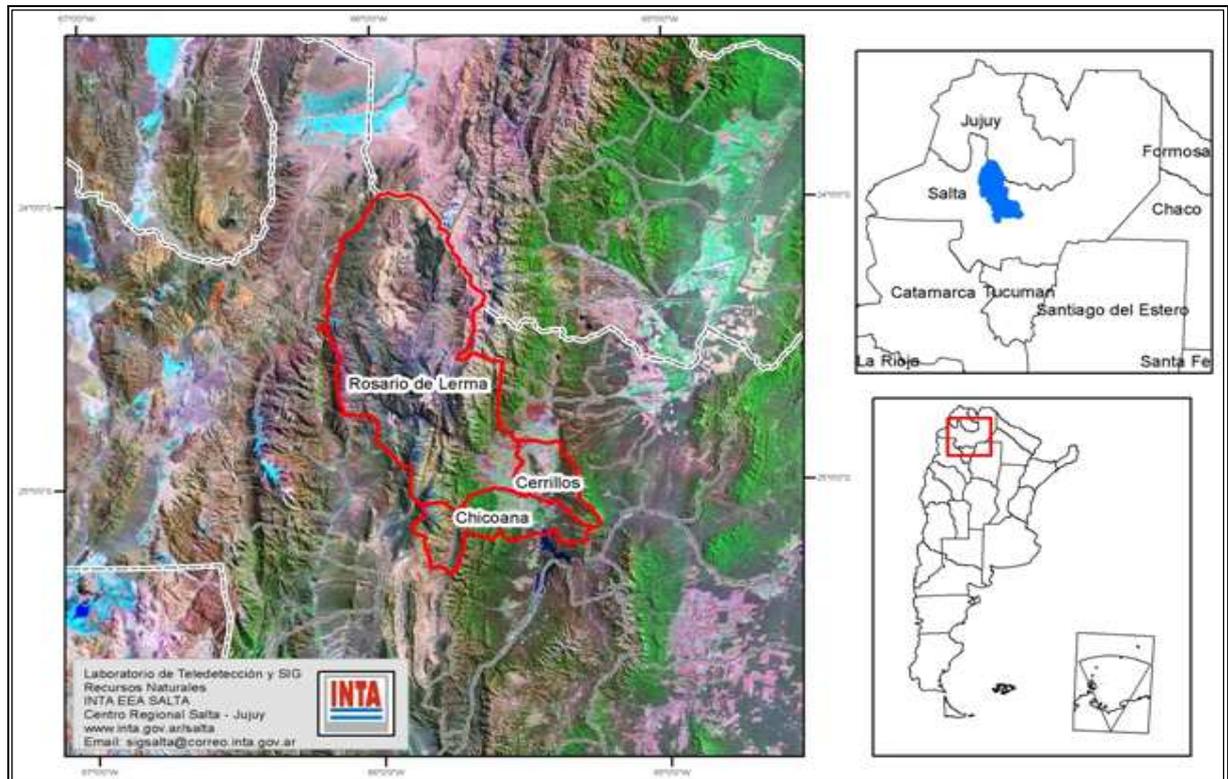


Figure 1.1. Cerrillos, Chicoana and Rosario de Lerma departments.

1.5 Objectives of the research

The overall objective of this study is to explore opportunities for diversification of specialized tobacco farms in the Valle de Lerma. This overall objective includes four specific research objectives:

1. To get insight in the current soil organic matter (SOM) content in tobacco' soils, to explore the potential for improving nutrients availability in the soil by increasing SOM content and to make a economic assessment of green manuring as a measure to improve SOM. It is expected that tobacco soils in the Valle de Lerma have low SOM content and there is scope for improving soils nutrients availability by increasing SOM.

2. To identify typical tobacco farms in terms of determinants of diversification in the Valle de Lerma. It is expected that there are different groups of tobacco farms and that the groups differ in terms of the characteristics that determine diversification possibilities.
3. To develop criteria for assessing diversification activities and to rank different diversification activities based on these criteria. Here, it is assumed that diversification activities can be ranked based on criteria for diversification.
4. To determine optimal plans of current and diversification activities for risk averse farmers on a specialized tobacco farm to stop soil degradation. It is assumed that it is possible to stop soil degradation by including diversification activities on a specialized tobacco farms.

1.6 Synthesis of methods and outline of the thesis

Following the four specific research objectives, the study includes four chapters (2, 3, 4 and 5) in which positive and normative bio-economic methods are used. In each chapter a literature review and a justification for the use of each method in relation with the specific objective are given. Chapter 2 and 3 apply positive approaches while Chapter 4 and 5 apply normative approaches.

Chapter 2 applies random and fixed effect econometric models to pseudo panel data from soil analysis reports of tobacco cultivated fields to explore the potential for improving Nitrogen, Phosphorus and Potassium availability by increasing SOM. Fixed and random effect models allow incorporating unobserved variables such as location specific conditions, management strategies, farmers' skills or preferences, which are not included as regressors. The random effect model provides more efficient parameter estimates than the fixed effect model but assumes that the individual effects and regressors are not correlated. When this condition is not fulfilled, the fixed effect model gives consistent but less efficient parameters estimates (Baum, 2006; Greene, 2002). Also, an economic assessment of the increase of SOM by using green manure is provided. An estimation of an increase of SOM to reach a break-even situation where benefits and costs from green manuring are equal is provided.

Chapter 3 reviews the literature on reasons and determinants for diversification. According to determinants for diversification, a typology of tobacco farms is built using Agricultural Census data. First, Principal Components Analysis (PCA) and then Cluster analysis are applied. By applying PCA, original variables are combined in a lower number of components which are used in the cluster analysis to classify the total number of observations in homogeneous groups of farms (Lattin et al., 2003).

Chapter 4 develops important criteria for assessing diversification activities based on literature review and ranks different diversification activities with respect to those criteria by applying the Analytic Hierarchy Process (AHP) technique developed by Saaty (1980). AHP is a Multiple-Attribute Decision making (MADM) used to get expert judgments of relative weights of different elements (in this case, criteria and activities). Next, weighted goal programming (WGP) and extended goal programming (EGP) are used to aggregate individual weights and group weights respectively (Linares and Romero, 2002). Diversification activities to be included in the ranking are based on farming activities other than tobacco that were observed from the data in Chapter 3, on expert opinion and on literature.

Following the ranking of activities from Chapter 4, Chapter 5 evaluates the potential for applying a number of diversification activities on a representative specialized tobacco farm derived from Chapter 3, to stop soil degradation. A quadratic programming method that includes expected income, income variance and different risk aversion levels is used (Hazell and Norton, 1986; Scott and Baker, 1972). Current SOM level to be included in the model in Chapter 5 will come from the findings of Chapter 2.

Chapter 6 discusses methodological and data issues of the previous chapters and it presents synthesis of results, implications for policy, research and business. The chapter finishes with the main conclusions of the thesis. Figure 1.2 provides an overview of the objectives and methods of the core chapters and the links between them.

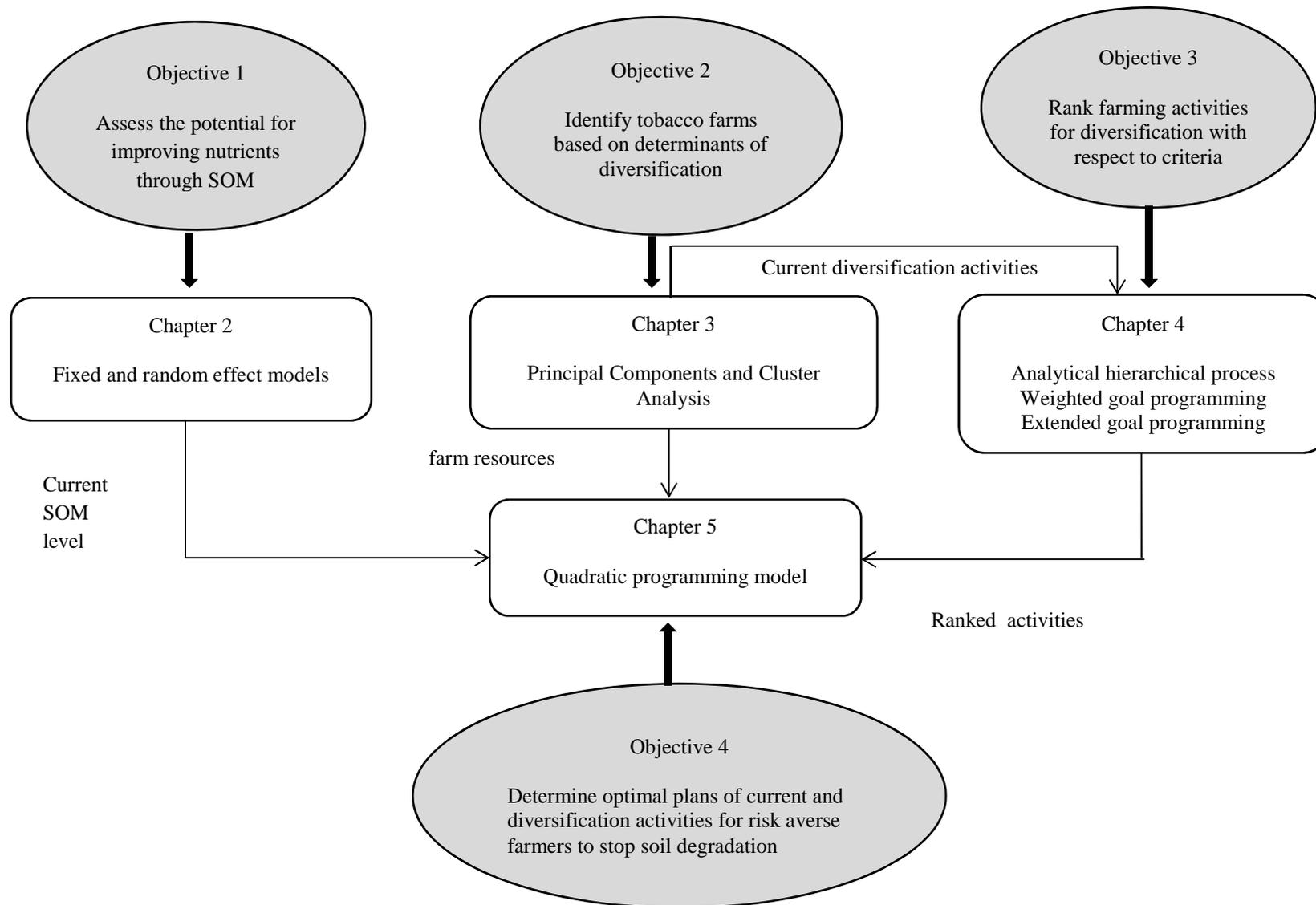


Figure 1.2. Research outline.

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Chapter 2

Exploring the potential for increasing soil nutrient availability via soil organic matter improvement using pseudo panel data

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Abstract

Fixed and random effect models were applied to a pseudo-panel data built of soil analysis reports from tobacco farms to analyze relationships between soil characteristics like SOM and soil N, P and K and to explore the potential for improving nutrients availability by increasing SOM content. These econometric models may account for unobserved specific characteristics such as location-specific characteristics, management strategies, farmers' skills and preferences and environmental heterogeneity. Positive relationships were found between N, P and K availability and SOM. The random effect model reports a highly significant elasticity of N with respect to SOM of 0.75, meaning that an increase of 1 % of SOM will increase soil N by 0.75 %. Using this elasticity, the required SOM improvement of green manuring was calculated at which costs of green manuring would exactly equal benefits in terms of reduced N fertilizer use. Costs and benefits equal if the SOM increased from 1.55 % to 3.61% which is barely achieved according to the literature. Hence, growing green manure crops to increase SOM and thereby N availability is economically not attractive. However, additional benefits may arise from SOM improvement and growing green manuring crops.

Key words: soil degradation, fixed and random effects, SOM improvement benefits and costs, green manure

2.1 Introduction

Soil degradation can be a consequence of erosion, soil nutrient depletion, soil organic matter (SOM) decline, soil pollution, salinization and/or a collapse in soil structure (Wiesmeier et al., 2009; Farquharson et al., 2008; Syers, 1997). SOM is commonly seen as an important indicator of soil productivity; it is a reserve of nutrients, it helps the formation of soil aggregates, enhances soil porosity, increases the water holding capacity and cation exchange capacity, improves root growth, and it activates soil biota development (Yadav and Malanson, 2007; Liu, 2006; Reeves, 1997; Syers, 1997; Pimentel et al., 1995). Soil degradation ultimately leads to a decline of soil productivity. Crop yields tend to decrease and the incidence of a complete crop failure tend to increase when soils become more degraded.

The research reported here, was motivated by the observation that soils devoted to tobacco (*Nicotiana tabacum* L.) production in the Valle de Lerma in Salta province (Argentina) show signs of degradation after almost 70 years of continuous tobacco production (Giménez Monge et al., 2009). Tillage, improper water and nutrient management and absence of crop rotations have been suggested as main reasons for soil degradation (Arzeno, 2009; Carmona et al., 2008). Soils under tobacco show 60 per cent less SOM than soils under 40-year-old forests in the same area. Low SOM content has been implicated for poor soil structure, low nitrogen availability, poor soil aeration and soil compaction. The utilization efficiency of applied nitrogen (N), phosphorus (P) and potassium (K) is low and farmers have increased the application of fertilizers in the last years, to be able to maintain productivity (Arzeno et al. 2008; Corvalán, 1997).

Experiments are broadly applied to study relationships between nutrients availability and soil characteristics and management practices (Hatch et al., 2010; Segal, 2010; Vanlauwe et al., 2000). Also, effect of management practices on SOM have been well-addressed (e.g., Lal, 2009; Liu et al., 2006; Zingore et al., 2005; Reeves, 1997), in part on the basis of simulation models (Torquinst et al., 2009; Syers, 1997). What remains short is quantitative information on the influence of SOM level on nutrient availability in farmers' field and on economic aspects of increasing SOM. This empirical study adds a novel approach on the analysis of soil nutrient availability by applying econometric models to analyze farmers' field data, and by using the established relation to determine economics of SOM improvement through green manure. To our knowledge an assessment of the economic impacts of changes in SOM has not been reported before. Studies usually reveal

the importance of SOM in increasing crop yields but do not provide cost-benefits analyses of measures to improve SOM (e.g., Johnston et al., 2009; Lal, 2009; Pan et al., 2009; Lal, 2006).

The first aim of this study was to get insight in the current SOM content in farmers' fields in the Valle de Lerma. The second aim was to analyze relationships between soil characteristics like SOM and soil N, P and K to explore the potential for improving nutrients availability by increasing SOM content. The third aim was to estimate the required level of SOM improvement by means of green manuring that would be required to make green manuring an economically feasible option for SOM improvement.

2.2 Materials and methods

2.2.1 Study area

The Valle de Lerma (between S24° 30' and S25° 38', and W65° 22' and W65° 37') is a plain with a temperate climate and an annual rainfall between 500 and 1000 mm. Tobacco is cultivated on irrigated land (Bravo et al., 1999; Baudino, 1996). Besides tobacco, bean, corn, vegetables, pastures, fruits, beef and dairy are produced in the region. Tobacco is a highly fertilized with a dosage of 600 to 1000 kg NPK per ha. Soils have a loamy texture in 60%, sandy loam in 20% and silt loam in 20% of the area (Corradini et al., 2005). Soils under tobacco are tilled to allow a good development of plants roots. However, the excessively tilling and mechanical weeding that is found in the region (12 or more operations in a year) contributes to soil degradation (Arzeno, 2009; Arzeno et al., 2008; Guardo, 2002).

2.2.2 Data acquisition

Data were analyzed from three departments (Cerrillos, Chicoana and Rosario de Lerma), which together produce 73% of the tobacco in Salta province (MinAgri, 2008). Here, 90 % of the farms producing tobacco are specialized tobacco farms (Chavez et al., 2010).

The data were derived from 311 soil analysis reports from farms producing tobacco. Those reports cover the period 1999 to 2009. The soil analyses have been made by the Laboratory of the National Institute for Agricultural Technology (INTA- EEA Salta) on requests by farmers and professionals to get a diagnosis of the soil fertility status in the

upper 20-25 cm of the soil (Guardo, 2002). Unfortunately, no field-specific information was available about the number of years of tobacco production and management practices.

Total N was determined by Kjeldahl method. Extractable P was determined by Bray and Kurtz method. Carbon (C) was determined by the procedure proposed by Walkley and Black method. To estimate SOM, the C content was multiplied by 1.724 (Van Bemmelen factor), assuming that SOM contains 58% C. Texture was determined by Bouyoucos. The exchangeable cations K, calcium (Ca), magnesium (Mg) and sodium (Na) were determined following ammonium acetate extraction. The pH was determined in paste (Huidobro, 2009).

2.2.3 Pseudo panel data

Analyzing panel data would be useful to address the problem at hand, because panel data provides the cross-sectional information reflected in differences in nutrient availability and SOM content between farms and time-series or within-subject information reflected in the changes in nutrient availability and SOM content within farms over time (Princeton University, 2012). An ordinary panel data set includes repeated observations of the same unit of observation (firms, individuals) collected over a number of periods (Verbeek, 2004; Yafee, 2003). However, panel data are not available for this research. As an alternative, we construct pseudo panel data for statistical analysis, meaning that observations of different years and different farms are aggregated into groups (cohorts). The averages per year of the groups are treated as individual observations which are followed over time. The cohorts need to have time invariant characteristics and observations should be homogeneous within cohorts and heterogeneous across cohorts (Weis and Axhausen, 2009; Whitaker, 2009; Inoue, 2008).

The geographic area and soil textural class are used to create the cohorts. Reports were sorted following soil textural class. Then, reports concerning a particular texture were grouped by farm (every time it was possible), or the same region or the same department. So each cohort is a farm, a region or a department for which at least two year of data is available. When more than one report was available for the same year and cohort, the average was included as one observation for that cohort and year. When a cohort had only one year of observations it was discarded, since panel data techniques require at least two observations from one cohort. In total 70 cohorts and 190 observations were included in the data set. In Appendix 2.A (Table 2.A.1) the number of cohorts by textural classes and

departments are displayed. The descriptive statistics for all the variables included in the study are displayed in Table 2.1.

Table 2.1. Cohort descriptive statistics of selected variables

Variables	Units	Mean	Median	Std. dev.	Min	Max
SOM	%	1.55	1.48	0.37	0.61	2.31
Sand (particles >50 μm) (Sa)	%	44	44	12	18	73
Clay (particles <2 μm) (Cl)	%	19	18	7	7	56
Silt (particles 2-50 μm) (Si)	%	37	38	7	20	53
Total N (N) ^a	%	0.10	0.10	0.02	0.05	0.14
Extractable P (P)	mg/kg	25.2	24.5	10.1	8.0	53.3
Exchangeable K (K)	mmol _c /kg	8.7	7.5	4.5	3.4	25
pH (H ₂ O)	-	6.95	6.98	0.64	5.65	8.30
C/N	-	9.2	9.1	1.0	5.5	12.5
Exchangeable Calcium (Ca)	mmol _c /kg	70.3	61.9	23.5	41.0	136.0
Exchangeable Magnesium (Mg)	mmol _c /kg	19.3	19.5	5.9	8.5	40.0
Exchangeable Sodium (Na)	mmol _c /kg	5.4	5.0	2.1	2.0	13.9
Water saturation (Ws) ^b	%	29.8	29.1	4.6	21.7	42.0

^a Total N represents the amounts of organic and ammonium nitrogen

^b Water needed to saturate 100 g of dried soil

Mean SOM content is low (<10 g per kg of C), Total N is somewhat limited and extractable P and exchangeable K is relatively high. Soil pH (H₂O) is neutral, while extractable Ca, Mg and Na seem not limiting crop growth (Ortega and Corvalán, 1992).

2.2.4 Econometric models

Fixed and random effects models were used to assess factors influencing N, P and K availability. The random effect model provides more efficient parameter estimates (low standard errors) than the fixed effect model, but it assumes that the individual effects are

uncorrelated with regressors (Baum, 2006; Greene, 2002). If this condition is violated, parameter estimates of the random effect model are not consistent. In that case, the parameter estimates of the fixed effects model are still consistent, though less efficient (Baum, 2006).

The formulation of the fixed effect model assumes that differences across cohorts can be captured in differences in the constant (Greene, 2002). The theoretical form of the fixed effect model is as follows:

$$y_{it} = \alpha_i + \beta x_{it} + \varepsilon_{it} \quad (1a)$$

where y_{it} is the dependent variable, namely N, P and K contents for cohort i in year t , x_{it} is a vector of explanatory variables for the cohort i in year t , and β is the coefficient for explanatory variables. The α_i is the intercept for each cohort and it captures the effect of those variables that are specific for the i -th cohort, they are constant over time and they are considered as fixed unknown parameters. Finally, ε_{it} is assumed to be independent and identically distributed over individuals and time, with mean zero and variance σ_ε^2 (Torres-Reyna, 2010; Verbeek, 2004).

The random effect model assumes that the individual effects, the intercepts of cohorts, are different but they are considered as random, with mean μ and variance σ_α^2 . The theoretical model is as follows:

$$y_{it} = \mu + \beta x_{it} + \alpha_i + \varepsilon_{it} \quad (1b)$$

where y_{it} is the dependent variable, namely N, P, K for cohort i in year t , μ is the intercept term and it represents the mean of the unobserved heterogeneity, x_{it} is a vector of explanatory variables for the cohort i in year t and β is the coefficient for explanatory variables. The error term consists of two components: a time invariant component α_i that accounts for heterogeneity specific to the i th cohort (cross-section specific error) and a remainder component ε_{it} that is uncorrelated over time (Baum, 2006; Verbeek, 2004; Yafee, 2003; Greene, 2002).

A Hausman test was performed to test the random effects model versus the fixed effects model (Verbeek, 2004). If the individual effects are correlated with the regressors, then the Hausman test rejects the random effects model. Because of its simplicity, a log-linear function is used in this research.

Nitrogen

The general specification of the model for nitrogen for a log-linear function is as follows:

$$\log_e y_N = a_{0N} + \sum_{i=1}^k \alpha_{iN} \log_e x_i + \varepsilon_N \quad (2)$$

where $\log_e y_N$ is the natural logarithm of total soil N; $\log_e x_i$ are the natural logarithms of the k variables, namely SOM, pH, clay (Cl), silt (Si) particles and a time trend (tt) variable. This time trend variable is included to reflect technological and management change; α_{0N} , α_{iN} , $i= 1, 2, \dots, k$ are parameters; ε_N is the error term.

Phosphorus

The general specification of the model for P for a log-log linear function is as follows:

$$\log_e y_P = a_{0P} + \sum_{i=1}^k \alpha_{iP} \log_e x_i + \varepsilon_P \quad (3)$$

where $\log y_P$ is the natural logarithm of extractable P; $\log_e x_i$ are natural logarithms of the k variables, namely SOM, pH, saturation water (Ws), clay (Cl), calcium (Ca), sodium (Na) and a time trend (tt) variable. This time trend variable is included to reflect technological and management change; α_{0P} , α_{iP} , $i= 1, 2, \dots, k$ are parameters; ε_P is the error term.

Potassium

The general specification of the model for K for a log-linear function is as follows:

$$\log_e y_K = a_{0K} + \sum_{i=1}^k \alpha_{iK} \log_e x_i + \varepsilon_K \quad (4)$$

where $\log_e y_K$ is the natural logarithm of exchangeable K; $\log_e x_i$ are the natural logarithms of the k variables, namely SOM, pH, clay (Cl), water saturation (Ws), calcium (Ca) content, magnesium (Mg) content and a time trend (tt) variable. This time trend variable is included to reflect technological and management change; α_{0K} , α_{iK} , $i= 1, 2, k$ are parameters; ε_K is the error term.

STATA 10.1 software was used to run the models (StataCorp, 2007).

2.2.5 Analyses of benefits and costs of SOM improvement through green manure

One simple way to increase SOM may be to grow a green manure crop after tobacco harvest at the end of summer time and beginning of autumn. Green manuring relates to the incorporation of fresh plant tissue into the soil (Hamza and Anderson, 2010). By growing green manure the soil is kept covered in winter time and it does not compete with tobacco for land; at the end of winter the green manure can be incorporated to the soil before tobacco plantation starts. Possible green manure crops in the area include the following winter crops: wheat, barley, oat, rye and triticale (Vorano, 2007).

Improvement of SOM might mean a higher soil nutrient availability (this is to be confirmed by the econometric model) leading to economic benefits because of lower fertilization requirements. So, benefits of SOM improvement refer to costs savings in commercial fertilizers. To calculate those cost savings, three effects need to be known: 1) the effect of growing a green manure crop on SOM, 2) the effect of increasing SOM on N, P, and K availability, and 3) the effect of increased soil N, P, and K availability on the required amount of fertilizer.

Long terms experiments are required to assess the effect of growing green manure on SOM improvement. In this study, we estimated the necessary SOM improvement by green manure to be economically feasible because data of the effect of growing a green manure on SOM is not available for the area.

The effect of increasing SOM on soil N, P and K is given by the elasticity of SOM with respect to N, P and K, which was estimated by the econometric models. The effect of increased soil N, P, and K on the required amount of fertilizer is specific for each nutrient. The functions that relate N, P, K fertilizer necessary for tobacco production to changes in soil N, P and K were derived from data of Fernández de Ulibarri (1990). It takes a quadratic form for N and a lineal form for K and P:

$$y_{NF} = 52 - 118x_{TN} - 200x_{TN}^2 \quad (5a)$$

where y_{NF} is N fertilizer, in kg per ha, required for tobacco production, and x_{TN} is soil N, in %.

$$y_{PF} = 93 - 1.8x_{EP} \quad (5b)$$

where y_{PF} is P fertilizer, in kg per ha, required for tobacco production, and x_{EP} is extractable P, in mg/kg. For x_{EP} larger than 20 mg/kg, y_{PF} takes the value of 60 kg.

$$y_{KF} = 127 - 9x_{EK} \quad (5c)$$

where y_{KF} is K fertilizer, in kg per ha, required for tobacco production, and x_{EK} is exchangeable K, in mmol_c/kg. For x_{EK} larger than 8 mmol_c/kg, y_{KF} takes the value of 60 kg.

The common NPK fertilizer in the Valle de Lerma is the compound 11-17-24 (Guardo, 2002), indicating that 100 kg of fertilizer contains 11 kg of N, 17 kg of P₂O₅ and 24 kg of K₂O. The price was US\$ 780 per ton (Coprotab, 2010). Labor costs for fertilizer application was estimated at around 25.25 US\$ per 300 kg of fertilizer.

