Tendency of production decisions of the farmers of the Southeast Pampa region in Argentina under uncertainty conditions

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Abstract: *Medium agricultural production enterprises in the southeast of the Pampa Region in Argentina have been characterized by their diversified production. However, grain markets conditions and technological change in soybeans and wheat crop raise the question if intermediate farms would maintain a diversified production. This paper analyses the productive strategies of farms with intermediate levels of capitalization to infer the resource allocation tendency. The analysis incorporates market and production risk considerations through application of two Minimization of Total Absolute Deviations (MOTAD) models. The first one includes conservationist recommendations on soil use; in the second one, these restrictions are not included. Comparative analysis of the representative productive system with the efficient plans reached, places the farmer within a range of intermediate profit-risk levels solutions. While pastures and corn play an important role in the representative farm model, efficient plans tend to be less diversified increasing acreage with wheat. When matrixes with and without agricultural limitations are contrasted, results can improve the discussion about the ecological sustainability of the productive systems in the region. Relaxation of the land use restriction allows obtaining any similar expected profit at a lower level of risk. However, solutions are more specialized than those with crop restriction. Results indicate that regardless the producer's degree of aversion to risk soybeans and wheat will be the basis of productive plans. Specialized cash crop production will increase, unless efforts are made to promote adoption of sustainable practices by farmers independently of their level of income and risk aversion degree.*

Keywords: *uncertainty, decision, sustainability, farming system, resources allocation*

Introduction

Medium and large scale farms in the southeast of the Pampa Region in Argentina have been characterized by their diversified production. Integrating cropping and livestock activities via rotations of grain crops with pastures has been traditionally viewed as a strategy to conserve soil, maintain productivity and stabilize farm incomes.

However, since the beginning of this decade there has been a progressive increase in area planted with annual crops. This expansion of cultivated land was mainly because of higher relative grains prices and improved soybeans and wheat yields during the 1990's. Technology for the production of soybeans, either single year harvest or like double-crop planted after wheat is harvested, allowed higher and more stable yields in the southeastern region of the Pampas. The tendency towards annual crops is reinforced by the introduction of French wheat genetics (called Baguette varieties) that allowed increasing yields substantially.

The increase in area planted with crops has accelerated in recent years. Soybeans is leading this change by its advantageous cost/benefit ratio (Iorio and Mosciaro, 2008), displacing other crops like corn or sunflower. The regional area sown with soybeans increased from 115000 ha to 427000 ha (+271%) between 2002 to 2007. At the same time, the corn planted area decreased from 129400 ha to 84100 ha (-54%).

The recent increase of the soybeans area raises questions about whether intermediate farms will be able to maintain a diversified production plan.

The trend toward specialization may have negative implications on the sustainability of farming systems. Agriculture practices are considered sustainable if they tend to maintain or increase soil organic matter levels overtime (Robinson et al., 1994). The results of different rotations carried out in the region (Studdert et al., 2000; Studdert, 2003) reveal that sequences with high shares of soybeans have higher loss rate of organic matter due to biochemical characteristics and low carbon replenishment of its stubble. These authors conclude that negative effects of soybeans expansion can be reduced by diversifying the rotation with annual and perennial crops.

From the economic standpoint, diversification is a tool to mitigate the effect market and climate variability on farm incomes. Nevertheless, this strategy involves an implicit cost, which constitutes a sub-optimal outcome (Anderson et al., 1977; Hardaker et al., 1997). This background makes necessary to analyze whether the fall on profit carries on a significant risk reduction.

The existing literature allow us think that producers would choose diversified production plans, not necessary following conservationist criteria but because diversification constitutes an efficient strategy to reduce production and market risk.

The objective of this work is to analyze the trade off between returns and risk for plans with different degrees of diversification and to infer the tendency of farms with intermediate levels of capitalization in terms of soil use. We address this question using the classical approach to decision making under-uncertainty by modeling representative farm using a linear programming Minimization of Total Absolute Deviations (MOTAD) model.

Method

A whole-farm model of a typical farm of the southeast of the Pampa region is developed. The necessary parameters that define the representative farm were defined by a focus group formed by local producers and agronomic consultants (experts).

Analysis Model

The economic analysis is conducted using two different formulations of a linear programming model. The first formulation models the use of soil conservation practices while the second does not include such practices.