Costs of SOM improvement refer to yearly variable costs of green manure crops. These costs include seeds, gasoil, labor and machinery maintenance. Technical data to estimate variable costs of green manure crops were obtained from Valdez and Galli (2008), Vorano (2007) and local experts. Variable costs of these crops were estimated at 140 US\$/ha and include one irrigation event (1 US\$= 3.96 Argentinian pesos). The cost of green manure of 140 US\$ per ha equals the value of 162 kg of 11-17-24 commercial fertilizer (including price and application), which is equivalent to 17.8 kg N fertilizer.

2.3 Results

2.3.1 Econometric models

Tables 2.2, 2.3 and 2.4 show the parameter estimates for the fixed and random effects models that were not rejected by the Hausman test. For the log-linear function the elasticity is given by each parameter coefficient.

Nitrogen

The Hausman test ($\chi^2 = 1.02$, Pr= 0.9607) suggests that the random effects model was appropriate for explaining variation in N. The overall R-squared (0.78) is high. SOM content is the only variable with a significant effect; its positive elasticity of 0.75 suggests that an increase of SOM increases soil N. The intercept suggests that there are negative and significant cohorts' specific effects on N availability. The value of rho suggests that almost 25 % of the variability in N was due to differences in cohorts' specific effects.

Table 2.2 Parameter estimates of the random effect model for Nitrogen

<i>Parameter</i>	<i>Coefficient</i>	<i>Std error</i>	<i>Z</i>	<i>P > z</i>
SOM	.75	.03	23.18	0.000 **
pH	-.11	.10	-1.12	0.264
Si	.03	.05	.52	0.603
Cl	.01	.03	.17	0.868
tt	-.01	.02	-0.51	0.609
Intercept	-2.52	.27	-9.26	0.000 **

R-sq (overall) = .7864
Wald chi2 (5)=635.04.21 Prob> chi2= 0.0000
Rho= 0.246
Hausman test: chi2 (5) = 1.02 Prob>chi2= 0.9607

Notes: Number of observations = 190. Number of cohorts=70
Significantly different from zero at ** 5% level.
SOM= soil organic matter; pH= level of acidity or alkalinity; Si= silt; Cl= clay; tt= time trend

Phosphorus

The Hausman test ($\chi^2 = 3.71$, Pr= 0.7165) suggests that the random effect estimator is consistent and is appropriate for explaining variation in P availability. SOM had a positive effect on P, although the effect is not significant at 5%. Notably, pH shows a negative effect on extractable P. The negative elasticity of pH is consistent with results obtained in alkaline soils, where P uptake is negatively influenced by pH (Chandra Sekhara Rao and Subba Rao, 1991). Exchangeable Na was negatively related to P availability, in agreement with results that show a decreased P uptake when salinity is increased (Attumi et al., 1999). The negative elasticity of water saturation is the opposite of what is expected *a priori*. A negative effect of the time trend variable indicates that there has been a decrease of P availability over time. This reduction can be explained by the changes in fertilizer formulation (with lower P content) that has been taking place in the last years (Corvalán, 2012). The intercept suggests that there are positive and significant cohorts' specific effects on P availability. The value of rho indicates that 13% of P variability is due to differences in cohorts' specific effects.

Table 2.3. Parameter estimates of the random effects models for Phosphorus

<i>Parameter</i>	<i>Coefficient</i>	<i>Std. Error</i>	<i>Z</i>	<i>P > z</i>
SOM	.25	.17	1.53	0.127
pH	-.89	.45	-1.98	0.047 **
Na	-.27	.07	-3.73	0.000**
Ws	-1.17	.45	-2.61	0.009 **
Cl	.24	.17	1.39	0.166
tt	-.19	.09	-2.08	0.037 **
Intercept	8.75	1.26	6.92	0.000 **

R-sq (overall) =.2009

Wald chi2 (6)=43.22 Prob> chi2= 0.0000

Rho= 0.132

Hausman test: chi2 (6) = 3.71 Prob>chi2= 0.7165

Notes: Number of observations = 186. Number of cohorts=70

Significantly different from zero at ** 5% level

SOM= soil organic matter; pH= level of acidity or alkalinity; Na= sodium; Ws= water saturation; Cl= clay; tt= time trend

Potassium

The Hausman test ($\chi^2 = 14.55$, Pr= 0.0125) suggests that the cohort effects are correlated to the regressors and that the random effect estimator is not consistent. The fixed effect model is appropriate for explaining the variation in exchangeable K. The only variable with significant and positive effect is time trend, suggesting a positive effect of technological and management change on K availability. The value of rho suggests that 44% of the variance in exchangeable K is due to differences in cohorts' specific effects. In addition to the fixed effect model, a least square dummy variable model (LSDV) was run, to get the particular effect of each cohort. A positive elasticity suggests an increase of K availability due to specific characteristics of that cohort.

Table 2.4. Parameter estimates of the fixed effects models for Potassium

<i>Parameter</i>	<i>Coefficient</i>	<i>Robust Std. Error</i>	<i>t</i>	P > t
SOM	.31	.23	1.34	0.18
pH	1.04	.67	1.54	0.13
Ws	-.08	.58	-0.13	0.90
Cl	.31	.18	1.66	0.10
tt	.28	.09	2.99	0.004 **
Intercept cohort 39	.85	.35	2.44	0.016* *
Intercept cohort 40	.80	.37	2.16	0.033 **
Intercept cohort 48	1.27	.43	2.93	0.004 **
Intercept cohort 49	1.15	.40	2.90	0.005 **
Intercept	-1.28	2.00	-0.64	0.525

R-sq (overall) =.27

F (5, 69)= 6.54 Prob> F= 0.0000

rho= 0.44

Hausman test: chi2 (5) = 14.5 Prob>chi2= 0.0125

Notes: Number of observations = 190. Number of cohorts=70

Significantly different from zero at ** 5%.level

SOM= soil organic matter; pH= level of acidity or alkalinity; Ws= water saturation; Cl= clay; tt= time trend

2.3.2 Analyses of benefits and costs of SOM improvement through green manure

Benefits due to an increase of SOM were estimated only in terms of reductions of N fertilizer required. A positive elasticity of SOM with respect to P and K was also found, but not statistically significant, and therefore no cost savings were estimated for these nutrients. Benefits must cover the costs of SOM improvement via green manure.

The mean N content was 1.0 g per kg of soil. Applying equation (5a) to the basis situation with a soil N content of 0.1% results in a N fertilizer requirement of 38.2 kg/ha. If 17.8 kg of N fertilizer can be saved due to green manuring, the requirement decreases to 20.40 kg/ha. Applying again equation (5a) it can be seen that this requirement corresponds to a total soil N content of 2.0 g per kg, which means an increase of 100% relative to the original soil N content. The elasticity of SOM from the random effect model is 0.75. This means an increase of 133% of SOM is required from the green manure to achieve a N content of 2 g per kg. So, SOM content would have to rise from 1.55 % to 3.61 %.

2.4 Discussion

Fixed and random effect models allow incorporating unobserved cohort (units of observation) effects such as location specific conditions, management strategies, farmers' skills or preferences, which are not included as regressors. Strategies to improve fertilizers management have to account for those particular characteristics of farmers and local conditions.

Factors influencing the availability of N, P, K were searched from literature (Ballari, 2005; Troeh and Thompson, 2005; Hofman and Van Cleemput, 2004; Attumi et al., 1999; Pimentel et al., 1995). Those factors for which data were available were included in the models as explanatory variables.

The significant N elasticity with respect to SOM of 0.75 obtained in the random effect model is consistent with the results found in the work of Shuhao (2005). By applying a two-stage least square regression to evaluate determinants of soil quality, a positive and significant elasticity of 0.65 of N with respect to SOM was found.

Costs of growing green manure were estimated at 140 \$ per ha. However, this may vary depending on the cost of seeds and the number of irrigations.

We estimated that mean SOM content will have to increase by 20.6 g per kg of soil to reach a break-even situation, i.e. benefits and costs of green manure are equal. Such an increase of SOM via green manuring is hardly found in literature. Hamza and Anderson (2010) got a total increase of SOM of 6 g per kg of soil in a 4 year experiment of green manure crops. Hsu et al. (2009) reported a SOM increase of 5 g per kg of soil from green manure after 13 years in a cash crops rotation. Cherr (2006) report increases of SOM between 0 and 10 g per kg of soil following green manure application in short-term experiments.

It is worth mentioning here that a soil N content of 2 g per kg represents a high value for tobacco production (Ballari, 2005). Values higher than 1.8 g per kg may produce problems on leaves maturity and on the final quality of tobacco (Fernández de Ulivarri, 1990). Assuming a maximum target of 1.7 g per kg, green manure should provide an increase of SOM of around 107 %, which is still high and difficult to reach by green manure crops, according to the literature.

Only the reduction of N fertilizer use has been taken into account as the economic benefit of SOM improvement via green manure. However, benefits of SOM improvement may also result from the enhancement of soil aggregates, soil porosity and water infiltration, cation exchange enabling, root growth and soil biota development (Pimentel et al., 1995). In

addition, growing green manure crops may contribute to a reduction of weeds and plant diseases (Hamza and Anderson, 2010). Also green manure crops can be used partially to feed animals (Vorano, 2007).

Future research would benefit from systematic surveys among farmers in the area to allow for building a real panel data set. In this way, a more precise assessment of changes over time of SOM and nutrients will be possible. In addition, it is necessary to relate soil characteristics and nutrient contents to production indicators, like tobacco yields. Also, more detailed information about management practices farmers usually apply is needed. While it is widely recognized that soils have been degraded in the Valle de Lerma, knowledge about cost-effective methods for improving SOM is still limited.

2.5 Conclusion

The average level of SOM of the pseudo panel data was low. This empirical observation indicates that there is soil degradation in the reported tobacco fields.

Pseudo panel data and panel data estimation techniques can be useful tools to establish relationships between soil characteristics and N, P and K availability in farmer's field. Specific cohorts (as proxy for farms) helped to explain differences in nutrient availability.

The random effect model gave a positive and significant elasticity of SOM with respect to N, which means that it is possible to increase N in soil with an improvement of SOM and in this way to save on N fertilizer use. However, a large increase of SOM through green manure crops is required to realize savings in N fertilizer use. Hence, increasing SOM content through green manuring appears economically not beneficial, although additional benefits may arise from green manure, which have not been accounted for in this study.

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Appendix 2.A

Table 2.A.1. Number of cohorts by textural class and department

<i>Department</i>	<i>Clay loam</i>	<i>Loam</i>	<i>Sandy loam</i>	<i>Silty loam</i>	<i>Silty clay loam</i>	<i>Clay</i>	<i>Cohorts</i>	<i>observ</i>
Cerrillos	1 (n= 5) 1 (n=2)	1 (n=6) 1 (n=4) 5 (n=3) 7 (n=2)	2 (n=3) 4 (n=2)	1 (n=4)	1 (n=3) 1 (n=2)	1 (n=2)	26	71
Rosario de Lerma	1 (n= 3) 1 (n= 2)	1 (n=5) 3 (n=3) 6 (n=2)	2 (n=3) 2 (n=2)	1 (n=3)			17	44
Chicoana	1 (n=3) 2 (n=2)	1 (n=5) 3 (n=4) 5 (n=3) 6 (n=2)	5 (n=3) 3 (n=2)	1 (n=3)			27	75

The number of observation (years) per cohort are in parenthesis.

Chapter 3

Creating a typology of tobacco farms according to determinants of diversification in Valle de Lerma

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Abstract

The objective of this article is to identify typical tobacco farms according to determinants of diversification that can be used to explore possibilities of diversification in the province of Salta (Northwest of Argentina). National Agriculture Census data of 278 farms in the main tobacco production area of Salta were used for the analysis. The variables selected concerning determinants of diversification were: land area, irrigation, general capital goods and specific capital goods, ownership of land, education, off-farm work, and labour availability. The analysis of the principal components applied to 16 selected variables allowed to reduce the dimensionality of the data to four components. Those 4 components were used to apply K-means cluster approach to classify the farms. Four clusters were determined. Cluster 1 and Cluster 2 are the largest clusters. These concern highly specialized tobacco farms. They differ regarding determinants for diversification due to different levels of education of the farmer and different levels of off-farm work. Both clusters are interesting for further analysis regarding diversification alternatives to maintain or improve income and to reduce soil degradation. Cluster 3 concerns large tobacco farms being somewhat less specialized than the farms in clusters 1 and 2. Farms in cluster 4 already have a high level of diversification with substantial livestock production. The presence of perennial pastures suggests a better soil management than the other clusters.

Key words: clusters, determinants of diversification, income, *Nicotiana tabacum*, principal components, soil degradation

3.1 Introduction

Tobacco (*Nicotiana tabacum* L.) is the most broadly produced non-food crop in the world and it is cultivated in more than 120 countries, as it can be grown under a wide range of climatic and soil conditions. The share of tobacco produced by developing countries increased from 57 % in 1961 to 86 % in 2006 (Geist et al., 2009; ITGA, 2008). Tobacco is a controversial crop not only because of the negative impact of smoking on health, but also because of environmental issues. In fact, soil degradation, deforestation and water pollution are part of the costs of tobacco production (Geist et al., 2009). The World Health Organization (WHO) recommended measures to control tobacco production and consumption within the Framework Convention on Tobacco Control (FCTC). Recommended measures aimed at reducing the demand for tobacco include, among others, price and tax measures, measures to protect non-smokers from exposure to tobacco smoke and a ban on advertising, promotion and sponsorship. Regarding the reduction of supply of tobacco, the WHO suggests, among others, the promotion of economically feasible alternatives for workers, growers and sellers (WHO, 2003).

Tobacco production represents around a quarter of the total gross value of the agricultural production of the Salta province, in the Northwest of Argentina, and about 175,000 people depend on tobacco production for a living (Cámara de Tabaco de Salta, 2008; Fittipaldi, 2004). Salta produced 30 % of the total tobacco production in the country in 2008. From 1989 to 2008, local tobacco production increased by 93 %. Virginia tobacco represents 97 % of the total production in Salta (MinAgri, 2009). Virginia is a flue-cured tobacco type that is dried in closed buildings with a heating system (ITGA, 2008). The tobacco cultivated area is mainly concentrated in the Valle de Lerma, in the centre of Salta. Cerrillos, Chicoana and Rosario de Lerma departments are the main producers in the Valley; they contribute 73 per cent of the total production in tons in Salta (MinAgri, 2008).

Tobacco production has a relevant economic and social impact in Salta. However, also in this region, the negative environmental effects of intensive tobacco production, like soil degradation are recognized (Corvalán, 1997). In addition, tobacco farming involves production and price risk. Tobacco production is sensitive to temperature, precipitation and irrigation variations. The price of tobacco paid by the industry is completed so far by the national government. Future governmental support is uncertain because of international pressure to reduce tobacco production and consumption and because of the fact that the

governmental price complement is the result of a political bargain process at national level (Fittipaldi, 2004).

The need for a diversification strategy for tobacco production in Valle de Lerma is widely recognised by national and provincial authorities and farming cooperatives (Fittipaldi, 2004). A first step required to be able to explore options for diversification is an inventory of existing tobacco growing systems.

Senthilkumar et al. (2009) suggest that a classification of farms to investigate future alternatives is needed, as it is not possible to conduct an exploration of every farm. The variables used in a typology depend on the aim of the research. In general, variables related to farm size, capital, labor, production model, soil quality and managerial skills are included to identify types of farming systems (Köbrich et al., 2003). Titonell et al. (2005) categorized farms according to resource endowment, production orientation, main constraints faced by farmers, position in farm cycle and main source of income. Anderson et al. (2007) classified farms with different environmental performance. Quantitative techniques have been applied to build typologies to understand the variety of farming systems (Senthilkumar et al., 2009; Pardos et al., 2008; Milán et al., 2006; Nahed et al., 2006; Usai et al., 2006; Köbrich et al., 2003).

This article aims at building a typology to identify typical tobacco farms according to determinants of diversification in the main departments of Valle de Lerma. The results will provide representative farms which will be used in subsequent research to develop prospective models and evaluate potential diversification alternatives.

For the purpose of this article, the concept of diversification entails not only the number of farm activities but also the balance or share of them (Minot et al., 2006). Off-farm activities are excluded from the definition of diversification.

3.2 Reasons for and determinants of diversification

3.2.1 Reasons for diversification

Literature shows a wide variety of reasons for diversification, but all of them can be summarized in two main reasons, namely risk reduction and improvement of income.

Risk reduction can be achieved when different sources of income have low or negative correlations. Thus, the diversification of farming activities may be a way to handle risk (Minot et al., 2006; Upton, 2004; Hardaker et al., 1997).

An improvement in income may arise from scope economies. The concept of scope economies refers to cost savings due to joint production of products compared to costs of separate production. Cost savings were identified for different outputs in German dairy farms (Fernández-Cornejo et al., 1992). The shared use of inputs like labour, machinery and equipment led to cost savings in Dutch vegetable farms (Oude Lansink, 2001). Apart from scope economies, current literature reveals empirical evidence that suggests that diversification influences farmers' income positively (Bravo-Ureta et al., 2006). By building scenarios, Hengsdijk et al. (2007) found that diversification emerged as the most encouraging option to improve per capita income in traditional rice farms, compared to intensification, land expansion and exit from agriculture. Manos et al. (2009) observed that the implementation of alternative crops to a plan including tobacco can increase the income of farmers. Long distances to roads and markets can lead households to diversify into many activities to fulfill consumption needs. This way, transaction costs are saved (Minot et al., 2006; Barrett et al., 2001). Another example is given by Sharma and Sharma (2005). Cost savings can be realized through a rice-wheat crop continuous growing system and replacing the use of fertilizer with the inclusion of a short duration pulse or replacing wheat or rice by other crops, which can be considered as diversification. A shift from food production for own consumption to a cash crop production contributes to improvement of income for smallholders (Minot et al., 2006).

3.2.2 Determinants of diversification

Determinants define the diversification possibilities of a farm. Land area, irrigation, capital goods, land ownership, age, education level, off-farm work and labour availability are considered determinants of diversification in current literature.

Total area of land is important in the case of arable farms. There is empirical evidence in current literature that the area of land has a positive effect on diversification (Bravo-Ureta et al., 2006; Benin et al., 2004). The larger the area of land, the more motivated a farmer will be to devote part of it to introduce diversification.

Irrigation may have a negative influence on the decision to diversify the farm. An empirical analysis showed a positive relation between irrigation and the share of tobacco growing area at household level in India. These results suggest that irrigation does not encourage farmers to diversify (Panchamukhi, 2000).

The type of capital goods may have opposite effects on diversification. Specific capital goods may contribute to output specialization whereas general capital goods may facilitate diversification. For example, general machinery can be used more efficiently if used for different activities at different times of the year (Hardaker et al., 1997; Fernández-Cornejo et al., 1992). It can be expected that the availability of specific capital goods like tobacco curing barns, backpacks, grain machinery, and pasture machinery will prevent farmers from shifting to diversification. Conversely, general capital goods like tilling tools, tractors, sprayers and fertilizer drill, trucks and barns can motivate farmers to diversify.

Empirical data reveal very positive effects of land tenure on output diversification in Central America, suggesting that owners grow a wider variety of production items (Bravo-Ureta et al., 2006). A person who relies on rented land to produce will be limited in the decisions regarding land management (Caballero, 2001). The owner of the land may be more willing to experiment new activities to improve income in a medium or long term. Conversely, a farmer that rents the land may focus on making a profit in the short run.

The age of the farmer may affect diversification decisions. Empirical research found that the number of crops increase with the age of farmers in Vietnam, suggesting that they try new crops as they earn experience along their lives (Minot et al., 2006). The same was found within more diversified farms in West Midlands (United Kingdom). Farmers involved in more diversified farms have significant farming experience; a survey showed that 70 percent of them were over 45 years of age (Ilbery, 1991). The results of a survey carried out on growers in tobacco growing states in the southeast of the USA showed a negative relation between age and being interested in trying different activities from tobacco (Altman et al., 1996). The findings of another survey on tobacco farmers of North Carolina (USA) suggest that younger farmers are more interested in diversification while older growers are more likely to continue cultivating tobacco until they retire (Altman et al., 1998).

Education level has a strong and positive influence on the number of grown crops, stressing the importance of education and ability to understand information coming from extension services or other sources (Minot et al., 2006). Bravo-Ureta (2006) found a positive effect of the average level of education for household members on diversification in Central America.

Labour factors can reflect the social structure and composition of farms and they could be determinants for taking decisions regarding diversification (Manos et al., 2009; Birthal et al., 2006). Off- farm work may influence the decision to diversify. A farmer who Works also outside the farm will probably be less disposed to be involved in many different production

activities due to lack of time. Results of an empirical study suggest that farmers more occupied in other activity than agriculture are less expected to include high value crops because of lack of time and skills (BIRTHAL et al., 2006).

Labour will be used more efficiently if it can be allocated all along the year in a combination of activities (Hardaker et al., 1997). Economies of scope can arise from sharing labor for different outputs. Empirical data suggest that diversification in high-value crops is concentrated among households having enough labour supply (BIRTHAL et al., 2006). If labour supply is a problem, substitution of a high-value and labour intensive crop as tobacco by lower-value and lower labour crops can be a solution (Manos et al., 2009).

3.3 Data and method

3.3.1 Study area

This study focuses on three departments with tobacco production in Valle de Lerma (24° 30' and 25° 38' Southern latitude and 65° 22' and 65° 37' Western longitude), in Salta, in the Northwest of Argentina. The valley is an extended plain between mountains and it has a temperate climate and the annual rainfall varies from 500 to 1000 mm. Tobacco is grown on irrigated land (Bravo et al., 1999; Baudino, 1996). Next to tobacco as the main crop, vegetables, bean, corn, fruits, pastures, beef and milk cattle are products of the area. The departments are Cerrillos, Chicoana and Rosario de Lerma (Figure 1.1.).

3.3.2 Description of data

The source of data for this study was the Agricultural Census carried out by the National Institute of Statistics and Census (INDEC) in 2002. Although the following census was held in 2008, at the moment of submitting the final version of this paper, results from this census were not available yet. The reference period of the census comprises July 1st, 2001 to June 30th, 2002. To summarize, the variables show general information about the farm and the farmer, use of land, agronomic practices, stock of livestock, inventory of buildings, facilities, machinery, equipment and vehicles, permanent and temporary labour, forms of management and marketing channels.

The total number of farms in the study area was 641. Only farms that grow tobacco in Cerrillos, Chicoana and Rosario de Lerma departments were included in this study. After checking important missing values the final usable number of observations was 278.

3.3.3 Selected variables

The selected variables are developed from the original variables in the database that concern determinants for diversification. In total, 16 variables are included to identify types of tobacco farms to explore potential diversification (Table 3.1).

Table 3.1. Selected variables to be used for principal components

Name of the variable ^{a)}	Description	Mean	St.deviation	Maximum
<i>Land area</i>				
Suitable land ^{b)}	Hectares	91.37	169.8	1990
<i>Irrigation</i>				
Irrigated area	Hectares	41.14	58.4	480
<i>General capital goods</i>				
Tractors	Number	3.09	2.7	16
Tilling tools	Number	3.53	2.7	17
Trucks and other vehicles	Number	3.48	4.6	37
Fertilizer drill	Number	0.52	0.7	6
Sprayers	Number	0.83	1.4	14
Barns	Number	2.64	2.0	12
<i>Specific capital goods</i>				
Tobacco curing barns	Number	10.68	11.6	86
Backpacks for spraying	Number	4.56	4.6	30
Grains machinery	Number	0.49	0.8	5
Pastures machinery	Number	0.24	0.9	6
<i>Ownership of land</i>				
Land in property	Hectares	73.47	171.1	2000
<i>Education ^{c)}</i>				
Education level of the farmers	=1 more educated =0 less educated	0.58	0.5	1
<i>Off-farm work ^{d)}</i>				
Farmers with work outside the farm	=1 works =0 does not work	0.05	0.2	1
<i>Labor availability ^{e)}</i>				
Permanent workers	Number	5.08	6.9	52

^{a)}Minimum value for all variables= 0. ^{b)} Suitable land includes not only the cultivated land, but also natural forests and pastures land and apt but not used land. ^{c)} The binary variable level of education of farmers takes the value 1 in when farmers have at least graduated from secondary school. It takes the value of 0 in case farmers have not graduated from secondary school. ^{d)} The binary variable of farmers working outside the farm takes the value of 1 when farmers work outside the farm and 0 when farmers work in the farm exclusively. ^{e)} The variable of permanent workers includes the number of workers that work every day during six or more months per year in the farm.

3.3.4 Principal components analysis

The objective of principal components analysis is the reduction of the dimensionality of the selected data. Data have to be correlated to successfully apply principal components analysis. Two tests are used in this article to verify the feasibility of the data for the analysis: the sphericity test and the Kaiser-Meyer-Olkin (KMO) measure of Sampling Adequacy. The sphericity test developed by Bartlett (SPSS, 2005; Lattin et al., 2003) tests the null hypothesis that the correlation matrix of the population is the identity matrix (a perfectly spherical set of data). If so, data are independent. If the null hypothesis can be rejected it may be justified to use principal components for data reduction. The KMO test indicates the amount of variance in the variables that might be caused by principal factors. High values, close to 1, suggest that a factor analysis may be useful, and values less than 0.5 indicate the analysis is not helpful (SPSS, 2005).

In principal component analysis, the original variables are linearly combined in new variables which are called components. The first components explain as much of the available information as possible. Each component is uncorrelated with each other. There are different criteria that can be followed to decide the number of components to be retained. In this research, Kaiser's rule is followed. This criterion suggests keeping principal components with eigenvalues (variance of each component) larger than one (Köbrich et al., 2003; Lattin et al., 2003). The retained components are used in cluster analysis to determine types of tobacco farms to explore potential diversification. Statistical analyses were performed with SPSS 14.0 and 15.0 (SPSS, 2006; SPSS, 2005).

3.3.5 Cluster analysis

Cluster analysis entails the division of a large group of observations into smaller and more homogeneous groups. A combination of a hierarchical method and a partitioning method for clustering is applied in this study. The hierarchical method is applied in an exploratory way and the solution is used in a partitioning method to improve the cluster solution (Hair et al., 2006; Valeeva et al., 2005; Sharma, 1996).

First, Ward's method, a hierarchical agglomerative method is applied. Ward's method seeks to achieve clusters with the smallest sum of squares within the cluster. This approach starts with each observation in a single cluster and in the following steps clusters are joined, until only one cluster contains all the observations. The graphical result of these steps is called

dendrogram, which is a hierarchical tree structure (Köbrich et al., 2003; Lattin et al., 2003). The agglomeration schedule is another result of the hierarchical method. It shows the two clusters that are combined at each stage and the increase in heterogeneity that happens when two clusters are combined (Hair et al., 2006; SPSS, 2005; Byrne, 1998).

The partitioning method following the hierarchical method is the K-means clustering. The goal of K-means method is to split the total number of observations into a prearranged number of K homogeneous groups based on preferred characteristics. The method can deal with big number of cases and it seeks to make distances within the group as short as possible. In this study, the prearranged number of clusters comes from the previous step. Kruskal-Wallis non parametric test was performed to examine whether the values of the selected variables vary between the groups (SPSS, 2005; Valeeva et al., 2005; Lattin et al., 2003).

A variable used to show current diversification of the farms in each cluster is the Simpson diversity index. The Simpson diversity index (SID) is a scalar number, ranging from 0 to 1, built from the area shares allocated to crops (including those crops devoted to livestock production, natural forests and pastures) and it shows both the number of crops and their relative presence (Benin et al., 2004). The value of the index is 0 in case of complete specialisation and approaches to 1 as the Lumber of crops increases. The SID is calculated as follows:

$$SID = 1 - \sum_{i=1}^n P_i^2$$

where P_i is the proportionate area of i^{th} crop in the total cropped land (Joshi et al., 2003). Crops include cereals, tobacco, crops for seed production, pulses, annual pastures, perennial pastures, vegetables, flowers, aromatics, fruits, other crops, cultivated forests, nurseries, natural pastures and natural forests.

3.4 Results

3.4.1 Principal component analysis

KMO test and Bartlett's test were performed to test the suitability of the data to apply principal components analysis. KMO test result is 0.839 and Bartlett's test result is highly significant ($p = 0.000$) to reject the hypothesis of sphericity of multivariate data.

Principal components analysis was applied on the 16 selected variables as shows Table 3.1. Following Kaiser’s rule, four components were selected. Table 3.2 shows the variance explained by the four extracted components.

Table 3.3 presents the rotated component matrix. This matrix shows the correlations (loadings) between each of the extracted four components and the original variables. It facilitates to establish what each component represents.

Table 3.2. Principal component analysis. Total variance explained by 4 components

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	7.034	43.964	43.964
2	1.462	9.136	53.099
3	1.235	7.718	60.817
4	1.105	6.907	67.724

The total column shows the amount of variance in the original variables accounted for by each component (eigenvalue).The column of percentage of variance presents the ratio of the variance accounted for by each component to the total variance of the entire variables. The cumulative column explains the percentage of variance accounted for by n components. The four components explain 67.724% of the total variance in the original variables. These components can be used to reduce the complexity of the data losing 32.276% of the information.

Table 3.3 presents the rotated component matrix. This matrix shows the correlations (loadings) between each of the extracted 4 components and the original variables. It facilitates to establish what each component represents.

Table 3.3. Correlation of four components with initial variables using principal components analysis

Variables	Component			
	1 ^{a)}	2 ^{b)}	3 ^{c)}	4 ^{d)}
Suitable land	0.253	0.180	0.919	0.029
Irrigated area	0.644	0.422	0.389	0.040
Tractors	0.810	0.426	0.201	0.008
Tilling tools	0.555	0.623	0.169	-0.036
Trucks and other vehicles	0.788	-0.032	0.193	0.110
Fertilizer drill	0.650	0.261	0.072	0.235
Sprayers	0.303	0.532	0.178	0.218
Barns	0.717	0.138	0.214	-0.071
Tobacco curing barns	0.835	0.092	0.263	0.001
Backpacks for sparring	0.684	0.151	-0.148	0.059
Grains machinery	0.403	0.578	0.188	-0.098
Pastures machinery	0.009	0.834	0.053	0.100
Land in property	0.172	0.146	0.946	0.064
Education level of the farmers	0.029	0.257	0.066	0.583
Farmers with work outside the farm	0.073	-0.116	-0.003	0.826
Permanent workers	0.658	0.365	0.332	0.071

Extraction method: Principal Component Analysis. Rotation method: Varimax with Kaiser Normalization. Correlations above 0.5 are in bold. ^{a)} The first component explains 43.964% of the variance and it is positively and highly correlated with tobacco curing barns and tractors. Since tobacco curing barns is less correlated with the other two components it represents better the component. ^{b)} The second component (9.136% of variance) is related to pastures machinery, tilling tools and grains machinery and it can represent production activities that different from tobacco. ^{c)} The third component (7.718% of variance) is correlated with suitable land and land in property and it represents the size and ownership of the farm. ^{d)} The fourth component (6.907) is correlated with education level and work outside the farm and it represents characteristics of the farmer.

3.4.2 Cluster analysis

The four components were used for cluster analysis. First, Ward's method was applied. From this method a preliminary cluster solution was identified. The agglomeration coefficient and the dendrogram were used as stopping rules to choose the number of clusters. A large increase of the agglomeration coefficient suggests that two rather different clusters were combined. In Table 3.4 the agglomeration coefficients of the last stages of Ward's method are presented.

Table 3.4. Agglomeration coefficient of Ward's cluster analysis of the last 10 stages

Number of clusters	Stage	Agglomeration coefficients	Percentage of change in agglomeration coefficient
10	268	225.043	10.19
9	269	255.011	13.32
8	270	288.635	13.19
7	271	334.451	15.87
6	272	393.106	17.54
5	273	455.182	15.79
4	274	596.078	30.95
3	275	756.743	26.95
2	276	927.096	22.51
1	277	1,108	19.51

The last column gives insight about the increase in cluster heterogeneity. The highest change in heterogeneity happens between stages 273 and 274. The agglomeration coefficient of 596.078 represents the heterogeneity when five clusters are reduced to four clusters. The significant jump when five clusters are combined in four clusters suggests the five-cluster solution as a potential cluster solution to be examined in the K-means cluster analysis. The dendrogram (not shown here because of its huge length) also suggests a possible solution of five clusters. Then, the number of clusters used in K-means method was five. A single farm cluster was deleted from the description, ending with four clusters.

Table 3.5 presents the farm types that arise from the four clusters (K-means method). All the selected variables are significant at 0.001 level (Kruskal-Wallis non parametric test), suggesting that farm size, irrigation, general capital goods, specific capital goods, ownership of land, education, off-farm work and labor availability are useful for discriminating clusters with respect to determinants for diversification. Mann-Whitney Test was performed to compare clusters. Bonferroni adjustment for a 0.05 significance level was utilized. Results are given in the description of the clusters. Other variables are used for cluster description next to the initially selected variables, like cultivated area of main cash crops and annual and perennial pastures, number of heads of different livestock and the Simpson diversity index.

Table 3.5. Means values of variables to compare the different clusters

Variables	<i>Cluster 1</i> N= 122	<i>Cluster 2</i> N= 126	<i>Cluster 3</i> N=8	<i>Cluster 4</i> N=21
<i>Land area</i>				
Suitable land (ha)	71.61	49.64	402.38	247.64
<i>Irrigation</i>				
Irrigated area (ha)	26.39	29.94	208.88	128.26
<i>General capital goods</i>				
Tractors (n°)	2.33	2.71	11.13	6.76
Tilling tools (n°)	2.65	3.24	7.38	8.95
Trucks and other vehicles (n°)	2.65	2.93	22.00	4.67
Fertilizer drill (n°)	0.49	0.36	2.00	1.10
Sprayers (n°)	0.75	0.58	2.25	2.33
Barns (n°)	2.05	2.66	8.25	3.76
<i>Specific capital goods</i>				
Tobacco curing barns (n°)	7.80	9.66	56	16.48
Backpacks for spraying (n°)	3.80	4.25	14.63	7.19
Grains machinery (n°)	0.29	0.37	1.50	2.00
Pastures machinery (n°)	0.07	0.02	0.00	2.62
<i>Ownership of land</i>				
Land in property (ha)	59.15	32.34	329.38	214.21
<i>Education</i>				
Education level of the farmers	0.98	0.16	0.63	0.81
<i>Off-farm work</i>				
Farmers with work outside the farm	0.11	0.00	0.13	0.00
<i>Labor availability</i>				
Permanent workers (n°)	3.39	4.22	24.88	12.57
<i>Current level of diversification</i>				
Index of diversification	0.17	0.20	0.51	0.67
<i>Crop production</i>				
Cereals (ha)	1.66	2.58	6.25	14.76
Tobacco (ha)	22.87	24.30	176.25	43.50
Pulses (ha)	9.35	8.01	130.38	52.95
Pastures (ha)	2.69	3.31	23.63	78.57
Vegetables (ha)	0.52	0.82	8.25	2.38
Other crops (ha)	1.73	0.13	0.0	0.95
<i>Livestock production</i>				
Calves (n°)	0.78	4.90	32.00	26.52
Fatten livestock (n°)	0.57	1.25	30.25	62.14
Dairy livestock (n°)	1.61	1.33	0.00	83.38

Cluster 1. *Specialized tobacco farms with a more educated farmer*

This cluster represents 44% of the total farms. The education level of farmers is the highest of all. This group shows a high level of specialization, since the mean value for the SID is 0.17. Farms produce an average of 23 ha of tobacco, which is the lowest of the four clusters. Fifty seven per cent of the farms are farms specialized in tobacco growing (SID = 0). Those farms that are not specialized present also production of pulses, pastures, cereals, vegetables, other crops and livestock.

The variables of education level of farmers and off-farm work help to discriminate cluster 1 from Cluster 2 ($p = 0.000$). Farmers in Cluster 1 are much better educated and work outside the farm in some cases. With respect to Clusters 3 and 4, main differences arise when suitable land, irrigated area, capital goods, land in property education level of farmers and permanent workers are compared ($p \leq 0.003$), except for pastures machinery when it is compared with Cluster 3.

Cluster 2. *Specialized tobacco farms with a less educated farmer*

This is the largest cluster, representing 45% of the total number of farms. This group is the smallest in terms of suitable land. Farmers have the lowest level of education of all the clusters. All farmers in the group work exclusively at the farm. The SID is the second lowest of all (0.20). The mean value for tobacco area is 24 ha. Fifty six per cent of the farms in this cluster show a SID = 0 and they only grow tobacco. This cluster also produces cereals, pulses, pastures, vegetables, other crops and livestock.

In general, this cluster shows differences with Clusters 3 and 4 in terms of suitable land, irrigated area, availability of capital goods, land in property, education level of farmers and permanent workers ($p \leq 0.005$), except for pastures machinery when it is compared with Cluster 3 and for trucks and other vehicles when it is compared with Cluster 4. It is similar to Cluster 4 with respect to a full time devotion to the farm work.

Cluster 3. *Large diversified tobacco farms*

This cluster accounts for 3% of the total number of farms. It has the highest average values for many of the variables selected for sorting out the clusters. The mean value for the SID is 0.51. This group is the largest in tobacco production of the four. The mean value for the

tobacco cultivated area is 176 ha. Full tobacco specialization is not found within the cluster. It is also the largest pulse and vegetable producer of all. They produce also calves and fatten livestock.

Differences with Clusters 1 and 2 mainly follow from suitable land, irrigated area, capital goods, land in property, education level of farmers and permanent workers ($p \leq 0.003$), except for pastures machinery. This cluster also differs from Cluster 2 with respect to off-farm work. The variables that show a higher power to discriminate this cluster from Cluster 4 include general capital goods like tractors, barns, trucks and other vehicles, and specific capital goods like tobacco curing barns and pastures machinery ($p \leq 0.002$).

Cluster 4. *Highly diversified farms with important livestock production*

This cluster comprises 8% of the total number of farms. This cluster shows the highest value in pastures machinery. Besides, farms grow annual and perennial pastures and present the highest number of heads of fatten and dairy livestock. The mean value of the SID is 0.67. The average value for tobacco cultivated area is 43.50 ha, being the second biggest tobacco producers of all the clusters. Full tobacco specialization is not found in this group.

This cluster differs from Cluster 1 and Cluster 2 in almost all the variables selected to discriminate groups (p -value 0.005 or lower), except for off-farm work and trucks and other vehicles when it is compared with Cluster 2.

3.5 Discussion and Conclusion

The combination of principal components analysis and cluster analysis was useful to discriminate four clusters with respect to determinants of diversification. The results reveal that there is heterogeneity among tobacco farms regarding variables that define the possibilities of a farm for diversification in Valle de Lerma.

The results of this study provide a framework to analyze the problems of tobacco production and the possibilities for diversification. Besides the classification of farms according to determinants of diversification, this typology provides insight into the needs for diversification. The clusters recognized in this study will be useful to develop mathematic programming models concerning the analysis of diversification possibilities in the region. Developments from this work include the exploration of the impact of different farming activities on farm income, risk and soil degradation on the specialized tobacco farms in Valle

de Lerma. Cluster 1 and Cluster 2 present the lowest level of diversification of the four clusters and they are highly specialized in tobacco production. Therefore they show the highest need for diversification. They differ mainly in the characteristics of farmer. Farmers in Cluster 1 are much better educated and, in some cases, they have another work in addition to the work in the farm. According to the literature, a more educated farmer will be in better conditions to pick up information regarding different crops and production activities (Bravo-Ureta et al., 2006; Minot et al., 2006). In contrast, off-farm work may prevent farmer to be involved in new and different activities (Birthal et al., 2006). Both clusters have a good availability of suitable land, this being higher for Cluster 1. Availability of land may encourage diversification (Bravo-Ureta et al., 2006; Benin et al., 2004). Ownership of the land would encourage diversification of crops (Bravo-Ureta et al., 2006). Cluster 1 has a higher availability of own land. Farms in Clusters 1 and 2 seem to have an acceptable level of general capital goods and specific capital goods for tobacco. General capital goods may contribute to diversification of outputs, while specific capital goods may encourage output specialization (Hardaker et al., 1997; Fernández- Cornejo et al., 1992).

Cluster 3 is the smallest in terms of number of farms and, in this sense, it is not very representative of the farms in the sample. Diversification in this group may contribute to reduce risk (Minot et al., 2006; Upton, 2004; Hardaker et al., 1997). Irrigated land is devoted mainly to grow tobacco. The intense tobacco production may imply a decrease in soil organic matter content and soil fertility (Corvalán, 1997). The problems of soil fertility may have an impact on the farm income.

Cluster 4 is the most diversified cluster and in this sense they may be reducing risk. They grow perennial pastures, suggesting that they have a better management of the soil than the others. Therefore, this group looks appealing to consider farming activities of diversification for other clusters.

The selected variables were useful to discriminate clusters of tobacco farms. Nevertheless, it is worth noting some limitations and consequences of the selection of those variables. For example, it is inferred from the literature that irrigation does not encourage tobacco farmers to diversify (Panchamukhi, 2000). This statement is reasonable for Valle de Lerma, because tobacco is a profitable crop and farmers with more availability of water will try to grow more tobacco instead of other crops. This, however, does not imply that the provision of irrigation facilities would prohibit shifting away from tobacco. An encouraging plan, taken by the government and/or cooperatives is required to persuade farmers to shift away to other crops (Panchamukhi, 2000). Labour supply can motivate farmers to diversify to

alternative production activities that are less labor demanding than tobacco. If this would be the case then some social consequences may arise. In this sense, Manos et al. (2009) found an increase of unemployment when tobacco was replaced by less labor demanding and more mechanized crops.

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Chapter 4

Assessment of criteria and farming activities for tobacco diversification using the Analytical Hierarchical Process (AHP) technique

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Abstract

Continuous mono-cropping of tobacco, excessive tillage and inadequate irrigation management have caused soil degradation in tobacco farms in the Valle de Lerma. Soil degradation due to tobacco mono-cropping and uncertain economic perspectives for tobacco farming call for diversification strategies for tobacco farmers. The objective of this paper is to develop useful criteria for assessing diversification activities and to provide a ranking of different diversification activities on these criteria. The Analytical Hierarchical Process (AHP) technique is applied to get consistent assessments of criteria and activities from experts and stakeholders. Next, goal programming methods are used to aggregate individual assessments in order to arrive at the final ranking of farming activities for diversification. The five criteria to judge production activities for tobacco diversification are contribution to income, suitability for biophysical conditions, availability of technical information, market feasibility and contribution to soil improvement. The feasibility to market the products stands out with clearly high relative weight, while the other criteria received similar weights. The obtained weights of farming activities showed that especially livestock activities and spring-summer crops are important alternatives for tobacco production. Livestock activities stand out because they have high scores on all criteria. Livestock activities and spring-summer crops will compete with tobacco for resources because tobacco is a spring-summer crop. Therefore, these activities may be more suitable for tobacco farms that operate large area of land. The results of this research can be used in optimization models for determining the optimal mix of farming activities in combination with tobacco production.

Key words: criteria for tobacco diversification, group decision-making, Analytical Hierarchical Process, goal programming

4.1 Introduction

Tobacco (*Nicotiana tabacum* L.) production has an important economic and social impact in Salta province, in the Northwest of Argentina. Tobacco production represents around a quarter of the total gross value of agricultural production of Salta and about 175,000 people rely in this area on tobacco production for a living (Cámara de Tabaco de Salta, 2008; Fittipaldi, 2004).

Many years of continuous mono-cropping, excessive tillage and inadequate irrigation management have caused soil degradation (Giménez Monge et al., 2009; Arzeno, 2009; Carmona et al., 2008; Guardo, 2002). Soil degradation refers to a decline in soil aptitude to produce goods for humans and it is the outcome of erosion, soil nutrient depletion, soil pollution, soil organic matter decrease (SOM), salinization and soil structure collapse (Wiesmeier, 2009; Farquharson et al., 2008). Cultivated soils used for tobacco production in the area show a 60 per cent lower SOM content compared to forests soils (Giménez Monge et al., 2009). Low SOM content causes problems like poor soil structure, weak total nitrogen availability, poor soil aeration and soil compaction (Corvalán, 1997). Wilting and death of plants observed in farmers' field in recent years are related, among other reasons, to soil degradation (Giménez et al., 2009).

To maintain the profitability of tobacco production, the national government supports the price of tobacco paid to the farmers. Since beginning of this century governmental support is uncertain because of international pressure to reduce tobacco subsidies and consumption and because the price support is the outcome of political negotiation processes at national level (Fittipaldi, 2004).

Both, the uncertainty regarding the price of tobacco and soil degradation because of tobacco mono-cropping call for diversification strategies for tobacco farmers in the Valle de Lerma (Fittipaldi, 2004; Guardo, 2002).

Broadly defined, diversification includes a reorganization of farm resources into new agricultural and non-agricultural products or services on and off the farm (López-i-Gelats et al., 2011). This study uses the more restricted definition of Barbieri et al. (2008) which excludes off-farm employment and off-farm investments. Farm diversification refers to farming activities different from tobacco production that use farm assets (land, labor, capital) to produce agricultural products (crops and animals), while at the same time improving soil conditions.

Criteria for selecting diversification activities, such as economic and ecological criteria are not well-defined for the situation in Salta. Moreover, an evaluation of farming activities with respect to diversification criteria is missing. Little is known about which farming activities are suitable for diversifying tobacco farms. Available information on diversification activities includes ecological, technical and economic, and in a few cases market information (Fittipaldi, 2004; Bazán et al., 1995).

Multiple-Attribute Decision Making (MADM) is used within the area of decision making to rank a limited number of alternatives in the presence of conflicting criteria (Sadok et al., 2008). The Analytic Hierarchy Process (AHP) is one of the MADM methods. AHP was developed by Saaty (1980) and is based on a hierarchy structure to represent the importance and relationships of elements (criteria, activity, etc.) in a multi-criteria decision situation. AHP has a broad application in different disciplines. Recent applications are the selection of sustainability criteria and partnership models for agriculture (Poursaeed et al., 2010), evaluation of risk factors in agriculture (Toledo et al., 2011), evaluation of landscape quality components (Vizzari, 2011), selection of sustainable technology for wastewater treatment (Bottero et al., 2011) and evaluation of effective factors for achieving leanness in industry (Anvary et al., 2011).

The objective of this article is to develop criteria for assessing diversification activities and to rank different diversification activities on these criteria. AHP is applied to get consistent assessments of criteria and activities from experts and stakeholders. Next, goal programming methods are used to aggregate individual assessments in order to arrive at the final ranking of farming activities for diversification.

The remainder of this article is structured as follows. The data and method section gives an overview of farming activities for tobacco diversification in the study area. Next, criteria are defined for a farming activity to be considered as a diversification activity. This is followed by a description of the analytical hierarchical process (AHP) technique, the aggregation procedures and the steps to get the final ranking of activities. Results of each step are presented and the paper concludes with a discussion and conclusions.

4.2 Data and Methods

4.2.1 Study area

The Valle de Lerma (24° 30' and 25° 38' Southern latitude and 65° 22' and 65° 37' Western longitude) is a plain between mountains placed in Salta, in the Northwest of Argentina (Baudino, 1996). Next to tobacco as the main crop, bean, corn, fruits, pastures, vegetables, fruits, beef and milk livestock and pastures are farming activities in the area (Chavez et al., 2010). This study is carried out in the central part of the valley, in the departments of Cerrillos, Chicoana and Rosario de Lerma. These three departments cover more than 70 per cent of the total production of tobacco in Salta (MinAgri, 2008). A map of the area is shown in Figure 1.1.

4.2.2 Farming activities for tobacco diversification

Regarding potential diversification activities, garlic, strawberry, onion, peach, nut, fig and dairy cows (including alfalfa, maize and winter pastures) were studied from a technical, economic and financial perspective for the Valle de Lerma (Bazán et al., 1995). Fittipaldi (2004) proposed feedlot production using sugar cane. Seven experts in different farming activities and extension services reported the following activities as technically feasible for tobacco diversification in the Valle de Lerma: onion, bean, soybean, oat (green manure and pasture for animals), wheat, paprika, chili, flowers (in field and greenhouse), flowers for food coloring, maize, aromatic crops, strawberry, stone fruits, apple, blueberry, nut, vegetables, lentil, chickpea, forest trees, dairy cows (including alfalfa, winter and summer pastures and maize), feedlot (including alfalfa), dairy goats (including pastures), and rabbits (Chavez, 2007). Also chia has been reported as a feasible crop for the Valle de Lerma (INTA, 1996).

Chavez et al. (2010) found that highly diversified tobacco farms in the Valle de Lerma produce (next to tobacco) mainly pulses, cereals, pastures, and fatten and dairy cows. A recent survey about currently used diversification alternatives of local advisers (31 persons) suggested that the main alternatives for tobacco are: bean, maize, feedlot and dairy cows, followed by winter crops (wheat, oats, green manure) and pastures. Activities with a minor presence are vegetables, pig production, chicken, aromatic crops, potatoes, paprika and soybean (INTA, 2011).

The diversification activities considered in this study are based on potential and current activities reviewed in the literature and surveys mentioned above. Moreover, the activities are grouped in clusters (groups of farming activities) according to the growing season, type of production (livestock or crops), and length of life cycle of crops (annuals or perennials crops). Clustering enables a proper comparison of activities as it is impossible for an individual to compare more than 7 alternatives at a time (Saaty, 1980). Table 4.1 shows the clusters and the farming activities included in them.

Table 4.1. Farming activities for each cluster

Cluster	Group of farming activities	Farming activities for each cluster
Cl ₁	Autumn-winter crops	Wheat (grain and green manure), oat (for selling fodder and green manure), onion, lentil, chickpea, other vegetables (leafy vegetables, carrots, peas, cabbage, garlic)
Cl ₂	Spring-Summer crops	Bean, soybean, paprika, chili, field flowers (viceroy, gladiolus, chrysanthemum), potatoes, chia
Cl ₃	Perennial crops and forests	Fruit trees and scrubs (blueberry, stone fruits, fig, nut, pome fruits), forest trees (pine and poplar), strawberry, aromatics and medicine herbs (oregano, rosemary, stevia), alfalfa (for selling fodder)
Cl ₄	Livestock production	Beef bulls (including maize and alfalfa), dairy cows (including alfalfa, maize and other pastures), dairy goats (including alfalfa, maize and oats), pigs (including maize) and other small farm animals (rabbits, chickens)

4.2.3 Criteria to select farming activities for tobacco farm diversification

This section develops criteria for selecting diversification activities on specialized tobacco farms in the study area. The selection of criteria is based on a literature review on adoption of crops, innovations, and of technologies by farmers.

Income improvement is an important reason for farmers to diversify (Windle and Rolfe, 2005). The adoption of an alternative cropping plan including tobacco may increase tobacco farmers' income (Manos et al., 2009). Cost savings may appear due to joint

production in a diversification strategy (Chavez et al., 2010). Diversification into high value-added crops may increase farmers' income, provide them with income throughout the year and reduce income risks (Kasem and Thapa, 2011).

Also, in order to be suitable for diversification, production activities have to fit the local bio-physical conditions. In fact, climate and soil conditions impact on adoption of agricultural innovations (Kasem and Thapa, 2011; Wejnert, 2002).

Availability of technical information on a new farming activity or practice is necessary for its adoption by farmers, and in this way, the presence of extension services and attendance to trainings can an important role in adopting the alternative activities (Kasem and Thapa, 2011; Knowler and Bradshaw, 2007; Doss, 2006).

Uncertainty about where new crops can be sold and the contribution to income may influence farmers' decision to diversify to other crops (Kasem and Thapa, 2011). Market accessibility is necessary for purchasing inputs and selling outputs. Marketing and transportation facilities play an important role in adopting new crops. The lack of credits may limit the adoption of agricultural innovations (Kasem and Thapa, 2011; Doss, 2006; Rasul et al., 2004).

Crop diversification may be recommended as a way of improving sustainability of a system, i.e. a rotation strategy can improve soil fertility, reduce soil erosion and reduce soil borne pests and diseases (Hennessy, 2006; Sharma and Sharma, 2005). Conservative practices improve soil fertility, increasing yields and lowering yield variation in the long run (Knowler and Bradshaw, 2007). Fertilizer use may be an indicator of environmental pollution (Manos et al., 2009). Farmers are more motivated to adopt soil conservative practices, if they visualize long-term benefits like increased production and reduced labor input (De Graaff et al., 2008). Furthermore, in the case of tobacco farms, a diversification activity needs to reduce soil degradation (Chavez et al., 2010).

Based on this literature review, five criteria for adoption of diversification activities are defined, i.e. contribution to income, suitability of local bio-physical conditions, availability of technical information, market feasibility and soil improvement. The hierarchical model for ranking farming activities for diversification is shown in Figure 4.1.

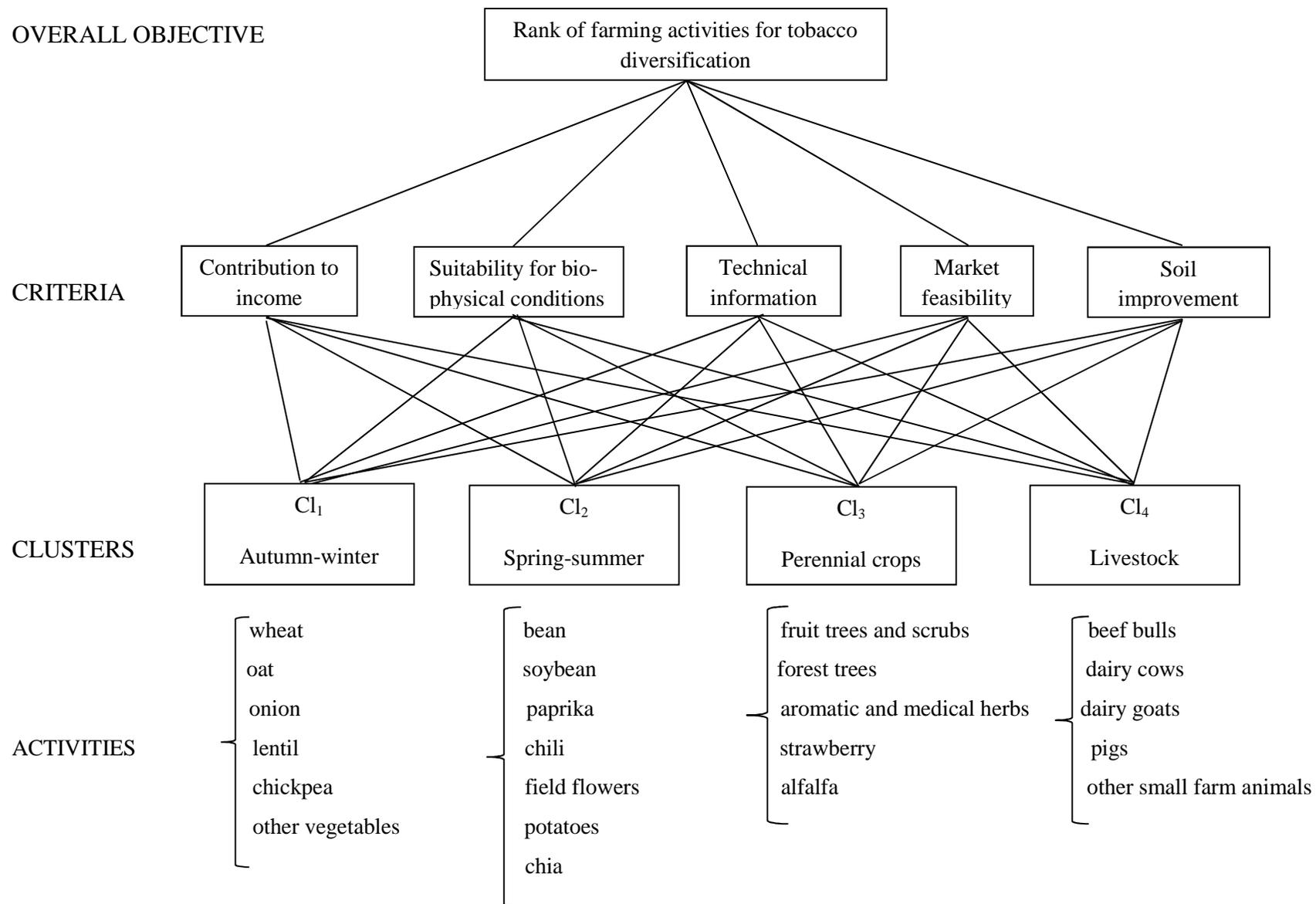


Figure 4.1. Hierarchical model for ranking farming activities for a diversification strategy.

4.2.4 Method

4.2.4.1 The Analytic Hierarchy Process

The AHP method is used to determine consistent sets of estimates of relative weights and criteria from experts (Saaty, 1980). Each expert makes a judgement of relative weights (w_i) of all pairs of the n elements and these judgements are included in as a number (a_{ij}) in a square matrix A (i.e. the comparison matrix):

$$A = (a_{ij}), (i, j = 1, 2, \dots, n) \quad (1)$$

where $a_{ij} = w_i/w_j$ and $a_{ji} = 1/a_{ij}$

If all judgments are perfectly consistent, then $a_{ik} = a_{ij}a_{jk}$ for all $i, j, k = 1, \dots, n$. This characteristic is known as cardinal consistency or cardinal transitivity. This requirement, however, is often not achieved in practice, since making perfectly consistent value judgments is difficult. Therefore, it is important to know the degree of deviation from consistency in every judgment (Keeney, 2002; Saaty, 1980).

Matrix A has an associated eigenvector with the maximum eigenvalue. The normalized eigenvector gives the priority ordering and the maximum eigenvalue is a measure of the consistency of the judgment. The eigenvector is found using the following condition:

$$AW = \lambda_{\max} W \quad (2)$$

where A is the comparison matrix, W is the eigenvector and λ_{\max} is the maximum eigenvalue, which is used to estimate the consistency of the result. A positive reciprocal matrix like matrix A is fully consistent when λ_{\max} is equal to n (Saaty, 1980). The closer λ_{\max} is to n , the more consistent is the judgement. The deviation from consistency is called the consistency index (CI) and is represented by:

$$CI = \frac{(\lambda_{\max} - n)}{(n - 1)} \quad (3)$$

The estimated consistency is compared with the consistency value from a randomly generated reciprocal matrix, which is called the random index (RI). The Consistency Ratio (CR) relates the CI to the average RI for the same order matrix (fixed value):

$$CR = CI / RI \quad (4)$$

If the CR is lower than or equal to 0.10 then the consistency is acceptable (Saaty, 1980). When a CR larger than 0.10 is detected, the respondent is asked to reconsider changing her/his more problematic judgments.

The procedure described above establishes the priorities of the elements of one level of hierarchy with respect to an element of the next level. If there are more than two levels, several priority vectors are combined in a final priority vector for the lowest hierarchy level.

To perform the pairwise comparisons, a scale of numbers is needed. This scale indicates how many times more important or dominant one element is over another element with respect to the criteria on which they are compared (Saaty, 2008). The Saaty's scale, which is a scale from 1 (equally important) to 9 (extremely more important) is used for comparisons (Saaty, 2008).

4.2.4.2 Aggregation procedures

In the process of ranking activities, individuals belonging to different groups of stakeholders are asked to give scores. These individual scores are aggregated into a unique collective preference using a group decision making process (González-Pachón and Romero, 2007). First, from the individual weights, group weights have to be derived and second, the weights of the different groups are aggregated to get final weights of the analyzed elements (Linares and Romero, 2002).

Aggregation of individual weights

Once the priority vector for each respondent is estimated, the next step is to aggregate the individual weights to get the weights of each group of stakeholders. Linares and Romero (2002) propose a weighted goal programming (WGP) model to get the weights for each group. The model is as follows:

Achievement function

$$\text{Min} \sum_{i=1}^q \sum_{k=1}^{N_j} (n_{ik} + p_{ik})^\pi$$

s.t

Goals:

$$W_i^j + n_{ik} - p_{ik} = a_i^{kj} \quad i \in \{1, \dots, q\}, \quad k \in \{1, \dots, N_j\}, \quad (5)$$

where N_j is the number of members of the j th group, a_i^{kj} is the weight attached to the i th element (criteria, activity) by the k th member of the j th group, W_i^j is the weight attached to the i th element by the j th group, n_{ik} and p_{ik} are negative and positive deviation variables and π is a parameter representing a general metric. Model (5), using the value $\pi = 1$ is applied to each of the respondent groups and weights assigned to each element by every group are obtained. For $\pi = 1$ the sum of individual disagreements is minimized which is suitable when possible outliers are members of the same groups and their relative influence may not be important (Linares and Romero, 2002). If the number of group members is uneven, the resulting group weight using this procedure is the median of the weights given by the group members. However, if the number of group members is even, the solution space is the interval enclosed by the two central values (Linares and Romero, 2002). When two answers were available to aggregate individual weights, both weights represent alternative optimal solutions; in those cases the average was taken and normalized to get the group consensus weight.

Aggregation of group weights

After the priority vector for each group of respondents has been estimated, the group weights are aggregated to obtain the final weight for each element. Linares and Romero (2002) propose an extended goal programming (EGP) model to get the weights for all the groups. The EGP model is a compromise between the maximization of the average agreement (WGP model) and minimization of the disagreement of the most displaced group (MINIMAX or Chebyshev model). The model is as follows:

Achievement function

$$\text{Min}(1 - \lambda)D + \lambda \sum_{i=1}^q \sum_{j=1}^m (\bar{n}_{ij} + \bar{p}_{ij})$$

s.t

Goals:

$$\sum_{i=1}^q (\bar{n}_{i1} + \bar{p}_{i1}) - D \leq 0,$$

.

$$\sum_{i=1}^q (\bar{n}_{im} + \bar{p}_{im}) - D \leq 0,$$

$$W_i^G + \bar{n}_{ij} - \bar{p}_{ij} = W_i^j \quad i \in \{1, \dots, q\}, \quad k \in \{1, \dots, m\},$$

Accounting rows:

$$\sum_{i=1}^q (\bar{n}_{i1} + \bar{p}_{i1}) - D_1 = 0,$$

$$\sum_{i=1}^q (\bar{n}_{im} + \bar{p}_{im}) - D_m = 0,$$

$$\sum_{i=1}^q \sum_{j=1}^m (\bar{n}_{ij} + \bar{p}_{ij}) - Z = 0$$

(6)

D represents the disagreement of the group that deviates mostly from the consensus achieved. The variables D_1, \dots, D_m represent the disagreement of each group with the consensus obtained, W_i^G is the weight attached to the i th criteria by all the groups, Z is the sum of all disagreements, and λ is a control parameter. For $\lambda = 0$ the disagreement of the most displaced group is minimized. This situation is generally indicated as the principle of the minority. For $\lambda = 1$ the average agreement is maximized. This is indicated as the principle of the majority. Intermediate values of λ represent compromises between these two solutions (Linares and Romero, 2002). GAMS 23.7 software was used for the aggregation procedure.

4.2.4.3 Ranking of farming activities for diversifying tobacco farms

In this research two hierarchy levels are distinguished (criteria and farming activities) and four steps are made to rank farming activities. The first step entails the assessment of the weights of the criteria. The second step consists of the assessment of the weights of clusters (groups of farming activities) with respect to each criterion. The third step entails the assessment of the weights of farming activities within each cluster with respect to each criterion and the fourth step ranks farming activities. In the first three steps, priority vectors are obtained and combined into a priority matrix, which results in a final priority vector for the farming activities level (Saaty, 1980). The scheme is presented in Figure 4.2.

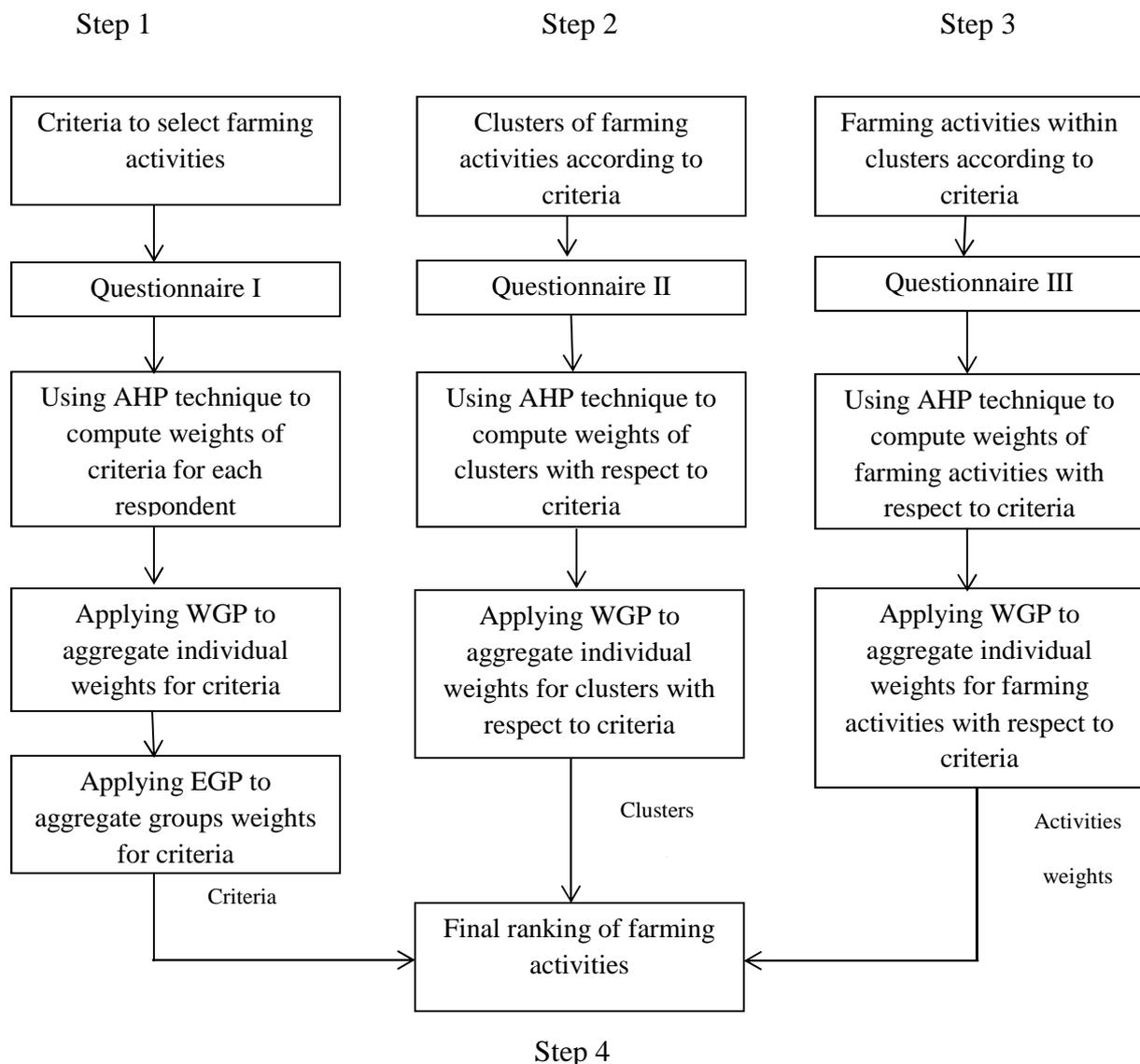


Figure 4.2. An overview of the four steps to rank farming activities.

Step 1. Assessment of criteria weights

The five criteria required for evaluating farming activities in terms of their suitability for diversifying tobacco farms defined in 4.2.2 were included in a questionnaire for pairwise comparisons. The questionnaire form included an introduction with the objective of the research, a description of each criterion, the meaning of each number of the comparison scale and a table to be filled in for criteria comparison. This questionnaire was submitted to a panel of five farm advisers, three researchers, three farmers, two tobacco cooperative representatives and two government representatives. Farm advisers include public extension services employees and private farmers' advisers. Researchers work for a public institute for agricultural technology located in the study area. Farmers are tobacco producers in the area. Tobacco cooperative representatives are employees of the tobacco cooperative that represent the opinion of the tobacco cooperative. Government representatives are employees of the governmental Secretary of Agricultural Issues at local level. The purpose was to get a view of the main stakeholders in tobacco monocropping issues and diversification possibilities. After receiving a questionnaire back from a respondent consistency was determined. If consistency was too low, a meeting with the respondent was organized. In this meeting the cycle of pointing the respondent at the inconsistencies, revision of the judgement by the respondent, and recalculation of the consistency was repeated until the consistency ratio was equal to or lower than 0.1.

Assuming that each group of stakeholders is a homogeneous group, model (5) was applied to get aggregated weights per group. Next, model (6) was applied to aggregate the groups' weights.

Step 2. Assessment of cluster weights with respect to criteria

To make comparisons between groups of activities (clusters) in terms of the selected criteria, a second questionnaire was designed. The completion of this questionnaire required broad technical knowledge. For this reason, only researchers with a general overview of farming activities were asked to fill out the questionnaire. The groups of farming activities in the questionnaire came from Table 4.1. Data are processed using the procedure described in Section 4.2.4.1, consistencies were checked for each respondent and corrected as explained in step 1, if inconsistencies were detected. Assuming that researchers are a homogeneous group,

model (5) was applied to produce an aggregation of weights. From this step, the cluster weights were obtained.

Step 3. Assessment of farming activity weights within each cluster with respect to criteria

This step compares farming activities within each cluster in terms of the selected criteria. A questionnaire per group of activities was sent to researchers. The researchers differ per group of farming activities because this step required specific and detailed knowledge about the activities within each group. These researchers differ from the ones selected for the previous step. Diversification farming activities to be included in the questionnaire come from Table 4.1. Respondents' judgments were processed following the procedure in 4.2.4.1. Judgments were checked and corrected as explained in step 1 if inconsistencies were detected. Assuming that researchers are a homogeneous group, model (5) is applied to aggregate the weights of them. From this step the activity weights with respect to each criterion were obtained.

Step 4. Ranking of farming activities

The final ranking of a farming activity is achieved by first multiplying the criterion weight, cluster weight and farming activity weight for that criterion and then summing up these scores for the five criteria.

4.3 Results

This section describes the results of the four steps in the previous section. More detailed results from individual experts can be obtained from the authors upon request.

4.3.1 Step 1. Assessment of criteria weights

Table 4.2 presents the criteria weights aggregated per group. These weights are obtained by applying model (5) to the judgments of the individual group members.

Table 4.2. Criteria weights aggregated for each group

Group	Criteria				
	Contribution to income	Suitability for biophysical conditions	Technical information	Market feasibility	Soil improvement
Farm advisers	0.263	0.265	0.147	0.279	0.046
Researchers	0.105	0.420	0.251	0.091	0.133
Farmers	0.192	0.178	0.064	0.509	0.057
Tobacco cooperative representatives	0.131	0.156	0.203	0.149	0.361
Government representatives	0.220	0.083	0.188	0.302	0.207

Market feasibility is the most important criterion for three of five stakeholder groups. Farmers give by far the highest weight to market feasibility, suggesting that the possibility to sell the product is of utmost importance for them when considering alternative activities. Researchers are clearly focusing more on the suitability of alternative activities to local conditions. Tobacco cooperative representatives judge the contribution of any alternative to the soil as the most important criterion. This suggests they are more focused on preserving tobacco production in the area, since soil conditions are among the main conditions for future tobacco production.

Next, model (6) was applied to aggregate the five groups' weights. Table 4.3 presents the final normalized weights for criteria by applying EGP for two ranges of parameter λ .

Table 4.3. Normalized aggregated criteria weights for two ranges of parameter λ

λ	W_1	W_2	W_3	W_4	W_5	Z	D	D_1	D_2	D_3	D_4	D_5
[0-0.5]	0.146	0.199	0.210	0.296	0.149	2.047	0.505	0.361	0.505	0.505	0.381	0.295
[0.51 -1]	0.198	0.184	0.194	0.288	0.137	1.972	0.580	0.286	0.580	0.430	0.456	0.220

Note: W_1 weight for contribution to income; W_2 weight for suitability for biophysical conditions; W_3 weight for technical information; W_4 weight for market feasibility; W_5 weight for soil improvement
 D_1 disagreement of farmers' advisers; D_2 disagreement of researchers; D_3 disagreement of farmers; D_4 disagreement of tobacco cooperative members; D_5 disagreement of government members

Two solutions were obtained: one corresponds to the principle of the minority and the other to the principle of the majority. In the interval for λ of [0-0.50], which includes the principle of the minority, there was no unique solution. Instead, a range of values for W_1 and W_4 led to the same Z (total disagreement) and D (maximum disagreement). To end up with a unique solution an additional criterion next to minimizing D was introduced, i.e. minimization of maximum disagreement for each criterion individually. The results show that researchers and farmers have the highest disagreement with the weights determined in the λ interval [0-0.50]. The resulting weights confirm the importance of market feasibility for different groups.

In the interval for λ of [0.51-1] the emphasis shifts towards maximization of the average agreement over all groups and weights (i.e. the principle of the majority). Results for this interval show that the final weights get closer to those of farmers' advisers, farmers, and government representatives. It is clear that the judgments of researchers deviate from the judgments of the other stakeholder groups. Regarding the change of weights, contribution to income becomes more important while the weights of all other criteria slightly decrease.

4.3.2 Step 2. Assessment of cluster weights with respect to criteria

In Table 4.4 the normalized aggregated weights for clusters with respect to criteria of the researchers are presented.

Table 4.4. Cluster weights aggregated for two respondents

	Contribution to income	Suitability for biophysical conditions	Technical information	Market feasibility	Soil improvement
Cluster 1: autumn- winter crops	0.095	0.165	0.166	0.134	0.109
Cluster 2: spring-summer crops	0.488	0.232	0.454	0.444	0.066
Cluster 3: perennial crops and forests	0.094	0.062	0.060	0.058	0.460
Cluster 4: livestock production	0.323	0.541	0.320	0.364	0.365

The total of each criterion (column) is equal to one. Higher weights represent a higher contribution to a criterion. Clusters 2 and 4 present the highest weights, except for soil improvement in the case of spring-summer crops. Cluster 4 presents a more balanced contribution to the five criteria. Cluster 2 receives the highest weights for three of the five

criteria while it got the lowest score for soil improvement. These results show that respondents highly value spring-summer crops because of its contribution to income, the availability of technical information, and its market feasibility. When it comes to soil improvement, however, spring summer crops have the lowest score, probably because of more soil movements and low soil protection during the period of highest rainfall and temperature in the year. Clusters 3 and 4 represent perennial crop production (alfalfa in case of livestock production), which keeps the soil more protected along the year. Cluster 1 includes green manure crops, contributing to improve soil organic matter in the soil and decrease erosion effects during winter time.

4.3.3 Step 3. Assessment of farming activity weights within each cluster with respect to criteria

The aggregated farming activity weights are displayed in Table 4.5. Total for each column (criterion) within each cluster is equal to one. Weights can only be compared within each cluster and not over the clusters, since the clusters as a whole have different weights as is shown in Table 4.4.

Table 4.5. Aggregated farming activity weights within four clusters with respect to criteria

Farming activities	Contribution to income	Suitability for biophysical conditions	Technical information	Market feasibility	Soil improvement
Cluster 1: two respondents					
Wheat	0.119	0.137	0.205	0.156	0.315
Oat	0.053	0.243	0.188	0.135	0.433
Onion	0.098	0.132	0.084	0.189	0.043
Lentil	0.287	0.168	0.177	0.141	0.076
Chickpea	0.337	0.193	0.215	0.208	0.075
Other vegetables	0.105	0.127	0.131	0.170	0.059
Cluster 2: two respondents					
Soybean	0.079	0.052	0.221	0.403	0.159
Paprika	0.288	0.256	0.220	0.135	0.081
Chili	0.177	0.187	0.230	0.121	0.069
Field flowers	0.157	0.188	0.061	0.071	0.355
Potatoes	0.053	0.031	0.061	0.100	0.040
Chia	0.058	0.139	0.021	0.027	0.135
Cluster 3: two respondents					
Fruit trees and scrubs	0.488	0.186	0.267	0.227	0.193
Forests trees	0.073	0.154	0.077	0.166	0.250
Strawberry	0.140	0.039	0.148	0.076	0.038
Aromatic and medical herbs	0.145	0.286	0.284	0.249	0.056
Alfalfa	0.154	0.336	0.223	0.283	0.463
Cluster 4: three respondents					
Beef bulls	0.285	0.227	0.414	0.442	0.312
Dairy cows	0.463	0.204	0.313	0.252	0.312
Dairy goats	0.090	0.204	0.112	0.080	0.258
Pigs	0.124	0.182	0.107	0.084	0.075
Other small farm animals	0.038	0.182	0.054	0.142	0.043

Chickpea looks as the winter crop with better performance in contribution to income and technical information, while oats performs as better adapted to biophysical conditions and

it reports as the best crop to improve soil, because as a green manure it contributes to increase soil organic matter content.

Paprika shows the highest weights for two criteria (contribution to income and suitability for biophysical conditions) within cluster 2. Soybean presents the highest weight of all crops and it corresponds to market feasibility criteria (soybean is one of the main exports of Argentina, principally to China). Field flowers production requires less tillage and they keep the soil more covered than other crops; these may be reasons for their high contribution to soil improvement criterion.

Fruit trees and scrubs stand out in their contribution to income, suggesting that they are a promising diversification activity for tobacco farms, mainly because of their profitability. Alfalfa has the highest weights for soil improvement, suitability for biophysical conditions and market feasibility; its contribution to income has the second place below fruits trees and scrubs, however its relative weight is lower.

Beef bulls and dairy cows show the highest weights for the five criteria. While dairy cows get a higher score in contribution to income, market feasibility is lower, due to limitations to sell milk to the local milk cooperative. The high weights for soil improvement are due to growing alfalfa as roughage.

4.3.4 Step 4. Ranking of farming activities for diversifying tobacco farms

Table 4.6 shows the final farming activity weights for each criterion and overall weight for λ between 0 and 0.5 (results for λ between 0.51 and 1 are shown in Appendix 4 A). The activities are ranked based on their overall weight. The final weight of the farming activity for each criterion is calculated as the product of the weight of the farming activity within a cluster by the weight of the cluster for the criterion and by the weight of the criterion. The overall weight is calculated as the sum of the five weights divided by the total sum of all weights (normalization).

Table 4.6. Farming activities weights with respect to criteria and overall weight ($\lambda = [0-0.5]$)

	Contribution to income	Suitability for biophysical conditions	Technical information	Market feasibility	Soil improvement	Overall weight
Beef bulls	0.013	0.024	0.028	0.048	0.017	0.137
Dairy cows	0.022	0.022	0.021	0.027	0.017	0.114
Soybean	0.006	0.002	0.011	0.053	0.002	0.077
Paprika	0.021	0.012	0.011	0.018	0.001	0.065
Dairy goats	0.004	0.022	0.008	0.009	0.014	0.059
Bean	0.013	0.007	0.009	0.019	0.002	0.052
Chili	0.013	0.009	0.011	0.016	0.001	0.051
Pigs	0.006	0.020	0.007	0.009	0.004	0.048
Alfalfa	0.002	0.004	0.003	0.005	0.032	0.048
Other small farm animals	0.002	0.020	0.004	0.015	0.002	0.045
Field flowers	0.011	0.009	0.003	0.009	0.004	0.037
Fruit trees and scrubs	0.007	0.002	0.003	0.004	0.013	0.031
Chickpea	0.005	0.006	0.007	0.008	0.001	0.029
Oat	0.001	0.008	0.007	0.005	0.007	0.029
Wheat	0.002	0.005	0.007	0.006	0.005	0.026
Forests trees	0.001	0.002	0.001	0.003	0.017	0.025
Lentil	0.004	0.006	0.006	0.006	0.001	0.024
Potatoes	0.004	0.001	0.003	0.013	0.000	0.023
Other vegetables	0.001	0.004	0.005	0.007	0.001	0.019
Aromatic and medical herbs	0.002	0.004	0.004	0.004	0.004	0.018
Onion	0.001	0.004	0.003	0.008	0.001	0.018
Chia	0.004	0.006	0.001	0.004	0.001	0.017
Strawberry	0.002	0.000	0.002	0.001	0.003	0.009

Beef bulls and dairy cows show a substantially higher overall weight than the other activities. Both activities present a more balanced contribution to the five criteria than the other activities. Beef bulls present the highest weights for suitability for biophysical

conditions and technical information of all activities. Soybean has the highest contribution to market feasibility of all activities; however contributions of soybean to the other four criteria are low. Paprika is below soybean in the overall ranking and it has a less unbalanced contribution to criteria than soybean. Alfalfa has the highest contribution to soil improvement of all activities, but very low weights for of the remaining criteria. Dairy cows and paprika present the highest weights for contribution to income. Dairy goats share the second place with respect to suitability for biophysical conditions with dairy cows and it is close to pigs and other small farm animals.

4.4 Discussion

This study is the first to define and evaluate the relative importance of criteria for diversification of specialized tobacco farms and in ranking farming activities in terms of the criteria. Analytical Hierarchical Process (AHP) was used to determine and evaluate criteria. This decision making method allows to convert subjective assessments into numerical scores, which is valuable especially when there is a lack of quantitative and precise data and when knowledge and judgment of stakeholders or experts is used to improve decision making (Sadok et al., 2008; Alphonse, 1997).

To realize a consistency ratio of 0.1 or lower with regard to the judgments of respondents, the cycle of reconsidering judgments needed to be used zero to a maximum of three times. A consistency ratio of 0.1 being acceptable is criticized among others by Bana e Costa and Vansnick (2008). They claim rightfully that a consistency ratio of 0.1 does not match with the requirement of cardinal consistency. However, reaching cardinal consistency will in practice be very difficult if not impossible, because it will often require many more cycles of reconsideration, leading to frustrated respondents as they are constantly pointed at their inconsistency. In such cases the risk is high that respondents will quit their cooperation to the research before full consistency is reached. Moreover, we consider the ranking of farming activities following from the procedure we used absolutely plausible.

Stakeholders in tobacco production and diversification compared criteria and assessed their relative importance in the first step of the research. A specific group, namely researchers compared farming activities in terms of their importance with respect to the different criteria in the second and third steps. In these steps only researchers were involved because of the required specific and detailed knowledge about activities that are in many cases not familiar to the other stakeholder groups.

Available literature does not recommend a specific number of respondents for AHP applications. In the investigation carried out by Lai et al. (2002) six individuals participated in software selection. Anvari et al. (2011) got opinions of 5 and 6 experts in automotive industries. Vizzari (2011) does not mention the number of experts included to compare landscape components. In this study, the number of respondents in each group ranged from two to five which is in line with Linares and Romero (2002) who included two to four respondents in each group.

4.5 Conclusion

From literature research, it appears that five criteria are important when judging alternative activities for diversification of tobacco production. These are the contribution to income, the suitability for biophysical conditions, the availability of technical information, the feasibility to market the products, and the contribution to soil improvement. The feasibility to market the products stood out with clearly high relative weight, while the other criteria received similar weights. The high weight for market feasibility indicates that market research is important for assessing the suitability of current and potential farming activities as diversification activities for tobacco farms.

The obtained weights of farming activities showed that especially livestock activities and spring-summer crops are important alternatives. Livestock activities stand out because they have high scores on all criteria partly because ruminants are fed with alfalfa, which contributes highly to soil improvement. Livestock activities and spring-summer crops will compete with tobacco for resources because tobacco is a spring-summer crop. So these activities may be more suitable for tobacco farms that operate a large area of land. Tobacco farms that cultivate a small area of tobacco more likely have to devote all their land to growing tobacco and can grow something else during winter time, after tobacco harvest. Although farming activities like chickpea, oat, wheat, and lentil (autumn-winter crops) were not ranked in the first positions, they may be a feasible alternative for small farms to complement tobacco production. Also pigs and other small farm animals (rabbits and chickens) are appealing alternatives for farms with land constraints.

The results of this research can be used in optimization models for determining the optimal mix of farming activities in combination with tobacco production. Such models can provide further insights into the use of resources within a farm in a diversification strategy.

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Appendix 4.A

Table 4.A.1. Farming activities weights with respect to criteria and overall weight ($\lambda = [0.51-1]$)

	Contribution to income	Suitability for biophysical conditions	Technical information	Market feasibility	Soil improvement	Overall weight
Beef bulls	0.018	0.023	0.026	0.046	0.016	0.129
Dairy cows	0.030	0.020	0.019	0.026	0.016	0.111
Soybean	0.008	0.002	0.010	0.052	0.001	0.073
Paprika	0.028	0.011	0.010	0.017	0.001	0.067
Dairy goats	0.006	0.020	0.007	0.008	0.013	0.054
Bean	0.018	0.006	0.008	0.018	0.001	0.052
Chili	0.017	0.008	0.010	0.015	0.001	0.051
Pigs	0.008	0.018	0.007	0.009	0.004	0.045
Alfalfa	0.003	0.004	0.003	0.005	0.029	0.043
Other small farm animals	0.002	0.018	0.003	0.015	0.002	0.041
Field flowers	0.015	0.008	0.003	0.009	0.003	0.038
Fruit trees and scrubs	0.009	0.002	0.003	0.004	0.012	0.030
Chickpea	0.006	0.006	0.007	0.008	0.001	0.028
Oat	0.001	0.007	0.006	0.005	0.006	0.026
Wheat	0.002	0.004	0.007	0.006	0.005	0.024
Lentil	0.005	0.005	0.006	0.005	0.001	0.023
Forests trees	0.001	0.002	0.001	0.003	0.016	0.023
Potatoes	0.005	0.001	0.003	0.013	0.000	0.022
Other vegetables	0.002	0.004	0.004	0.007	0.001	0.017
Chia	0.006	0.006	0.001	0.003	0.001	0.017
Aromatic and medical herbs	0.003	0.003	0.003	0.003	0.004	0.004
Onion	0.002	0.004	0.003	0.007	0.001	0.016
Strawberry	0.003	0.000	0.002	0.001	0.002	0.008

Chapter 5

Exploring diversification as an option to address soil degradation on a specialized tobacco farm in the Northwest of Argentina

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Abstract

Many years of continuous tobacco mono-cropping, excessive ploughing and poor irrigation control have caused soil degradation in the Valle de Lerma in Salta. Moreover, tobacco farming in Salta entails a production and a price risk which is increasing because of uncertainty of governmental subsidies. Both soil degradation and future low prices call for diversification strategies for tobacco farmers in the Valle de Lerma. The objective of this article is to determine optimal plans of current and diversification activities for risk averse farmers on a specialized tobacco farm to stop soil degradation.

To reach this objective, a quadratic programming model of a typical specialized tobacco farm is developed. Soil organic matter is included in the model by means of the concept of the carbon balance. The carbon balance is the difference between carbon supply and carbon decline in a year. Two different situations with respect to soil degradation are evaluated using the model. The current situation includes no restriction on carbon balance while the desired situation includes the restriction that carbon balance cannot be negative.

The model results for the current situation show that land is devoted to tobacco and soybean production, no matter of the level of risk aversion of farmers. The carbon balance is negative and soil continues to degrade. In the desired situation, tobacco and soybean are replaced for an important part by beef bull production (including the production of alfalfa and maize for silage) to fulfill the requirement of a no negative carbon balance. As the risk aversion coefficient in this situation increases, beef bulls and soybean are partly replaced by the low risk crop chickpea. The requirement of no further soil degradation comes at a high cost since gross margin of the farm is decreased by some 35% compared to the current situation. Finally, the model is used to explore the effects of an abolishment of governmental subsidies on tobacco. In this situation the production plan consists of soybean, beef bulls and tobacco in such a proportion that carbon balance is positive. Income effects of an abolishment of governmental subsidies on tobacco would be enormous as the gross margin of the farm decreases by some 60%.

Key words: tobacco diversification, soil degradation, quadratic risk programming, income risk, risk aversion

5.1 Introduction

Tobacco (*Nicotiana tabacum* L.) is an economically and socially important crop in Salta province, in the Northwest of Argentina. Tobacco production represents around a quarter of the total gross value of agricultural production of Salta and about 175,000 people rely in this area on tobacco production for a living (Cámara de Tabaco de Salta, 2008; Fittipaldi, 2004). From 1987 to 2010, Virginia tobacco production in Salta increased by 146 % and the province produced around 48 % of the total of Virginia tobacco production in Argentina in 2010 (MiniAgri, 2011).

Many years of continuous tobacco mon-cropping, excessive ploughing and poor irrigation control have caused soil degradation, i.e. reduced soil aptitude for production (Arzeno, 2009; Giménez Monge et al., 2009; Carmona et al., 2008; Guardo, 2002). Soil degradation is the outcome of erosion, soil nutrient diminution, soil pollution, soil organic matter (SOM) decrease, salinization and soil structure collapse (Wiesmeier, 2009; Farquharson et al., 2008). Tobacco cultivated soils in the Salta province have a 60 per cent lower SOM content than forests soils (Giménez Monge et al., 2009). Low SOM content causes problems like poor soil structure, low total nitrogen availability, poor soil aeration and soil compaction (Corvalán, 1997). This paper uses SOM as the indicator of soil degradation.

Tobacco farming in Salta entails production and price risks. Fluctuations in temperature, precipitation and irrigation affect tobacco yield quantity and quality. Future tobacco yields are expected to decrease if SOM continues to fall on farms that practice tobacco mono-cropping. The national government supports the price of tobacco paid to the farmers. However, national political and international pressure to reduce tobacco subsidies and pressure to reduce tobacco consumption make future government support and hence the future revenues uncertain (Fittipaldi, 2004).

Both, the future uncertainty about the tobacco price and the expected yield decreases as a result of SOM decrease call for diversification strategies for tobacco farmers in the Valle de Lerma (Fittipaldi, 2004; Guardo, 2002). Still, there is little knowledge about the effect of diversification on expected income and income risk of tobacco farms and on SOM increase. Available information includes technical, economic and financial analysis of individual diversification farming activities or of a combination of one activity with tobacco production (Fittipaldi, 2004; Bazán et al., 1995). The existing literature often analyses diversification using positive approaches such as econometric modeling (Démurger et al., 2010; BIRTHAL et al., 2006; Bravo-Ureta et al., 2006; Benin et al., 2004; Joshi et al., 2003). Normative approaches

to explore diversification possibilities are less common. Normative approaches in the literature include mean-variance models (M-V), linear programming models and weighted goal-programming models (Manos et al., 2009; Hengsdijk et al., 2007; Guvele, 2001). The reason to apply a normative approach in this research is the need to explore how diversification can help to address the problem of decreasing SOM.

This article aims at determining optimal plans of current and diversification activities for risk averse farmers on a specialized tobacco farm to stop soil degradation. A mean-variance analysis is applied in this study, which assumes that farmers' choices are based on expected income and variance of income. Mean-variance analysis can be solved by Quadratic programming which allows evaluating diversification activities in terms of their contribution to income, risk and soil degradation (Hazell and Norton, 1986; McCarl et al., 1977; Scott and Baker, 1972).

5.2 Method and data

5.2.1 Study area

The Valle de Lerma (24° 30' and 25° 38' Southern latitude and 65° 22' and 65° 37' Western longitude) is a plain between mountains placed in Salta, in the Northwest of Argentina. Next to tobacco as the main crop, bean, corn, fruits, pastures, vegetables, fruits, beef and milk livestock and pastures are farming activities in the area (Chavez et al., 2010). This study is carried out in the central part of the valley, in the departments of Cerrillos, Chicoana and Rosario de Lerma. These three departments cover around 73 per cent of the total production of tobacco in Salta (MinAgri, 2007).

5.2.2 General structure of the model

The farm model is a static year model. The matrix notation of the quadratic programming model is as follows:

$$\text{Max } Z = C'X - 0.5dX'WX \quad (1)$$

Subject to $AX \leq B$

and $x \geq 0$

In this model Z is the expected utility to be maximized subject to constraints. C is a vector of gross margins for activities, X is a vector of activities, d is a scalar called the absolute risk aversion coefficient, W is the variance-covariance matrix of activities gross margin, A is the matrix of input-output coefficients and B is the vector of the resource constraints (Hazell and Norton, 1986; Scott and Baker, 1972).

Gross margin is defined as revenues from sales of crop products and fattened bulls minus variable costs. Variable costs are costs of seeds, pesticides, herbicides, fertilizers, own machinery maintenance, hired labor, energy and gas, contract work, transport costs and feeding and veterinary costs. The output of the model includes the optimal production plan at the chosen risk aversion level including irrigation water use and net effect of SOM expressed as the change in organic carbon.

Risk can be defined as uncertain consequences. Agriculture is an activity that entails risks. A risk averse farmer is willing to accept a reduction of income from farming for a reduction in risk, to a degree that satisfies the trade-off depending on how risk averse the farmer is (Hardaker et al., 1997). The relative risk aversion coefficient (R_r) relates d (the absolute risk aversion coefficient) to wealth (w). R_r takes the following values: 0 (risk neutral); 0.5 (hardly risk averse), 1.0 (somewhat risk averse, 2.0 (rather risk averse); 3.0 (very risk averse); 4.0 (extremely risk averse) (Acs et al., 2009).

Table 5.1 shows the structure of the farm model. The farming activities are shown at the top of the table: crops for sale, animal production, and feeding crops. Also an activity reflecting seasonal hired labor for general work is included. The rows of the matrix show the constraints: land availability, permanent labor for general work and for tractor driving, irrigation water availability, SOM (in terms of organic carbon balance) and a balance of animal feeding requirements and supply.

Table 5.1. General structure of the farm model

<i>Activities</i>	<i>Crops for sale</i>	<i>Animal Production</i>	<i>Feeding crops</i>	<i>Hired labor⁽²⁾</i>	<i>B vector</i>
Constraints					
Land availability	+1		+1		≤ available land
Labor for general work	+a _{ij}		+a _{ij}	+1	≤ available permanent labor general work
Labor for tractor driving	+a _{ij}	+a _{ij}	+a _{ij}		≤ available permanent labor tractor driving
Irrigation water availability	+a _{ij}		+a _{ij}		≤ water availability
Organic carbon	-a _{ij}	-a _{ij}	-a _{ij}		≥ carbon decline
Feeding requirements		+a _{ij}	-a _{ij}		=0
Objective function	Gross margin (US\$ ^{-ha})	Gross margin (US\$ ^{-kg}) ⁽¹⁾	Cost (US\$ ^{-ha})	Cost (US\$ ^{-day})	

(1) Excludes costs of feeding crops and includes feed from outside the farm

(2) For seasonal general work

5.2.3 Selection of farming activities

Farming activities for tobacco diversification to be included in the model come from a ranking of 23 activities performed according to five criteria (Chavez et al., 2012). Criteria include: contribution to income, suitability for bio-physical conditions, availability of technical information, market feasibility and soil improvement. The overall ranking of farming activities starting from the activity with the highest score is as follows: beef bulls, dairy cows, soybean, paprika, dairy goats, bean, chili, pigs, alfalfa, other small farm animals, field flowers, fruit trees and scrubs, chickpea, oats, wheat, forests trees, lentil, potatoes, other vegetables, aromatic and medical herbs, onion, chia, strawberry. Based on the overall ranking and on the four different groups of farming activities (livestock production, spring-summer crops, perennial crops and forests and autumn-winter crops), the following farming activities were chosen to be included in the model in addition to tobacco production: beef bulls including silage maize production for feeding, soybean, alfalfa (for feeding and/or selling hay) and chickpea. The months of production for these farming activities are shown in Figure 5.1.

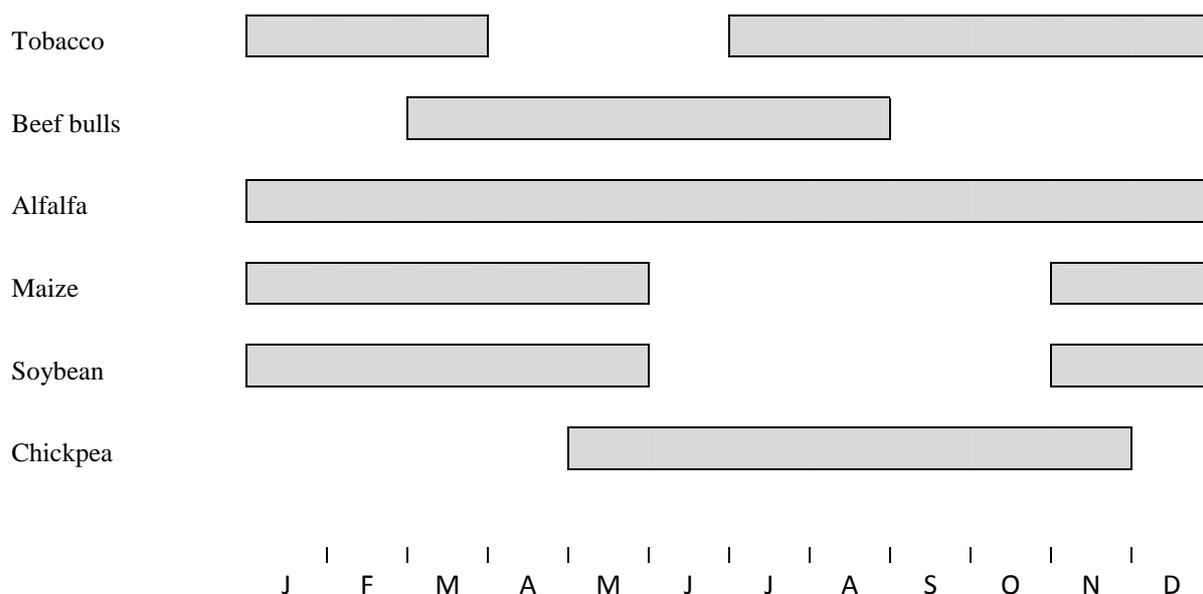


Figure 5.1. Months of production of farming activities

5.2.4 Data

Tobacco is assumed to be produced using own machinery. Labor for general work (transplantation and harvest) in peak periods is assumed to be hired in addition to permanent labor. Animals for fattening are assumed to be bought with 180 kg. Two subsequent diets for bulls are included. The first starts at 180 kg until 300 kg, with a daily weight gain of 0.9 kg and the second begins from 300 kg to 360 kg with a daily weight gain of 1.20 kg. Hence, it is assumed that the animals stay in the lot around six months (Navarro, 2012). Because of a higher market supply of animals for fattening in March, it is assumed that fattening beef bulls takes place from March to August. The diets are prepared basically with maize silage, maize grain and alfalfa hay. Maize grain is assumed to be bought outside the farm and maize silage and alfalfa hay are produced within the farm. A beef bull requires 408 kg of alfalfa (dry matter) and 469 kg of maize (dry matter) during the fattening period of six months on the farm (Navarro, 2012). Alfalfa production is included in the model for feeding own animals and as a cash crop activity (hay produced for selling). It is assumed to be grown for four years, with a lower yield in the first year than in the remaining three years. Alfalfa is assumed to be produced in rolls of 500 kg each using own machinery. Maize for silage is assumed to be produced using own machinery except for harvesting which is assumed to be done by contract work. Soybean is produced without plowing. Machinery for seeding and harvest are assumed

to be contracted and pesticides application is assumed to be done using own machinery. Chickpea is produced using own machinery while the work for harvesting it is contracted.

Input data about yields, prices, variable costs and total labor requirements as shown in table 5.2 were obtained from different sources. Tobacco and soybean yields are the historical averages for the study area (FET, 2009-2011; SIIA, 2009-2011). Alfalfa hay and maize silage yields are obtained from Navarro (2012) and chickpea from García Medina (2012), both researchers of INTA (National Institute for Agricultural Research). The tobacco price used in this research was the average final output price for 2009-2011 and it includes the market price paid by the industry to the farmers and the government subsidy (MinAgri, 2009-2010; FET, 2009-2011, Cámara de Tabaco de Salta, 2011). Soybean price is the average prices for 2009-2011 and were obtained from the Chamber of cereals of Rosario (CAC Ros, 2009-2011). It is assumed that the farmer gets 90 per cent of this price when the soybean is sold for feeding animals (Collado, 2012). Alfalfa hay historical prices and beef bull prices are obtained from Castignani (2012) and Suplemento Ganadero (2011). Chickpea prices are obtained from MinAgri (2009-2011). The prices published by MinAgri are FOB prices (free on board); the farmer usually gets 60% of the FOB-price when the product is sold at the farm. Transport costs, taxes, exporters' expenditures and profitability make the 40% difference (Méndez, 2012; Panadero Pastrana, 2012).

Variable costs for each farming activity were taken from different sources (as indicated in the footnotes below Table 5.2). In most cases, costs for the year 2011 were used as costs generally do not fluctuate much over time. Historical prices were corrected for inflation using the Price Index (IPIM) developed by the National Institute of Statistics and Census (INDEC, 2012), i.e. prices were expressed in US dollars of 2011.

The variance-covariance matrix of gross margin represents the variation in yields and prices, and is shown in Appendix 5.A (Table 5.A.1.1). The absolute risk aversion coefficient (d) was calculated by dividing the relative risk aversion coefficient (R_r) by wealth (w). Wealth was represented by owners' equity and was assumed to be equal to 242000 dollars, based on the typology of Chavez et al. (2010) and tobacco production costs of Cámara de Tabaco de Salta (2011). Considering ranges of R_r between 0 and 4, d can take values between 0 and 0.000017. GAMS 23.7 software was used for applying model (1).

Table 5.2. Yields, price, revenues, variable costs, gross margin, labor requirements and carbon supply for farming activities

<i>Farming Activities</i>	<i>Unit</i>	<i>Tobacco</i>	<i>Beef bulls</i>	<i>Alfalfa</i> <i>(for selling</i>	<i>Alfalfa</i> <i>(feeding</i>	<i>Maize</i> <i>(silage)</i>	<i>Soybean</i>	<i>Chickpea</i>
				<i>hay)</i>	<i>animals)</i>			
Yield	kg ha ⁻¹ or kg bull ⁻¹	1947 ¹	356 ²	7425 ²	7425 ²	14000 ²	2648 ¹	1700 ²
Price	US\$ kg ⁻¹ or kg bull ⁻¹	3.69 ³	1.685 ³	0.0405 ³			0.267 ³	0.538 ³
Revenues	US\$ ha ⁻¹ or bull ⁻¹	7185	600	301			706	915
Variable costs ⁴	US\$ ha ⁻¹ or bull ⁻¹	2633 ⁵	513 ⁶	188 ⁷	188 ⁷	602 ⁸	354 ⁹	557 ¹⁰
Gross margin (GM)	US\$ ha ⁻¹ or bull ⁻¹	4552	87	113			352	358
Standard deviation of GM	US\$ ha ⁻¹ or bull ⁻¹	488	198	18			58	19
Coefficient of variation of GM		0.11	2.3	0.16			0.17	0.05
Labor requirements								
Tractor driving	working days ha ⁻¹	4.70 ⁵	0.37 ⁶	0.87 ⁷	0.87 ⁷	0.8 ⁸	0.625 ⁹	1.5 ¹⁰
General work	working days ha ⁻¹	99 ⁵		4.5 ⁷	4.5 ⁷			4 ¹⁰
Carbon supply	(t C ha ⁻¹ or bull ⁻¹)	0.34	0.06	0.56	0.56	0.63	1.19	1.3

Note: ¹ historical average yields for years 2009-2011; ² estimated average yields; ³ averages for years 2009-2011; ⁴ labor costs are not included; ⁵ based on Cámara de Tabaco de Salta (2011), Bazán (2011) and INTA (2007); ⁶ costs of silage of maize and alfalfa hay are not included; based on Navarro (2012), Fiore (2011) and Fittipaldi (2004); ⁷ based on Cortez (2012), Navarro (2012) and Márgenes Agropecuarios (2011); ⁸ based on Navarro (2012) and Valdez (2012); ⁹ based on Collado (2012) and Bazán (2011); ¹⁰ based on García Medina (2012) and Bazán (2011)

5.2.5 Resource availabilities and requirements

Land

In the typology of tobacco farms of Chavez et al. (2010), farms specialized in tobacco growing represent 90 per cent of tobacco farms in the area and they devote around 40 ha to crop production. Based on this typology, we assume the tobacco farm in our analysis operates 40 ha of land.

Labor

Two types of work are distinguished in the model, i.e. general work and tractor driving work. Chavez et al. (2010) estimated an average of 3 to 4 permanent workers (which work at least six months per year, every day in the farm) in farms specialized in tobacco growing. For this analysis, 3 permanent workers are assumed: 2 for general work and 1 for tractor driving. The farmer has a management task and does not do field work. In peak periods (i.e. periods for tobacco plants transplantation and leaves harvest) farmers hire seasonal labor for general work in addition to permanent labor that is available on the farm. Hired labor for seasonal general work was added as an activity with a cost of 28.95 US\$ per man-day. In order to account for the seasonality in labor requirements; four periods differing in terms of labor requirement are distinguished in the model. Labor requirements for general work and tractor driving work for each farming activity and for each period are shown in Table 5.A.2.

Irrigation water

Water for crop production is available from rainfall and irrigation. In winter time, which is the dry season, water is crucial for production. It is assumed in this research that the availability of irrigation water is 81 mm per ha per month (Consorcio de Riego de Río Toro, 2012; Ledesma, 2012). Based on Chavez et al. (2010), it is assumed that 28 ha of land (70 %) have water available for irrigation.

Tobacco, alfalfa and chickpea need irrigation in periods of low rainfall, from May to November. The rest of the crops can fulfill water needs with rainfall. The water requirements for crops are estimated following Yañez (2012; 2003), García Medina et al. (2007) and García

Medina (2012). Monthly irrigation water requirement for tobacco, alfalfa and chickpea are shown in Table 5.A.3.

SOM and carbon balance

SOM improvement is necessary to decrease soil degradation. Carbon is part of *SOM*. To include *SOM* in the model the concept of carbon balance is used:

$$\Delta C = \text{Carbon supply} - \text{Carbon decline} \quad (2)$$

$$\Delta C = CarY * hc - Car * mic$$

Carbon balance (ΔC) is the difference between carbon supply and carbon decline, it reflects yearly *SOM* increase/decrease and it is expressed in tons of carbon per ha per year ($t C ha^{-1}$). Carbon supply follows from crop residues and carbon decline is the dioxide that is produced by microbial respiration during the mineralization process (Carrizo et al., 2009; Alvarez, 2007).

CarY is the yield of the above-ground post-harvest residue (including straw and excluding the economic product that is harvested) and of the roots of the crop expressed in terms of carbon content ($t C ha^{-1}$). In perennial crops *CarY* includes a proportion of the economic product that goes to the soil as harvest losses. A carbon content of 50 per cent in vegetable residues is assumed in this research (Manrique et al., 2010). *hc* is the humification coefficient which is the fraction of organic carbon that is left after one year of decomposition and it varies with the chemical composition of plant material (IRRI, 1984). *hc* is assumed to be 0.5 for all the considered materials (Alvarez, 2007).

Car is the current organic carbon in the soil ($t C ha^{-1}$) assuming 25 cm of soil layer and it is determined by soil analysis. Soil analysis results normally are expressed as percentage of *SOM*. Assuming the usually accepted 58 per cent of carbon content, *SOM* content has to be multiplied by 0.58 to get carbon content. For this research a *SOM* percentage of 1.55 per cent (Chavez et al., 2011) and a soil weight of $3375 t/ ha^{-1}$ for the first 25 cm of soil are assumed (Ballari, 2005). *mic* is the yearly mineralization coefficient of *SOM* which varies with climate, soil type, texture, pH and cultivation (Kolbe, 2007, IRRI, 1984). *mic* is assumed to be 3.5 per cent in a year for the area (Ortega, 2009). Thus, it is assumed that carbon decline equals $1.064 t ha^{-1}$ per year.

CarY estimation for different crops is based on the methodology proposed by Bolinder et al. (2007) and adapted for manure. *CarY* is estimated as follows:

$$CarY = C_p * hl + C_s + C_r \quad (3)$$

where C_p is the carbon content of the part of the crop that is harvested and that has an economic value (grain, leaves, etc.), hl is the proportion of this part that is returned to the soil as harvest losses (assumed to be 0 for annual crops and larger than 0 for perennial crops), C_s is carbon content in straw and C_r is carbon in root tissue, excluding any product. The formulae for C_p , C_s and C_r assuming a 50 per cent of carbon content for crops are:

$$C_p = Y_p * 0.50 \quad (3a)$$

$$C_s = Y_p * (1-HI)/HI * 0.50 \quad (3b)$$

$$C_r = Y_p / (S/R * HI) * 0.50 \quad (3c)$$

where Y_p is the dry matter of economic yield (grain, leaves, hay), HI is the harvested index and S/R is the shoot root ratio. HI is the economic part of a crop (kg of grain, leaves, etc.) expressed as the proportion of total above-ground biomass on a dry matter basis. As an extension of HI , C_r can be estimated by using relative C allocation coefficients. For alfalfa $C_r = Rro/Rp * C_p$, where Rro is the relative proportion of root with respect to *CarY* and Rp is relative proportion of the economic part with respect to *CarY*.

In the case of manure, Y_p is the dry matter of manure produced by a bull (t bull⁻¹) per year. A carbon content of 27 per cent in manure is assumed in this research (Bakayoko, 2009) and C_p is expressed in t C bull⁻¹. Carbon supply is presented for each crop and manure in Table 5.2. Details of the Carbon supply calculation are presented in Table 5.A.4.

5.2.6 Set up of calculations

The model (1) is run for two different situations to evaluate the impact of diversification on soil degradation. The first situation is referred to as the ‘current situation’ and it includes no restriction on the carbon balance. In the second situation a carbon balance restriction is included so implying that no further degradation of carbon is allowed. This situation is

referred to as the 'desired situation'. For both situations the model is run with different risk aversion coefficients to explore the effect of risk aversion.

Tobacco price includes two components, i.e. a component paid by the industry and a component paid by the national government as a subsidy. Since the persistence of the subsidy component is uncertain, a sensitivity analysis is carried out to evaluate the impact of an abolishment of the subsidy. The average price for tobacco including the industry and government payments is 3.69 dollars (2009-2011). The subsidy is 27, 6 % of this value (1.02 dollars), so the average tobacco price for the sensitivity analysis is 2.67 dollars (MinAgri, 2009-2011; FET 2009-2011; Cámara de Tabaco de Salta, 2011). Yield and variable costs for tobacco production are assumed to remain the same, while the gross margin decreases from 4552 dollars (see Table 5.2) to 2573 dollars. The standard deviation is then 501 dollars and the coefficient of variation is 0.195. The gross margin variance-covariance matrix is recalculated for the price without the subsidy (Table 5.A.1.2). Also in this situation the model is run with and without the restriction on the carbon balance and using different risk aversion coefficients.

5.3 Results

5.3.1 Basic results

The results are presented in Table 5.3. Optimal farms plans were determined for different values of absolute risk aversion coefficients and for the two situations regarding soil degradation. From the results it appeared that the degree of risk aversion of the farmer had no effect on the optimal plan in the current situation, so in Table 5.3 there is only one column for the current situation. The available land of 40 ha in the model is devoted to production of tobacco and soybean, due to their higher gross margin (see Table 5.2). The optimal plan uses all the irrigation water available in October and November to produce tobacco. Total land shows a shadow price of around 353 dollars per ha indicating an increase of expected utility by this value if one ha of land is increased. By increasing the availability of land by 1 hectare, an additional hectare of soybean is included in the optimal plan. Irrigation water in October has a shadow price of around 16 dollars per mm. A one mm increase of water availability would make alfalfa for beef production enter the solution. This can be checked by increasing the water availability in that month by one unit and re-running the model. Labor for general

work is necessary to be hired for planting and harvesting tobacco in periods 1 and 4 (see Table 5.A.2). The carbon balance is negative (-0.41 Tn per hectare per year), showing that the combination of tobacco and soybean do not supply enough carbon to cover the annual carbon decline of 1.064 Tn per hectare.

Adding the carbon balance constraint (i.e. the 'desired situation') changes the optimal plan. Three levels of risk aversion are included in Table 5.3: risk neutral, somewhat risk averse and very risk averse. For all risk aversion coefficients, the gross margin is far lower than for the current situation. The results for a hardly risk averse coefficient ($R_r = 0.5$) are the same as for the risk neutral farmer. The results for the rather risk averse ($R_r = 2.0$) and extremely risk averse coefficient ($R_r = 4.0$) are the same as those of a very risk averse farmer. For that reason the results for these values of risk aversion are not included in Table 5.3.

For a risk neutral farmer ($R_r = 0$), the optimal plan entails the use of 40 ha of land; beef bull production, tobacco and soybean enter the solution, because of their gross margin and carbon supply. Irrigation water is not limiting the optimal plan. Land has a shadow price of around 2330 dollars. Extra land would increase the tobacco and soybean area in the optimal plan while slightly decreasing beef bulls production. Permanent labor for tractor driving in period 2 has a shadow price of 173 dollars per day and extra availability of labor would increase the level of tobacco and beef bulls production while decreasing soybean production included in the optimal plan.

For a somewhat risk averse farmer ($R_r = 1.0$), the total gross margin is slightly lower than for the neutral risk averse farmer, while the standard deviation is considerably lower. Because of the increasing focus on risk, activities with a higher coefficient of variation (i.e. beef bulls including feed production and soybean) are partly replaced by activities with a lower coefficient of variation (i.e. tobacco and chickpea) while the production plan remains restricted by the carbon balance constraint. Irrigation water is not constraining the optimal plan. Land has a shadow price of around 2387 dollars. Extra land increases the level of all activities except chickpea, which shows a decrease. Permanent labor for driving the tractor has a shadow price of 142 dollars and increasing labor for tractor driving increases all activities except soybean which decreases.

For the very risk averse farmer ($R_r = 3.0$), again total gross margin is only slightly lower, while the standard deviation is considerably lower. Compared to the previous situation, the production plan changes in the same way. The shadow price of land increases to 2422 dollars; extra land will decrease chickpea while increasing tobacco, beef bulls and soybean.

Irrigation water in September is now limiting the solution (shadow price of 0.56 dollars). Extra water availability in this month will increase tobacco and chickpea production while beef bulls will decrease. Permanent labor for tractor driving in period 2 has a shadow price of around 94 dollars and an extra availability of labor in that period will increase all the activities in the optimal plan except chickpea and soybean which will decrease.

Table 5.3. Optimal farm plans for current and desired situation for different values of absolute risk aversion coefficient

	Current situation	Desired situation		
		Risk neutral	Somewhat risk averse	Very risk averse
<i>d</i>	0-0.000017	0	0.000004	0.000012
<i>Rr</i>	0 - 4.0	0	1.0	3.0
Total revenue (US\$)	191510	208510	198850	184150
Total variable costs (US\$)	71591	155540	144310	127240
Total hired labor costs (US\$)	61050	14300	16074	18771
Total gross margin (US\$)	58871	38672	38462	38141
Standard deviation (US\$)	11431	20471	17445	12878
Carbon balance (Tn C per ha per year)	-0.41	0	0	0
Optimal cropping plan (ha or bulls)				
Tobacco	25.2	7.8	8.3	9.1
Alfalfa (selling)				
Alfalfa (feeding)		13.3	11.8	9.7
Maize (silage)		8	7.2	5.8
Soybean	14.8	10.9	7	1.2
Chickpea			5.7	14.2
Beef Bulls		241	215	175

5.3.2 Sensitivity analysis

For the sensitivity analysis, it is assumed that farmers only receive the price paid by the industry (i.e. no subsidy). The results are the same for risk neutral and rather risk averse farmers ($R_r = 2.0$). For that reason, only the results for a risk neutral, very risk averse and extremely risk averse farmer are presented in Table 5.4. Only one situation with respect to carbon balance is presented, since the inclusion of a carbon balance restriction is not necessary to prevent a negative carbon balance. The optimal plan for the risk neutral farmer includes the production of beef bulls, soybean and a few hectares of tobacco. The optimal plan is determined by the total land area, the availability of labor for tractor driving in period 2, and the availability of general labour in period 4. Total land has a shadow price of around 351 dollars, and an extra hectare of land would increase soybean production because of its higher gross margin. Labor for tractor driving in period 2 has a shadow price of 124 dollars per man-day. Extra availability of this labor will increase beef bull production, and decrease soybean and tobacco production. General labor in period 4 has a shadow price of 10.4 dollars per man-day, indicating that it is not economically worthwhile to hire labour at the price of 28.9 dollars per man-day. Extra general labor in this period would slightly increase tobacco production while the others activities would decrease. Finally, the carbon balance in this situation is slightly positive.

Like in the basic situation a stronger focus on risk leads to slightly lower gross margins, considerably lower standard deviations and a decrease of the numbers of beef bulls, being the most risky activity. The area of land not needed for feed production goes to tobacco and soybeans. Extra labor for general work in period 4 will increase tobacco and beef bulls production while decreasing soybean. The shadow price of land goes up and the carbon balance remains positive.

Table 5.4. Optimal farm plans for current and desired situation for tobacco price without subsidy for different values of the coefficient of absolute risk aversion

	Risk aversion		
	Risk neutral	Very risk averse	Extremely risk averse
<i>d</i>	0	0.000012	0.000017
<i>Rr</i>	0	3.0	4.0
Total revenue (US\$)	179770	168070	132050
Total variable costs (US\$)	150590	139310	104590
Total hired labor costs (US\$)	3907	4020	4369
Total gross margin (US\$)	25278	24739	23082
Standard deviation (US\$)	23754	21685	15319
Carbon balance (Tn C per ha per year)	0.08	0.078	0.06
Optimal cropping plan (ha or bulls)			
Tobacco	3.9	4	4.2
Alfalfa (selling)			
Alfalfa (feeding)	13.7	12.4	8.7
Maize (silage)	8.3	7.6	5.3
Soybean	14.	15.9	21.8
Chickpea			
Beef Bulls	249	226	158

5.4 Discussion

This study aimed at assessing diversification possibilities for a typical tobacco farm to get insight into the impact of diversification on farms income, risk and SOM (expressed as carbon balance). The quadratic programming model proved to be a useful tool to account for yield and price risk.

A static model was used in this study. The development of dynamic models would be necessary for a more accurately evaluation of the evolution of the carbon balance over time for the different optimal plans and for farmers with different risk aversion coefficients.

The addition of the carbon balance concept allowed getting insight in the effect of the residues of farming activities on SOM content. However, the lack of specific local data regarding carbon supply from plant and manure residues and humification coefficients for different materials led to the use of data from other geographic areas, which makes the results less reliable. Moreover, other ways to improve SOM may be included, like urban wastes, green manure, and other animal wastes like bones and blood (IRRI, 1984). Again, local data are not available.

The model results for the current situation (no carbon restriction) are in line with what happens in practice in the Valle de Lerma. Tobacco is grown by farmers irrespective of their risk attitude and irrespective of any soil degradation.

The findings of this research are consistent with the results found by Manos et al. (2009) in the sense that as decoupling (direct subsidies to tobacco are stopped) increases, allocation of land to tobacco production decreases and other production alternatives enter the solution. The sensitivity analysis shows that a decline of government subsidy would make tobacco less attractive to farmers and other farming activities beef bulls and soybean are included in the optimal plan.

The results show that in all situations with a strongly reduced area of tobacco the costs of hired labour decrease to 7-30% of the original value. This decrease is equivalent to 1500-2000 man-days per farm. Given the number of tobacco farms, this points at a considerable regional loss of employment problem coming into being if tobacco production is abandoned.

Four farming activities in addition to tobacco were included in the model. A larger number of farming activities (see Chavez et al., 2012) can be included in future studies to improve the model. Reliable data of yields, inputs and prices are needed of the additional set of farming activities.

5.5 Conclusion

The quadratic programming model is a valuable tool to produce realistic results. The results showed that, like in reality, the optimal plan in the current situation includes mainly tobacco production, no matter how large the SOM decrease (negative carbon balance) is or what the level of farmer risk aversion is. The great difference of tobacco gross margin and low coefficient of variation with respect to other farming activities is the reason for these results.

In the current situation, soybean performs as the best diversification activity. The fact that it does not use irrigation water makes it a suitable complement for tobacco production.

This study provides valuable understanding on changes of the optimal plan according to farmers risk aversion in case a carbon balance restriction is included. First of all, the tobacco area needs to be replaced considerably to meet the carbon balance restriction which has a large effect on income. Suitable diversification activities are soybeans, beef bulls (including alfalfa and silage maize) and chickpea. Second, the number of diversification activities increases as the level of risk aversion increases, indicating that high risk averse farmers will tend to allocate their resources among different activities to reduce risk. Finally, the results show that it is possible to reduce risk with only a small impact on income.

A reduction of tobacco subsidy or a decrease of the industry price due to less demand from consumers would have two evident consequences: an enormous decrease of farmers' income and a spontaneous improvement of soil conditions.

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Appendix 5.A

Table 5.A.1.1. Variance-covariance matrix of gross margin. Price of tobacco includes industry and subsidy prices

	Tobacco	Alfalfa (for selling)	Soybean	Chickpea	Bulls
Tobacco	237675	-8200	-28178	5886	-40993
Alfalfa (for selling)	-8200	320	1016	-113	1128
Soybean	-28178	1016	3392	-592	4524
Chickpea	5886	-113	-592	364	-1709
Bulls	-40993	1128	4524	-1709	9271

Table 5.A.1.2 Variance-covariance matrix of gross margin. Price of tobacco includes only industry price

	Tobacco	Alfalfa (for selling)	Soybean	Chickpea	Bulls
Tobacco	250772	-8668	-25856	766	-21295
Alfalfa (for selling)	-8668	320	1016	-113	1128
Soybean	-25856	1016	3392	-592	4524
Chickpea	766	-113	-592	364	-1709
Bulls	-21295	1128	4524	-1709	9271

Table 5.A.2. Labor requirements per periods and farming activities (days per hectare)

Period of time	Farming activities					
	Tobacco	Alfalfa (selling or feeding)	Maize	Soybean	Chickpea	Beef bulls
Period 1 ¹						
Tractor driving	1.7	0.41	0.375	0.5		
General work	64					
Period 2 ²						
Tractor driving	0.375	0.22			0.88	0.183
General work		0.75			0.75	
Period 3 ³						
Tractor driving	1.28	0.03			0.13	0.183
General work	4.45	2.25			0.75	
Period 4 ⁴						
Tractor driving	1.35	0.21	0.45	0.125	0.5	
General work	30	1.5			2.5	

Note:

¹ 15 Dec-14March

² 15 March- May

³ Jun-Aug

⁴ Sep-14Dec

Table 5.A.3. Irrigation requirements for tobacco, alfalfa and chickpea in shortage rainfall periods (mm per ha).

Crop	Months						
	May	June	Jul	Aug	Sep	Oct	Nov
Tobacco			60	45	45	90	90
Alfalfa	60	60	60	60	60	60	60
Chickpea	60			45	90		

Table 5.A.4. Carbon supply calculation for each crop and manure

Crop	Yp (t ha ⁻¹ or bull ⁻¹)	Cp (t Cha ⁻¹ or bull ⁻¹)	hl	HI	Cs (t C ha ⁻¹)	S:R	Cr (t C ha ⁻¹)	CarY (t C ha ⁻¹ or bull ⁻¹)	hc ³	Carbon supply (t C ha ⁻¹ or bull ⁻¹)
Tobacco	1.56 ¹	0.78	0	0.67 ²	0.39	4 ²	0.29	0.675	0.5	0.34
Alfalfa	8.25 ⁴	4.13	0.10 ⁴	⁵			2.82 ⁶	1.12 ⁴	0.5	0.56
Maize (silage)	14 ⁷	7	0	⁵			1.3 ⁸	1.3	0.5	0.63
Soybean	2.28 ⁹	1.14	0	0.40 ¹⁰	1.71	4.25	0.67	2.38	0.50	1.19
Chickpea	1.41 ¹¹	0.71	0	0.32	1.50	2.01 ¹³	1.10	2.60	0.50	1.3
Manure	0.45 ¹⁴	0.12 ¹⁵						0.12	0.50	0.06

Note:

1 Average for the area (considering 80 per cent of dry matter)

2 Based on Diez et al (2008)

3 Based on Alvarez (2007)

4 Average for four years of production, based on efficiency of harvest Navarro (2012)

5 Based on Bolinder (2007) not calculated for perennial crops

6 It is calculated for the last year of four of cultivation. Relative plant C allocation coefficients were used for this calculation. Cr= (Rro/Rp)* Cp is used. Rro (relative proportion of root=0.308). Rp (relative proportion of economic value=0.492). Based on Bolinder et al. (2007)

7 Average yield of silage (considering 35 per cent of dry matter)

8 Relative plant C allocation coefficients were used for this calculation. Cr= (Rro/Rp)* Cp is used. Rro (relative proportion of root=0.138). Rp (relative proportion of economic value=0.772). Based on Bolinder et al. (2007)

9 Average for the area (considering 86 per cent of dry matter)

10 Based on Alvarez (2007), Forján (2002) and Bolinder (2007)

11 Average (considering 83 per cent of dry matter)

12 Based on Hay (1995)

13 Based on Ganjeali and Kafi (2007)

14 Based on Gil (2006) the daily production of manure represents 5.5 per cent of the animal weight. Manure production is estimated for the average weight the animal has along the fatten period (around 6 months). For that, it is assumed that an animal of 240 kg stays for 133 days and then when it is around 333 kg it stays 50 days in the lot. Dry matter is 17 per cent.

15 Based on Bakayoko (2009) carbon content of 27 per cent

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Chapter 6

General discussion

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6.1 Introduction

In the province Salta, located in the Northwest of Argentina, tobacco is economically and socially important, as many people depend directly or indirectly on its production. However, the current practice of tobacco monocropping, excessive tillage and inadequate irrigation management causes soil degradation, which negatively impacts tobacco yields. Also, the future of tobacco production is uncertain because of its dependence on subsidies and increasing concerns about health damage from tobacco consumption. Hence, there is a need for diversification by specialized tobacco farms. The overall objective of this study was to explore opportunities for diversification of specialized tobacco farms in the Valle de Lerma. This study attempts to integrate knowledge from different disciplines in a bio-economic approach to provide insight for developing more sustainable production systems in the Valle de Lerma.

The overall goal was achieved in four chapters of this thesis. Chapter 2 provides insight in the current soil organic matter (SOM) content in tobacco fields, it explores possibilities of soil nutrient improvement by SOM increasing and it makes an economic assessment of the use of green manure as a way to improve SOM in tobacco fields. Chapter 3 identifies a typology of tobacco farms in terms of determinants of diversification in the Valle de Lerma. This classification is based on existing data at farm level regarding available resources for production and farmers characteristics. Chapter 4 develops criteria for assessing diversification activities and ranks different diversification activities based on those criteria using the opinion of stakeholders. Chapter 5 determines optimal plans of current and diversification activities of risk averse farmers on a specialized tobacco farm to stop soil degradation.

This chapter discusses research issues and presents the main conclusions of the thesis. The remainder of this chapter is organised as follows. In the next section, the methodologies and data used are discussed. Then, a synthesis of result is presented. After that an overview of implications of the study for policy makers, researchers and business are provided and finally, the main conclusions are presented.

6.2 Methodological and data issues

6.2.1 Modelling at farm level

In this study, farm level models were developed to describe the current situation and to explore future options for diversification of specialized tobacco farms. Farm level modelling is valuable for analysis of tobacco mono-cropping and of possibilities of diversification, because the farm level is the level where decisions are made that have a direct impact on soil quality. The potential role of farmers in the protection of natural resources has been widely recognised by international organizations (Louhichi et al., 2010).

Farms that are less endowed in terms of land, capital goods, irrigated area and labor are less diversified (Chapter 3). This makes a farm level approach an appealing tool to investigate diversification possibilities on specialized tobacco farms.

However, the focus on the farm level brings along limitations, because there are feedback mechanisms that operate at higher levels of aggregation such as the watershed, regional and national level. Irrigation water availability is one factor that requires a higher level of analysis. An analysis at watershed level will be necessary to analyse the feasibility of the introduction of farming activities (like alfalfa for feeding bulls) to complement or replace tobacco in relation to their irrigation requirement and the total regional water availability. Yet another factor is the market price of outputs. At farm level, prices of tradable commodities are exogenous as they are generally determined on national or world markets (Sadoulet and de Janvry, 1995). However, in distant rural areas, far away from large markets (that could only be reached at high transportation and market costs) local production and demand may influence local prices of certain products (Sadoulet and de Janvry, 1995). In our study, this can be the case for alfalfa for selling. So, a demand study needs to be conducted in order to get an accurate measure of the capacity of the local market to absorb extra supply of products (in case many farms start to produce alfalfa) that will mainly be traded locally.

Social aspects of diversification also need attention at regional level. Tobacco uses more labor than the other farming activities, so it provides a source of income to many workers in the region. A substantial replacement of the tobacco area by less labor requiring farming activities would imply an increasing unemployment which could lead to an increase of social discontent.

6.2.2 Bio-economic modelling: positive and normative approach

Bio-economic modelling combines quantitative methodologies from biophysical (agronomic) and economic sciences in a way that results are relevant for both social and biophysical sciences and allow for policy debate and they are applied at different time and aggregation scales (Louhichi et al., 2010; Kruseman, 2000).

Diversification and soil degradation problems can be addressed using positive and normative approaches. In this thesis, positive approaches (econometric methods) are used to relate fertilizers to current nitrogen content in Chapter 2 and to develop a farm typology in Chapter 3. In Chapter 2, random and fixed effect models helped to understand the relation between organic matter content in tobacco fields and possibilities to improve nutrient availability, based on historical data (pseudo panel data). Given the scarcity of explanatory variables to be used in the models, the novelty application of econometric models to soil issues was the possibility to isolate cohorts' specific effects that may include management practices and farmers preferences. In Chapter 3, principal components and cluster analysis allowed getting insight into the clusters of tobacco farms in the study area, using census data. Positive approaches do not require an a priori assumption regarding farmers' decision rules, but may ignore factors that affect production (like timing of input use). In addition, the relative merit of the results of positive approaches critically relies on the availability of a sufficient number of observations and on the quality of data (Weersink et al., 2002; Verstegen et al., 1995). Normative approaches used in this study are the multiple criteria method applied in Chapter 4 and the optimization method applied in Chapter 5. The opinion of qualified experts and stakeholders to get insight into the performance of farming activities for diversification with respect to selected criteria was collected using the Analytical Hierarchical Process (AHP) in Chapter 4. In Chapter 5, the quadratic programming model was an appropriate tool for exploring a combination of farming activities. The method allows for including a large number of farming activities, different ways to produce them, (e.g. less intensity tillage), financial activities (e.g. credits to invest in facilities or machinery), rent land and constraints like water availability (because of dams disposal for storing water). In general, normative approaches are considered to have practical limitations; they tacitly assume that farmers decide according to pre-determined decision criteria, and do not account for inconsistencies in the decision process (Verstegen et al., 1995). In this sense, the application of (AHP) allowed improving respondents' inconsistency when it was detected. An

optimization model consists of a system of equations and/or inequalities that are designed to replicate farm-level activities and it involves the specification of a behavioural assumption, like profit maximization (Weersink et al, 2002). In Chapter 5, a single objective (utility) was optimized. However, farmers may be pursuing other objectives. Besides, due to reasons like imperfect information and limited management skills, farmers are not running the farm as model outcomes would suggest. The results of the optimization model in Chapter 5 generate the maximum achievable utility, given minimum requirements on soil degradation, and the differences between the outcomes of the model and what a farmer does in reality reflect the possibilities for farmers to improve the economic and soil management performance of the farm (van Calker et al., 2004).

Normative and positive approaches were useful for achieving the overall objective of this research. The positive approaches gave a better understanding of underlying statistical relations, like the relation between SOM and nutrient availability (Chapter 2). Moreover, farming activities observed in clusters of farms identified using a positive approach in Chapter 3 were included in the ranking of farming activities for tobacco diversification in the AHP of Chapter 4. The identification of clusters of farms in the region (Chapter 3) also helped in defining restrictions on resources like land, irrigation water availability, labor availability in the optimization model. Therefore, the positive approaches provided useful information for building the normative model in Chapter 5.

6.2.3 Data issues

The lack of data related to soil degradation and diversification of tobacco farms in the Valle de Lerma was an issue in all chapters of this thesis. Very limited historical data were available on the changes of SOM and soil management in tobacco fields in the region. Moreover, tobacco yields as a function of SOM levels for the analysed tobacco fields were not available. This scarcity in data limited the application of the econometric model to nutrients (Nitrogen, Phosphorus and Potassium) in Chapter 2 as a function of SOM. Data for Chapter 2 came from laboratory analysis reports requested by farmers to get fertility diagnosis of soils. Reports included percentages of clay, silt and sand which made it possible to determine soil texture to build cohorts. Other variables used in the econometric models are the normal variables that a soil analysis provides, like pH, nutrients contents, SOM, etc. Other important information like number of tillage practices, tobacco yield of the plot, applied fertilizer in the previous

year and use of green manure was not recorded. Also, results from experiments relating organic matter supply from different types of green manures are not available in the area. Soil degradation in this study was limited to soil organic matter. A more complete model needs to include other factors affecting soil degradation like erosion, nutrient depletion, soil pollution and salinization. Moreover, the analysis has to be broader; it should include other environmental impacts like water contamination by fertilizers and pesticides. Unfortunately, necessary data are still missing in the area.

Data to build the typology in Chapter 3 were taken from the Census that was completed in 2002. The Census questionnaire includes a predetermined number of variables. Another Census was carried out in 2008, but the results were not available at the time the research was done. More recent data regarding farm resources, size and farming activities could give a better knowledge of the current farm types in the region. Census data are published at aggregate levels (principally departments). An agreement between INTA (National Institute of Agricultural Technology) and the institute in charge of the realization of the Census (INDEC) made it possible to use the full data base for this study. However, due to confidentiality restrictions, it was not possible to identify individual farms and to relate each observation with the soil analysis reports used in Chapter 2.

In Chapter 4, only limited data were available on criteria for diversification of farm activities and the performance of farm activities with respect to selected criteria. Therefore, knowledge of experts and stakeholders was used.

Different data sources were used for parameterising the bio-economic model in Chapter 5. Severe lack of data regarding new diversification activities led to the decision to include in the quadratic programming model only the first ranked activity from each group of activities, namely autumn-winter crops, spring-summer crops, perennial crops and forests and livestock production. Historical yields in the region and experts' estimates of yields were used for farm activities. The use of expert estimates can be criticized because it might not precisely reflect reality. Experts that were asked about yields in this study are, however, well experienced in the region. The technical information to estimate variable costs also came from different sources: experts' knowledge, farmers' interviews and scientific publications. A farm survey on crop management and the use of inputs could, however, lead to a better parameterisation of the bio-economic model. Carbon supply data from crops were not available for the area. Based on local yields and coefficients and data from literature, carbon supply was estimated.

6.3 Synthesis of results

This section provides the relations between the results from the different chapters. Figure 6.1 helps to understand the link between the chapters.

Chapter 2 confirms the initial assumption that level of SOM in tobacco fields is low which means that soils have degraded, most likely as the result of the practice of tobacco mono-cropping. This result is in line with local experts' knowledge regarding SOM. Soils under tobacco in the Valle de Lerma show 60 per cent less SOM than forest soils taken as a reference in the same area and it is limiting production to some degree (Giménez Monge et al., 2009; Ortega and Corvalán, 1992). As is shown in figure 6.1, the average SOM content of 1.55 % derived from the data in Chapter 2 was used to estimate the current content of organic carbon in the soil in Chapter 5. This current content of organic carbon was multiplied by the mineralization coefficient, to obtain the yearly carbon decline, which is included in the carbon balance. Based on local experts' estimates (Ortega 2009; Ballari, 2005) yearly carbon balance declination of 1.064 t ha^{-1} per year is a reasonable assumption. The issue that soils have degraded due to mono-cropping as noted in Chapter 2, indicated that soil improvement should be a criterion for selecting farming activities for tobacco diversification in Chapter 4. This is illustrated by the arrow in figure 6.1 that connects Chapters 2 and 4. In addition, green manure (oats and wheat) were considered in Chapter 4 as alternatives for diversification.

In Chapter 3, it appeared that there are two types of highly specialized tobacco farms next to two other types of farm producing tobacco but being rather diversified. As the specialized tobacco farms are the farms having the severest problems with soil degradation and as these farms appear to be very similar in their setup, it was decided to conduct the farm level analysis in Chapter 5 on the basis of the average of these two farm types. The tobacco cultivated area was on average 23.5 in these specialized tobacco farms. These farms have around 40 ha of land for crop production, 28 ha of the land have irrigation, and they have 3 to 4 permanent workers on the farm. Land for crop production, irrigated land and permanent workers availability from this chapter were taken as available resources of the representative farm in the optimization model of Chapter 5, as the arrow from Chapter 3 to Chapter 5 indicates in Figure 6.1. The optimization model in Chapter 5 showed a cultivated tobacco area of 25 ha in the current situation of no restriction on carbon balance, irrespective the level of risk aversion. Results regarding the use of water to tobacco production from the optimization model are in line with what was observed on the farms in the study area (Chapter 3). In

Chapter 3, it was pointed out that limited irrigation water availability may have a negative effect on diversification. This is confirmed in Chapter 5 where irrigation water is a limiting factor and is totally devoted to tobacco production in the current situation without restrictions on soil degradation. The optimal plan in the current situation includes soybean production in addition to tobacco, where soybean does not use irrigation.

Current and potential farming activities for diversification were compared with respect to a number of criteria in Chapter 4 and a final ranking was made. Current farming activities identified in the farm clusters of Chapter 3 were included in Chapter 4 to make the ranking. This is illustrated by the arrow in figure 6.1 that connects Chapters 3 and 4. The criteria included in Chapter 4 did not consider the use of farm-specific resources. In Chapter 5, a selection of activities coming from the ranking made in Chapter 4 (an arrow from Chapter 4 to Chapter 5 illustrates this in Figure 6.1) were evaluated in their aptitude to improve expected farm income and SOM at given farm resources (land, labor, irrigation water) in different periods of the year. The optimization model of Chapter 5 did not include all the considered criteria in Chapter 4. In fact, the model assumes the same market feasibility, technical information and suitability for biophysical conditions for all the farming activities. The results of Chapter 4 showed that beef bulls production was the farming activity with the highest overall weight in the ranking of activities for tobacco diversification, soybean was third, alfalfa for selling hay was ninth and chickpea was thirteenth.

In Chapter 5, soybean was relevant in diversification in the current situation of soil degradation (no carbon balance restriction), while beef bulls and chickpea entered (in addition to soybean) the optimal plan when the restriction on the carbon balance was included. Chickpea has a higher share as the risk aversion coefficient increases (due to its low coefficient of variation of gross margin). Figure 6.1 shows in the frame of Chapter 5 the land share for the crops in optimal plans for current situation of no carbon balance restriction and for the desired situation with carbon balance restriction for a somewhat risk averse farmer. Alfalfa for selling hay did not enter any solution, despite its higher ranking than chickpea in Chapter 4. Alfalfa for selling hay had a low score in all criteria, except in its contribution to soil improvement (Chapter 4). As further soil degradation in Chapter 5 could be prohibited by including beef bulls (that included growing alfalfa for feeding) and chickpea, alfalfa for selling hay was not included in any optimal plan in Chapter 5. The methods for selecting farming activities in Chapter 4 and Chapter 5 are complementary and for proper decisions of diversification at farm level, both general and farm specific information is required. For a

better analysis of the usefulness of the different diversification activities of Chapter 4, it is necessary to include in the optimization model of Chapter 5 all the activities ranked in Chapter 4.

6.4 Implications of the study

6.4.1 Policy implications

Chapter 3 shows that land and irrigation availability are, among others, determinants for diversification. According to the results of the typology, there is still suitable land (natural forests and pastures) that may be incorporated in crop production. Policies may be oriented to make more land available for agricultural production, for example through the provision of subsidies or loans. Wood production in steep areas of the valley (not feasible for agricultural production) can be also considered. Depending on water requirement for different crops and periods, irrigation water may limit diversification (for example, if alfalfa is produced to feed beef bulls). Hence, policy makers can promote the adoption of diversification activities through subsidies or loans for making wells for irrigation in farms and building more dams in the area.

According to the results in Chapter 5, in a situation of unchanged prices and subsidy, tobacco remains very dominant in the region. Current national policies tend to strengthen tobacco production (e.g. by encouraging farmers and workers training, improving working conditions and improving tobacco cured processes) more than to promote diversification (MinAgri, 2012). Future policies can include incentives to diversify (like cheap credits), obligatory practices (like rotations) or fines to change current farmers' practices that worsen soil degradation. Tobacco production uses high levels of labor which is not the case of the farming activities for diversification included in Chapter 5. Large scale introduction of diversification activities would decrease the current employment level. Decision makers will have the task of combining conflicting purposes: conserving the environment (with emphasis on improving soil quality as a key factor for productivity) versus maintaining farmers' welfare and maintaining a high level of agriculture related employment in the region.

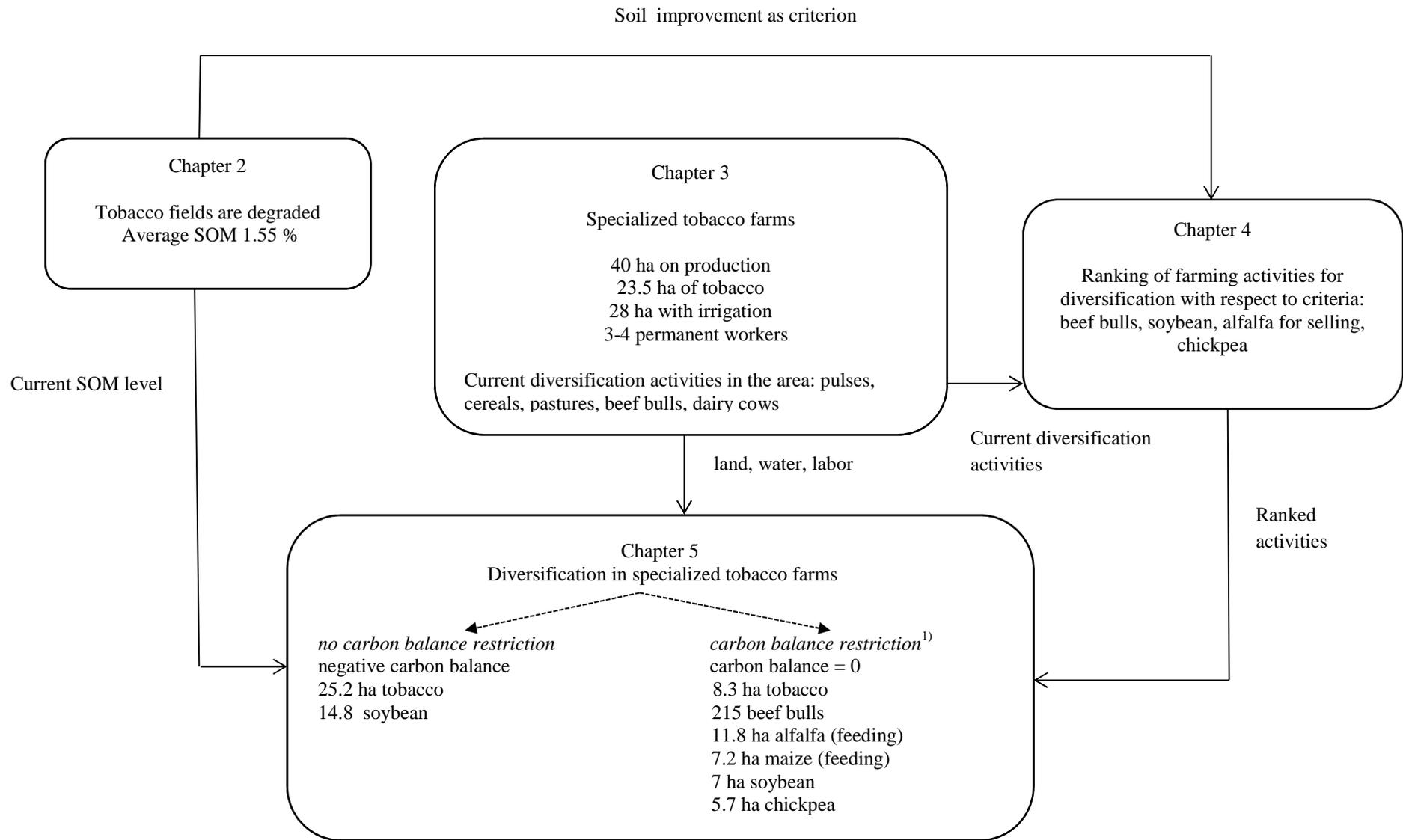


Figure 6.1. Links between different chapters

¹⁾ Somewhat risk averse farmer

6.4.2 Research implications

This research has provided insights that can be used in future disciplinary and interdisciplinary research. Chapter 2 showed that soils in the Valle de Lerma have degraded. Research regarding different methods to recover soils is still limited and an economic evaluation of those methods is missing. In addition to green manure practices, other ways to improve SOM like urban and animal waste and crop residues (IRRI, 1984) can be evaluated in terms of their effective supply of organic matter to the soil and by specifying a time horizon to achieve adequate levels of SOM in soil. In this way, technical information will be available for economic evaluation and recommendations for farmers can be improved. The results of Chapter 2 indicate that there are unobserved cohort effects that influence nutrient availability which are not evident from the explanatory variables used in the model. These variables may be related to the correct moment of application of the fertilizer, farmers' management skills, education level, age and soil management practices. These identified unobserved cohort specific effects raise the question of which variables are involved in nutrients availability in addition to applied fertilizers. By detecting and improving those variables affecting nutrients availability, a more efficient management of soil will be achieved.

An updated typology of tobacco farms based on a specific questionnaire including variables related to types of soils, management practices, farms resources, inputs use, farmers' characteristics and real crops yields is desirable. In this way, a better assessment of diversification will be possible.

Farming activities for tobacco diversification proposed in Chapter 4 were evaluated by invoking the opinion of expertise and different stakeholders. An alternative way of measuring farming activities could provide insight into the robustness of the results. To derive recommendations to farmers regarding activities for diversification, a quantitative estimation of expected income is required. For current activities, surveys from farmers with actual yields and technical information of common management practices could provide an alternative for expert opinion. For potential activities, estimation of expected yields and management practices from experts and experiments are required. Where and how to sell the production and buy inputs is crucial for farmers to take the decision to diversify. In this sense, market feasibility studies are required, principally on the demand side of products, to determine if extra supply can be absorbed by the market without causing price changes. On the input side the possibilities for buying specific inputs (e.g planting material) for new activities need to be

investigated. With respect to the criteria suitability for biophysical conditions of potential activities, the opinion of expertise is highly appreciated; however experiments for evaluating the suitability of new crops to local climate and soil conditions are required. Special emphasis has to be put on varieties of winter crops (like wheat and onion) that are suitable to be grown after tobacco harvest, to get additional income, and that can be harvested at the beginning of spring to give way for tobacco production again. The possibility of production in winter time is important, especially for farmers with limited land availability. Research on these topics will provide farmers with robust information regarding tobacco diversification possibilities.

Regarding environmental issues there is a broad scope for doing research. This study was limited to soil degradation and within this, only SOM was included (due to limited data availability). Soil erosion and soil and water contamination coming from tobacco production need attention in future research.

Carbon supply from crops was estimated from literature. An accurate assessment of carbon supply from different crops in the area is needed for realistic estimation of carbon balances.

Tobacco production and its diversification entail not only soil degradation and economic aspects but also social aspects, as can be derived from Chapter 5. The challenge for an interdisciplinary research is to develop sustainable production systems for the Valle de Lerma, addressing environmental, economic and social dimensions of sustainability.

6.4.3 Business implications

Market accessibility is crucial for tobacco farmers in their decision to pursue diversification strategies. Introducing new farm activities at a large scale requires access to large markets in terms of demand, like the market in Buenos Aires (1600 kilometres far from Salta). Selling in Buenos Aires entails high transportation costs and investments in marketing facilities, like conservation and packaging facilities. So, development of new marketing channels needs to be done.

With current tobacco prices and subsidies, a specialized tobacco farmer faced with the decision of diversifying production will have to be willing to give up income in order to diminish soil degradation by means of diversification, as shown in Chapter 5. If tobacco subsidies are abolished, or if tobacco prices decrease, then farmers will introduce more easily new activities because tobacco production then becomes relatively less profitable.

Specialized tobacco farmers in the area are well skilled in producing tobacco, but not yet in animal production. Therefore, training will be necessary for farmers to diversify into livestock production. In this sense, the education of the farmer will play an important role. According to determinants of diversification (Chapter 3) a better educated farmer is expected to have better access to information on the management of new farming activities.

6.5 Main conclusions

The main conclusions of this thesis are as follows:

- It is feasible to improve nutrient availability in fields of Valle de Lerma by increasing SOM, but it is not economically attractive to increase SOM by means of green manure (Chapter 2).
- Soil nutrient availability is explained in part by unobserved cohorts' specific effects like farmers' skills or preferences, local conditions and management strategies. (Chapter 2).
- Considering determinants of diversification, specialized tobacco farms with a better educated farmer have more possibilities for diversification. In addition to the level of education, more land availability, lower irrigated land availability, higher level of ownership of land, lower share of specific capital goods devoted to tobacco may encourage diversification (Chapter 3).
- The largest tobacco producers in terms of the area of tobacco are highly diversified while the smallest are specialized in tobacco production (Chapter 3).
- Market feasibility of inputs for production and of outputs is crucial for introducing diversification activities (Chapter 4).
- Livestock production activities like beef bulls and dairy cows are considered the best diversification activities by stakeholders in terms of the selected diversification criteria (Chapter 4).
- Price and yield risk, risk aversion, and soil degradation do not have an impact on the farmer's decisions to produce tobacco in the situation with current tobacco prices and subsidy and without restrictions on soil degradation (Chapter 5).
- In the situation of current prices and restrictions on soil degradation, tobacco and soybean are for the greater part replaced by beef bulls and chickpea (Chapter 5).

- The requirement of no further soil degradation in the situation of current tobacco prices strongly decreases total gross margin of the farm (Chapter 5).
- Tobacco subsidy abolishment leads to the replacement of tobacco by soybean and beef bulls and a strong decrease of the total gross margin of the farm (Chapter 5).
- Because of the highly labour intensive character of tobacco production compared to the alternatives, substantial replacement of tobacco in Salta will result in considerable loss of employment on the specialized tobacco farms (Chapter 5).

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Summary/Samenvatting/Resumen

Summary

In the province Salta, in the Northwest of Argentina, tobacco (*Nicotiana tabacum* L.) is economically and socially important, as many people depend directly or indirectly on its production. However, the current practice of tobacco mono-cropping, excessive tillage and inadequate irrigation management causes soil degradation, with negative impacts on production. Also, the future of tobacco production is uncertain because of its dependence on subsidies and increasing concerns about health damage from tobacco consumption. Hence, there is a need for research on diversification by specialized tobacco farms. Diversification is defined as the adoption of farming activities different from tobacco production that use farm assets (land, labor, capital) to produce agricultural products (crops and animals). The definition of diversification in this study excludes off-farm employment and off-farm investments.

The overall objective of this study was to explore opportunities for diversification of specialized tobacco farms in the Valle de Lerma. This overall objective was pursued in four different steps, which are described in chapters 2 to 5.

In Chapter 2, a pseudo-panel of data from soil analysis reports of tobacco cultivated fields was built to explore the potential for improving Nitrogen (N), Phosphorus (P) and Potassium (K) availability by increasing SOM, using random and fixed effect econometric models. Based on the results of this econometric analysis, an economic assessment of the increase of SOM by using green manuring crops was done. The average current content of SOM in the analysed sample was 1.55 %, which is considered low. Positive elasticities were found between N, P and K availability and SOM. The elasticity of N with respect to SOM of 0.75 was the only statistically significant elasticity. The elasticity suggests that an increase of 1 % of SOM will increase soil N by 0.75 %. The models results suggest that 25 % of N, 13 % of P and 44 % of K variations were explained by unobserved specific characteristics such as location-specific characteristics, management strategies, farmers' skills and preferences and environmental heterogeneity. The effect of SOM improvement through the use of green manure was evaluated in relation to N, being the only significant elasticity. The results showed that costs and benefits of green manuring would be equal if SOM would increase from 1.55 % to 3.61 % which is barely achieved according to the literature. Hence, growing green manure crops to increase SOM and thereby N availability is economically not attractive, although additional benefits may arise from SOM improvement and by growing

green manure crops, like enhancement of soil aggregates, of soil porosity and of water infiltration, biota development and weeds and plant disease reduction.

Chapter 3 reviewed the literature on determinants for diversification and developed a typology of tobacco producing farms in Salta, based on these determinants and by applying Principal Component Analysis and Cluster Analysis to Agricultural Census data. Risk reduction and income improvement are the main reasons for diversification. The variables selected concerning determinants of diversification were: land area, irrigation, general capital goods and specific capital goods, ownership of land, education, off-farm work, and labour availability. The analysis of the principal components applied to 16 selected variables allowed to reduce the dimensionality of the data to 4 components. Those 4 components were used to apply K-means cluster approach to classify the farms. Four clusters were determined. Cluster 1 and Cluster 2 were the largest clusters in terms of number of farms. These clusters concerned highly specialized tobacco farms with 23-24 ha of tobacco. They mainly differed in education level of the farmer and different levels of off-farm work. Both clusters were interesting for further analysis regarding diversification alternatives to maintain or improve income and to reduce soil degradation. Cluster 3 concerned large tobacco farms (average tobacco cultivated land is 176 ha) being somewhat less specialized than the farms in clusters 1 and 2. Farms in cluster 4 already had a high level of diversification with substantial livestock production.

Chapter 4 developed criteria for assessing diversification activities based on a literature review, and ranked different diversification activities with respect to those criteria. The Analytic Hierarchy Process (AHP) technique was used to quantitatively measure the scores on different criteria of activities from experts and stakeholders. Next, goal programming methods were used to aggregate individual assessments in order to arrive at the final ranking of farming activities for diversification. Four groups of diversification activities were determined, namely autumn-winter crops, spring-summer crops, perennial crops and forests and livestock production. The five criteria to judge the production activities for tobacco diversification were: contribution to income, suitability for biophysical conditions, availability of technical information, market feasibility and contribution to soil improvement. The feasibility to market the products stood out with a high relative weight, while the other criteria received similar weights. The obtained weights of farming activities showed that especially livestock activities and spring-summer crops are important alternatives for tobacco production. Livestock activities stood out because they got high scores on all criteria.

Livestock activities and spring-summer crops compete with tobacco for resources because tobacco is also a spring-summer crop. Following the ranking of activities from Chapter 4, Chapter 5 determined optimal plans of current and diversification activities for risk averse farmers on a specialized tobacco farm to stop soil degradation. SOM was included as an indicator of soil degradation. A quadratic programming model of a typical specialized tobacco farm including maximization of expected income minus risk was developed. SOM was included in the model using the concept of the carbon balance, being the difference between carbon supply and carbon decline in a year. Two different situations with respect to soil degradation were evaluated using this model. The current situation included no restriction on carbon balance while the desired situation included the restriction that carbon balance cannot be negative. The model results for the current situation showed that all irrigated land was devoted to tobacco production while the rest was used for soybean production, irrespective of the level of risk aversion of farmers, resulting in a highly negative carbon balance and continuous soil degradation. In the desired situation, tobacco and soybean were replaced for an important part by beef bull production (including the production of alfalfa and maize for silage for feeding) to fulfill the requirement of no negative carbon balance. As the risk aversion coefficient in this situation increased, beef bulls and soybean were partly replaced by the low risk crop chickpea. The requirement of no further soil degradation came at a high cost since gross margin of the farm was decreased by some 35% compared to the current situation. Finally, the model was used to explore the effects of an abolishment of governmental subsidies on tobacco. In this situation the production plan consisted of soybean, beef bulls and tobacco in such a proportion that carbon balance is positive. Income effects of an abolishment of governmental subsidies on tobacco would be enormous as the gross margin of the farm decreased by some 60%.

Based on the findings of this thesis the main conclusions are:

- It is feasible to improve nutrient availability in fields of Valle de Lerma by increasing SOM, but it is not economically attractive to increase SOM by means of green manure (Chapter 2).
- Soil nutrient availability is explained in part by unobserved cohorts' specific effects like farmers' skills or preferences, local conditions and management strategies. (Chapter 2).

- Considering determinants of diversification, specialized tobacco farms with a better educated farmer have more possibilities for diversification. In addition to the level of education, more land availability, lower irrigated land availability, higher level of ownership of land and lower share of specific capital goods devoted to tobacco may encourage diversification (Chapter 3).
- The largest tobacco producers in terms of the area of tobacco are highly diversified while the smallest are specialized in tobacco production (Chapter 3).
- Market feasibility of inputs for production and of outputs is crucial for introducing diversification activities (Chapter 4).
- Livestock production activities like beef bulls and dairy cows are considered the best diversification activities by stakeholders in terms of the selected diversification criteria (Chapter 4).
- Price and yield risk, risk aversion, and soil degradation do not have an impact on the farmer's decisions to produce tobacco in the situation with current tobacco prices and subsidy and without restrictions on soil degradation (Chapter 5).
- In the situation of current prices and restrictions on soil degradation, tobacco and soybean are for the greater part replaced by beef bulls and chickpea (Chapter 5).
- The requirement of no further soil degradation in the situation of current tobacco prices strongly decreases total gross margin of the farm (Chapter 5).
- Tobacco subsidy abolishment leads to the replacement of tobacco by soybean and beef bulls and a strong decrease of the total gross margin of the farm (Chapter 5).
- Because of the highly labour intensive character of tobacco production compared to the alternatives, substantial replacement of tobacco in Salta will result in considerable loss of employment on the specialized tobacco farms (Chapter 5).

Samenvatting

In de provincie Salta, in het noordwesten van Argentinië, is de tabaksproductie economisch en sociaal van belang, omdat veel mensen er direct of indirect van afhankelijk zijn. De manier waarop tabak geproduceerd wordt, in continueelt, met veel grondbewerkingen en met een vaak inadequate manier van irrigatie leidt echter tot verlies van bodemkwaliteit met als gevolg een daling van de bodemproductiviteit. Daarnaast is de toekomst van de tabaksproductie onzeker, omdat overheidssubsidies voor tabaksproductie in Argentinië onder druk staan vanwege de schadelijke effecten van tabaksgebruik voor de volksgezondheid. Deze ontwikkelingen vormen de achtergrond en de aanleiding voor het in dit proefschrift gepresenteerde onderzoek naar de diversificatiemogelijkheden voor gespecialiseerde tabaksbedrijven in Salta. Diversificatie is in dit onderzoek gedefinieerd als het opnemen van activiteiten door een agrarisch bedrijf, anders dan de tabaksproductie, die gebruik maken van de beschikbare productiemiddelen arbeid, grond en kapitaal voor het produceren van agrarische producten (gewassen en dieren). Deze definitie van diversificatie sluit activiteiten waarbij arbeid of kapitaal buiten het bedrijf worden aangewend uit.

Het doel van deze studie was het vaststellen van agrarische activiteiten geschikt voor diversificatie op gespecialiseerde tabaksbedrijven in de Valle de Lerma en het evalueren van de effecten van opname van deze activiteiten op het inkomen, op het inkomensrisico en op het organische stofgehalte van de bodem. De Valle de Lerma is een concentratiegebied ten aanzien van tabaksproductie in de provincie Salta met een oppervlakte van bijna 7000 km². Het doel van de studie is uitgewerkt in de hoofdstukken 2 tot en met 5 van dit proefschrift.

In hoofdstuk 2 worden de mogelijkheden onderzocht om de beschikbaarheid van N, P en K in de bodem te verhogen door middel van het verhogen van de organische stof in de bodem. Dit is gedaan in twee stappen. In de eerste stap werd het verband tussen het organische stofgehalte in de bodem en de N, P en K-beschikbaarheid vastgesteld. Hiervoor werd een database samengesteld met gegevens uit bodemanalyses van percelen met tabaksteelt. Deze database werd geanalyseerd met behulp van random en fixed effect econometrische modellen. De resultaten van deze econometrische analyse werden vervolgens gebruikt om vast te stellen of het economisch interessant is om de organische stof in de bodem te verhogen door middel van een groenbemester die geteeld kan worden in de periode tussen twee tabaksteelten. Het gemiddelde organische stofgehalte van de bodem op basis van de gegevens in de database bedroeg 1,55 % wat als laag aangemerkt kan worden. Uit de econometrische analyse bleek een positief verband tussen de organische stof in de bodem en

de beschikbaarheid van N, P en K, maar alleen de gevonden relatie met N bleek statistisch significant. De elasticiteit van de organische stof in de bodem met betrekking tot N bedroeg 0,75, hetgeen betekent dat een verhoging van de organische stof in de bodem met 1% leidt tot een verhoging van de beschikbaarheid van N met 0,75 %. De resultaten van de econometrische analyse laten verder zien dat 13 tot 44% van de variatie in N, P en K beschikbaarheid niet verklaard kon worden door de organische stof in de bodem, waardoor andere verklaringsfactoren als locatiespecifieke omstandigheden, managementstrategieën, en preferenties en vaardigheden van de ondernemer in beeld komen als mogelijke, maar in dit onderzoek niet onderzochte verklaringen. Voor de economische evaluatie van het verhogen van de organische stof in de bodem werd vervolgens alleen het effect op de N-beschikbaarheid, zijnde het enige significante effect, meegenomen. De resultaten laten zien dat een groenbemester economisch pas interessant wordt als de organische stof in de bodem door het verbouwen van de groenbemester omhoog gaat van 1,5 naar 3,61%. Omdat dit volgens de literatuur niet haalbaar is kan geconcludeerd worden uit dit onderzoek dat het verhogen van de organische stof in de bodem door het verbouwen van een groenbemester teneinde de N-beschikbaarheid te verhogen economisch niet interessant is. Hierbij moet opgemerkt worden dat additionele positieve, maar moeilijk te kwantificeren, effecten van een groenbemester, zoals verbetering van de bodemstructuur, van de wateropname door de bodem en van het bodemleven en reductie van onkruiden en ziektedruk niet meegenomen zijn in de berekeningen.

In hoofdstuk 3 wordt een typologie gemaakt van de bedrijven in de Valle de Lerma die tabak produceren. De typologie is gebaseerd op bedrijfs- en ondernemerskenmerken die bepalend zijn voor de mogelijkheden van een bedrijf voor diversificatie. Deze kenmerken zijn vastgesteld op basis van literatuuronderzoek. De vastgestelde kenmerken werden vervolgens gebruikt om een dataset met een beperkt aantal variabelen vast te stellen op basis van landbouwtellingsgegevens. Op deze dataset werd tenslotte principale componentenanalyse en clusteranalyse toegepast om te komen tot een bruikbare typologie. De diversificatiekenmerken die uit de literatuur naar voren kwamen en die zijn gebruikt in dit onderzoek waren de totale bedrijfsoppervlakte, de oppervlakte die geïrrigeerd kan worden, de omvang van algemene kapitaalgoederen en van kapitaalgoederen voor een specifieke productie, de eigendomsrechten van grond, de mogelijkheden voor werk buiten het bedrijf en de beschikbaarheid van arbeid. Dit leidde tot een dataset met 16 variabelen en 278 tabak producerende bedrijven. Principale componentenanalyse bracht het aantal variabelen terug tot

4 componenten. Clusteranalyse op basis van de vier componenten resulteerde tenslotte in vier clusters van duidelijk te onderscheiden bedrijfstypes. Cluster 1 en 2 bevatten samen 89% van alle bedrijven en zijn clusters van gespecialiseerde tabaksbedrijven met gemiddeld 23 en 24 ha tabak. Het belangrijkste verschil tussen deze twee clusters is het opleidingsniveau van de ondernemer dat het hoogst van alle clusters is in cluster 1 en het laagst van alle clusters in cluster 2. Cluster 3 bevat de grote minder gespecialiseerde tabaksbedrijven. Cluster 4 bevat bedrijven waar tabaksproductie van beperkt belang is naast de andere productieactiviteiten waaronder melkproductie en vleesproductie. De bedrijven in de clusters 1 en 2 zijn de bedrijven waarop dit onderzoek zich met name richt.

In hoofdstuk 4 wordt een ranking gemaakt van activiteiten geschikt voor diversificatie op tabaksbedrijven. Allereerst werden op basis van literatuuronderzoek criteria vastgesteld aan de hand waarvan diversificatie-activiteiten kunnen worden gerankd. Vervolgens werd het relatieve belang van elk criterium beoordeeld door experts en stakeholders die vervolgens een selectie van geschikte diversificatie-activiteiten beoordeelden op de verschillende criteria. Om de beoordelingen kwantitatief te maken werd de Analytical Hierarchy Process techniek gebruikt. Tenslotte werden doelprogrammeringsmethoden gebruikt voor het aggregeren van de beoordelingen van individuen tot één finale ranking van diversificatie-activiteiten. De vijf criteria voor de beoordeling van diversificatie-activiteiten die uit het literatuuronderzoek naar voren kwamen waren achtereenvolgens: de bijdrage aan het inkomen, de mate van geschiktheid gegeven de biofysische omstandigheden, de beschikbaarheid van productietechnische informatie, de mogelijkheden om de producten te vermarkten en de bijdrage aan bodemverbetering. Vier groepen van diversificatie-activiteiten werden vervolgens vastgesteld, namelijk: herfst- en wintergewassen, voorjaars- en zomergewassen, meerjarige gewassen en dierlijke productie. De beoordeling van de criteria door de experts en stakeholders leverde een duidelijk hoger gewicht op voor de vermarktingsmogelijkheden, terwijl de overige vier criteria vergelijkbare gewichten kregen. Uit de beoordeling van de diversificatie-activiteiten, met inachtneming van de gewichten voor de criteria, bleek dat dierlijke productie-activiteiten en voorjaars- en zomergewassen hoog scoorden, waarbij dierlijke productie-activiteiten hoog scoorden op alle vijf criteria. De uiteindelijke ranking van alle individuele activiteiten werd dan ook aangevoerd door vleesstieren, gevolgd door melkkoeien en sojabonen.

In hoofdstuk 5 zijn optimale plannen bepaald voor risico-averse ondernemers op gespecialiseerde tabaksbedrijven op basis van huidige en nieuwe diversificatie-activiteiten

waarmee verdere daling van de bodemkwaliteit voorkomen wordt. Hiervoor werd een kwadratisch programmeringsmodel van een gespecialiseerd tabaksbedrijf ontwikkeld waarin het saldo (opbrengsten minus variabele kosten) minus het risico als de te maximaliseren doelstelling werd gebruikt. Bodemkwaliteit werd in het model opgenomen door middel van de koolstofbalans, zijnde het verschil tussen de jaarlijkse koolstoflevering en koolstofafname. Twee situaties met betrekking tot bodemkwaliteit werden onderzocht met het ontwikkelde model. Voor de 'huidige situatie' werd het model geoptimaliseerd zonder beperking aan bodemkwaliteit. Voor de 'gewenste situatie' werd de beperking opgelegd dat de bodem niet verder mocht degraderen, met andere woorden de koolstofbalans mocht niet negatief zijn. De resultaten voor de 'huidige situatie' laten zien dat alle geïrrigeerde land gebruikt wordt voor tabaksteelt terwijl het overige land gebruikt wordt voor de teelt van sojabonen. De mate van risico-aversie zoals gebruikt in het model heeft geen effect op het resultaat. De sterk negatieve koolstofbalans wijst op een verdergaande bodemdegradatie. Om in de 'gewenste situatie' te kunnen voldoen aan eis van niet verdergaande bodemdegradatie, zijn tabak en sojabonen voor een belangrijk deel vervangen door alfalfa en snijmaïs voor de productie van vleesstieren op het bedrijf. Een toenemende risico-aversie in deze situatie leidt tot gedeeltelijke vervanging van de vleesstieren (op basis van alfalfa en snijmaïs) door kikkererwten, een gewas met een positieve koolstofbalans, met weinig risico, maar ook met een relatief laag saldo. De beperking ten aanzien van verdere bodemdegradatie heeft grote gevolgen voor het bedrijfssaldo. Dit neemt af met 35% ten opzichte van de 'huidige' situatie. Als laatste werd het model gebruikt om de effecten te verkennen van een afschaffing van de overheidssubsidie op tabak. Ook dit leidt tot een productieplan waarbij tabak een veel minder prominente plaats inneemt naast sojabonen en vleesstieren met in dit geval zelfs een positieve koolstofbalans als gevolg. De effecten voor het saldo zijn enorm met een daling van ongeveer 60%.

De belangrijkste conclusies van deze thesis zijn:

- Het is mogelijk de beschikbaarheid van nutriënten in de bodem in de Valle de Lerma te verhogen door het organische stofgehalte te verhogen, maar het is niet economisch interessant om dit te doen door middel van een groenbemester (hoofdstuk 2).
- De beschikbaarheid van nutriënten is voor een deel te verklaren uit niet vastgelegde effecten als locatiespecifieke omstandigheden, managementstrategieën en preferenties en vaardigheden van de ondernemer (hoofdstuk 2).
- Bedrijven met een beter opgeleide ondernemer hebben betere mogelijkheden om te diversifiëren. Andere aspecten die de mogelijkheden verbeteren zijn: de

beschikbaarheid van meer land en van minder geïrrigeerd land, een groter deel van het land in eigendom, en een lager aandeel van productiespecifieke productiemiddelen (hoofdstuk 3).

- De grote tabaksproducenten in de Valle de Lerma zijn veel meer gediversifieerd dan de kleine tabaksproducenten (hoofdstuk 3).
- De mogelijkheden om de benodigde inputs te kopen en om de producten te vermarkten zijn cruciaal voor de introductie van diversificatie-activiteiten (hoofdstuk 4).
- Dierlijke productieactiviteiten als vleesstieren en melkkoeien worden door stakeholders en experts beoordeeld als de meest geschikte diversificatie-activiteiten (hoofdstuk 4).
- In de situatie met de huidige prijzen en subsidies voor tabak hebben risico, de risicohouding en bodemdegradatie-effecten geen enkele invloed op de beslissing om maximaal tabak te produceren (hoofdstuk 5).
- In de situatie met de huidige prijzen en subsidies waarin verdere bodemdegradatie niet toegestaan is, wordt tabak voor een belangrijk deel vervangen door vleesstieren en kikkererwten (hoofdstuk 5);
- Het niet toestaan van verdere bodemdegradatie in de situatie met huidige prijzen en subsidies leidt tot een sterke daling van het bedrijfssaldo (hoofdstuk 5);
- Het afschaffen van de subsidie op tabak leidt tot de vervanging van tabak door vleesstieren en sojabonen, tot bodemverbetering en tot een grote daling van het bedrijfssaldo (hoofdstuk 5);
- Vanwege het arbeidsintensieve karakter van tabaksproductie in vergelijking met alternatieve producties, leidt een substantiële vervanging van tabak door andere producties tot een sterk verlies aan werkgelegenheid op tabaksbedrijven (hoofdstuk 5).

Resumen

La producción de tabaco (*Nicotiana tabacum* L.) es económica y socialmente importante en la provincia de Salta, en el Noroeste de Argentina, ya que numerosas personas dependen directa o indirectamente de su producción. Sin embargo, el monocultivo, el excesivo laboreo y el inadecuado manejo de riego producen degradación de suelo, con impactos negativos en la producción. También, existe incertidumbre en relación al futuro de la producción tabacalera debido a la existencia del subsidio al precio de tabaco y una creciente preocupación por los daños que ocasiona el consumo de tabaco en la salud. Emerge, entonces, la necesidad de realizar investigación de posibilidades de diversificación en explotaciones especializadas en la producción de tabaco. Se define diversificación como la adopción de actividades agropecuarias distintas al tabaco que usan recursos (tierra, tabaco, capital) para producir productos agropecuarios (cultivos y animales). El concepto de diversificación en este estudio excluye actividades extra-prediales e inversiones fuera de la explotación.

El objetivo general de este estudio fue explorar oportunidades de diversificación en explotaciones especializadas en la producción de tabaco en el Valle de Lerma. Este objetivo fue alcanzado en cuatro pasos, que son descriptos en los capítulos 2 a 5.

En el capítulo 2 se construyó un pseudo-panel de datos a partir de análisis de suelos de lotes tabacaleros, para explorar el potencial de mejora de la disponibilidad de Nitrógeno (N), Fósforo (P) y Potasio (K) mediante el incremento de materia orgánica (MO), usando modelos econométricos de efectos fijos y aleatorios. En base a los resultados de estos análisis econométricos, se realizó una evaluación económica del incremento de MO por el uso de abonos verdes. El contenido actual promedio de MO en la muestra analizada fue 1.55 %, lo que es considerado bajo. Se encontraron elasticidades positivas entre N, P y K y MO. La elasticidad de N con respecto a MO de 0.75 fue la única con significado estadístico significativo. Esta elasticidad sugiere que un incremento de MO del 1 % incrementaría el contenido de N en 0.75 %. Los resultados de los modelos aplicados muestran que el 25 % de la variación en la disponibilidad de N, 13% de P y 44% de K se explican por la presencia de características específicas no observadas, tales como características locales, estrategias de manejo, habilidades y preferencias del productor y heterogeneidad ambiental. El efecto del aumento en MO por el uso de abonos verdes fue evaluado en relación al N, que fue el único nutriente que presentó elasticidad significativa. Los resultados mostraron que los costos y beneficios de la aplicación de abono verde serían iguales si la MO se incrementara desde el 1.55% al 3.61%, lo cual es difícil de alcanzar, de acuerdo a bibliografía consultada. Así, la

aplicación de abonos verdes para mejorar el contenido de MO y de esta manera aumentar la disponibilidad de N no es económicamente atractiva, aunque pueden aparecer otros beneficios de aumentar la MO y cultivar abonos verdes, tales como mejora en la estabilidad de agregados, porosidad del suelo e infiltración de agua, desarrollo de microorganismos y reducción de malezas y enfermedades.

En el Capítulo 3 se realizó una revisión bibliográfica sobre determinantes de diversificación y se elaboró una tipología de explotaciones productoras de tabaco, basada en esos determinantes y mediante la aplicación de Análisis de Componentes Principales y Análisis de Conglomerados a datos censales. Las principales razones para diversificar son: reducción de riesgo y mejora del ingreso. Las variables consideradas como determinantes de diversificación son: superficie de tierra, disponibilidad de riego, bienes de capital general y específico, propiedad de la tierra, nivel de educación, trabajo extra-predial, disponibilidad de mano de obra. El análisis de componentes principales permitió reducir la dimensión de los datos a 4 componentes. Estos componentes fueron usados en la aplicación del método K-medias para clasificar las explotaciones. Se determinaron cuatro conglomerados. Los conglomerados 1 y 2 fueron los más grandes en términos del número de explotaciones. Estos conglomerados están altamente especializados en la producción de tabaco, con un promedio de 23-24 hectáreas plantadas. Difieren principalmente en el nivel educativo del productor y en la presencia de trabajo extra-predial. Ambos conglomerados son interesantes para investigar oportunidades de diversificación para aumentar el ingreso y reducir la degradación de suelos. El conglomerado 3 incluye a las grandes explotaciones productoras de tabaco (con un promedio de 176 ha) siendo menos especializado que los conglomerados anteriores. Las explotaciones del conglomerado 4 presentan un alto grado de diversificación con una gran presencia de producción ganadera.

El Capítulo 4 consistió primero, en el desarrollo de criterios para evaluar actividades de diversificación, en base a revisión bibliográfica y segundo, en la elaboración de una jerarquización de actividades en relación a esos criterios. La técnica de Análisis de Procesos Jerárquicos (AHP) fue aplicada para medir cuantitativamente los puntajes de las actividades con respecto a los criterios a partir de la opinión de expertos y actores involucrados en la temática de la diversificación. Luego, se aplicaron métodos de programación objetivo para agregar las evaluaciones individuales y arribar a la jerarquización final de actividades de diversificación. Se determinaron cuatro grupos de actividades: cultivos de otoño e invierno, de primavera-verano, cultivos perennes y forestales y producción animal. Los cinco criterios

para evaluar las actividades fueron: contribución al ingreso, factibilidad biofísica, disponibilidad de información técnica, factibilidad de mercado y contribución al mejoramiento de suelo. La factibilidad de mercado fue el criterio que recibió el más alto puntaje. Los puntajes finales de las actividades indicaron que las producciones animales y los cultivos de verano son importantes alternativas de diversificación. Las producciones animales recibieron puntajes elevados en todos los criterios. Estas actividades (que incluyen producción de forrajes) y los cultivos de primavera- verano compiten con el tabaco por recursos ya que el tabaco es un cultivo estival. A partir de la jerarquización realizada en el Capítulo 4, en el Capítulo 5 se determinaron planes óptimos de actividades de diversificación y producción de tabaco para distintos niveles de aversión al riesgo en una explotación especializada en la producción de tabaco, para detener la degradación de suelo. Se aplicó un modelo de programación cuadrática que incluyó la maximización del ingreso menos el riesgo. La MO fue incluida en el modelo usando el concepto de balance de carbono, que es la diferencia entre el aporte y la pérdida de carbono en el año. Se evaluaron dos situaciones con respecto a la degradación de suelos. La situación actual no incluyó ninguna restricción con respecto al balance de carbono, y la situación deseada incluyó la condición de no negatividad del balance de carbono. Los resultados del modelo para la situación actual mostraron que la superficie con riego se destinaba a la producción de tabaco y el resto a la producción de soja, independientemente del nivel de aversión al riesgo del productor, resultando en un balance de carbono negativo y continuidad de la degradación de suelo. En la situación deseada, el tabaco y la soja fueron reemplazados en parte por la producción de novillos (que incluía la producción de alfalfa y maíz para silo) para cumplir con la condición de no negatividad del balance de carbono. A medida que la aversión aumentaba la producción de novillos y soja fue reemplazada parcialmente por el garbanzo, un cultivo de menor riesgo. El requisito de no degradación de suelo significó un alto costo económico ya que el margen bruto de la finca decreció un 35 % en comparación con la situación actual de degradación de suelo. Finalmente, el modelo se usó para explorar los efectos de una supresión del subsidio al tabaco. En esta situación, el plan óptimo consistió en la producción de novillos, soja, y tabaco en una proporción en la que el balance de carbono es positivo. El impacto en el ingreso de la supresión del subsidio sería enorme ya que el margen bruto de la explotación tabacalera decaería en un 60%.

En base a los resultados de esta tesis las principales conclusiones son:

- Es factible aumentar la disponibilidad de nutrientes en los suelos del Valle de Lerma por el incremento de MO, pero no es atractivo desde el punto de vista económico aumentar la MO por medio del uso de abonos verdes (Capítulo 2).
- La disponibilidad de nutrientes en suelo es explicada en parte por efectos específicos no observados tales como habilidades o preferencias del productor, condiciones locales o estrategias de manejo (Capítulo 2).
- Considerando los determinantes de diversificación, aquellos productores con mejor nivel educativo tienen mayores posibilidades de introducir actividades de diversificación en la explotación. Además, mayor disponibilidad de tierra, menor disponibilidad de tierra bajo riego, la propiedad de la tierra y una menor cantidad de capital específico para tabaco son variables que alientan la diversificación (Capítulo 3).
- Los grandes productores de tabaco en el área están altamente diversificados, mientras que los más pequeños están altamente especializados en la producción de tabaco (Capítulo 3).
- La posibilidad de mercado de insumos y productos es decisiva para la introducción de actividades de diversificación (Capítulo 4).
- La producción ganadera, como novillos y vacas lecheras fueron consideradas como las mejores actividades para diversificar por diferentes actores en relación a criterios de diversificación (Capítulo 4).
- El riesgo en rendimientos y precios, la aversión al riesgo y la degradación de suelos no tienen impacto en la decisión de los productores de producir tabaco, en la situación actual de precios y subsidio y sin restricciones en relación a la degradación de suelos (Capítulo 5).
- En la situación de precios actuales y restricción en la degradación de suelo, el tabaco y la soja son reemplazados mayormente por la producción de novillos y garbanzo (Capítulo 5).
- El requisito de no degradación de suelo en la situación de precios actuales disminuye fuertemente el margen bruto total de la explotación (Capítulo 5).
- La supresión del subsidio conduce al reemplazo del tabaco por la soja y la producción de novillos y una fuerte disminución del margen bruto de la explotación (Capítulo 5).
- Debido a la característica de intenso uso de mano de obra de la producción tabacalera en comparación con otras alternativas, el significativo reemplazo del tabaco en Salta

resultará en una pérdida considerable de posibilidades de empleo en las explotaciones tabacaleras (Capítulo 5).

Publications

Refereed scientific papers

Chavez. M.D., Berentsen, P.B.M., Oude Lansink, A.G.J.M. 2010. Creating a typology of tobacco farms according to determinants of diversification in Valle de Lerma (Salta-Argentina). *Spanish Journal of Agricultural Research* 8 (2), 460-471.

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Conference papers

Chavez. M.D., Berentsen, P.B.M., Oude Lansink, A.G.J.M. 2007. Typification of current farming systems of Valleys of intensive production (Northwest of Argentina). Poster. Agricultural Economics Society 81st Annual Conference, 2-4 April 2007, Reading, United Kingdom.

Chavez. M.D., Berentsen, P.B.M., Oude Lansink, A.G.J.M. 2008. Types of farms for exploring diversification in Valley of Lerma (Salta- Argentina). 2nd Regional Congress of Agricultural Economics, 5-7 November 2008, Montevideo, Uruguay.

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Curriculum Vitae

Daniela Chavez was born in Salta (Argentina) on August 11, 1967. She graduated in Agricultural Engineering at the National University of Salta (UNSa) in 1993. In 1994, she was granted a fellowship to do research in Farm Management at the Experimental Station of Salta of the National Institute for Agricultural Technology (INTA- Salta). In 1996 she got a position as Practical Lecturer in Farm Management at UNSa. In 2000 the Dutch Government awarded her a fellowship to follow courses on participatory planning and research-extension-farmer linkages at the International Agricultural Centre (IAC) in Wageningen. In 2001 she got a researcher position in the Department of Economics Studies and Rural Sociology in INTA-Salta and she was granted a fellowship by the Joint Japan/World Bank Graduate Scholarship Program (JJ/WBGSP) to follow the MSc program in Agricultural Economics and Management (Farm Management specialization) at Wageningen University (2001-2003). In 2005 she was granted a fellowship by INTA to follow the Sandwich PhD program at Business Economics Group at Wageningen University. She participated in many research projects along her career in INTA and contributed in many technical publications and reports. From 2006 to 2009 she coordinated a regional research project for supporting decision making in production systems in Salta and Jujuy provinces. She continues working at the Experimental Station of Salta.

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Name of the activity	Department/ Institute	Year	ECTS*
A) Project related competences			
Models of Agrosystems Simulation	National University of Río Cuarto (Argentina)	2008	1.4
Spatial Econometrics: theory and practice	MGS	2008	1.5
Introduction to environmental economic Modelling	SENSE	2006	5
Crop simulation models	National University of Córdoba (Argentina)	2006	2
Quantitative research methods	MGS	2005	4
Mathematics methods for decision Making	Catholic University of Salta	2004	2
B) General research related competences			
Project and time management	WGS	2006	1.5
Mansholt Introduction course	Mansholt Graduate School	2006	1.5
Proposal writing		2006	2
PhD meetings of BEC		All years	1
C) Career related competences/personal development			
‘Typification of current farming systems of Valleys of intensive production (Northwest of Argentina)’	Reading, United Kingdom	2007	1
‘Types of farms for exploring diversification in Valley of Lerma (Salta- Argentina)’	Montevideo, Uruguay	2008	1
‘Soils nutrients in tobacco cultivated land: assessment of factors affecting their availability and economic implications of improving soil organic matter’	San Luis, Argentina	2010	1
‘Criteria for tobacco diversification activities: an assessment using the Analytical Hierarchical process (AHP) technique’	Valdivia, Chile	2011	1
Research Project coordinating	INTA (National Institute for Agricultural Research)	2006-2009	4
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* One ECTS is equivalent to 28 hours

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