The risk assessment is done through a MOTAD - Minimization of Total Absolute Deviations – model (Hazzell, 1971). MOTAD is used to analyze the trade-off between returns and risk of production plans with different degree of diversification and to evaluate if farms that diversify more are more efficient in reducing risk than specialized farms. In order to validate our model, production plans obtained from the MOTAD are compared with the representative farm plan.

The optimization done by the MOTAD works as follows, the absolute media deviation of returns (A) is taken as an indicator of benefits variability and interpreted as a measure of risk. Those plans that minimize A for given levels of expected return (E) constitute the efficient set of portfolios E - A. These portfolios yield the specified expect total margin (ETMs) assuming the minimum possible risks. This efficient set is further restricted by imposing a lower limit on the expected floor of the return (L), where L= ETM – 2s and s is the standard deviation which makes that the return is 95 percent unlikely to fall below this floor (Baumol, 1963).

Market and production are considered as sources of risk. Market risk is created by the variability of product prices, fertilizers and herbicides prices, and by the variability of land leasing fees. Production risks is created by the variability of crop and pasture productivity due to changing weather conditions. The impact of weather changes on pasture productivity, and in forage supply, is simulated through varying weight sale of the marketed animals. Random behavior of these variables is emulated through stochastic Monte Carlo simulations. A total of 100 iterations were used given that these iterations assured appropriate levels of convergence.

Representative Farming System

The representative farm operates 700 ha, 500 ha are owned by the producer and 200 ha are rented. Only about 10 percent of the owned land is unsuitable for annual crops. The land allocated to each activity is as reported in Table 1

Table 1. Land Utilization (ha).

	Own-land	Rent-land
Total land	500	200
Cropping activities	400	200
Wheat	140	100
French varieties (baguette)	140	
Traditional varieties	100	
Corn	20	-
Sunflower	60	-
Soybeans	180	100
Double cropping Soybeans*	100	60
Livestock activities (effective use)		
Perennial pastures on land suitable for annual crops	50	
Perennial pastures on land unsuitable for annual crops	50	
Annual pastures (oat)	40	
Stubble	60	

* Soybeans planted after wheat is harvested.

Wheat and soybeans are planted through custom farming using direct seeding machinery. The remaining crops are planted using the farmer's own conventional tillage machinery. Table 2 shows the modal rate for inputs used by the representative farm. These rates were used in the specification of the MOTAD model.

Table 2. Cropping activities: Main inputs.

		Wheat		Corn	Soybeans	Double Cropping soybeans	Sunflower
		Baguette	Traditional				
Seed	(kg/ha)	150	150	20	90	110	4.5
Glyphosate	(l/ha)	3	3	-	7.5	5	-
Phosphate diammonium	(kg/ha)	100	100	80	50	-	50
Urea	(kg/ha)	180	140	120	-	-	-

Cattle production includes breeding beef and the fattening of steers and heifers up to the slaughter weight. The performance measures used to model the beef breeding herd and the feeder cattle herd are shown in Table 3. The fattening period of females and half of the males is 9 to 10 months, while the rest of males are feed from pastures for about one year and receive a supplementation of 4 kg per head per day of wet-corn kernel silage during the last 2 months.

Table 3. Livestock. Technical coefficients.

Cows (head)	100	
Replacement heifers rate	20% - own	
Bull rate	4%	
Weaning rate	84%	
Weight gain (kg/day)		
Heifers	Variable, mode: 0,500	
Steers	Variable, mode: 0,550	
Sales own production	Weight (kg/head)	Sale Month
Heifers	Mode. 310	December / January
Steers	Mode: 340	December / January
	Mode: 380	March / May

Model Formulation

The MOTAD model is specified in a linear programming matrix form. Data and technical coefficients agreed as typical by the panel of local experts. In the case of harvest crop alternatives two tillage technologies are considered for wheat: conventional tillage and no-till seeding (direct seeding). Yield frequency distributions for each grain crop activity according to experts' opinions are shown on Table 4. Stochastic simulation takes into account the historic yield correlation between crop yields.

Table 4. Grain Crops Yields: frequency distribution.

	Wheat				Corn		Sunflower		Soybeans		Double cropped Soybeans	
	Traditional		Baguette									
	Conv	DS	Conv	DS								
Prob	ton/ha	ton/ha	ton/ha	q/ha	Prob	ton/ha	Prob	ton/ha	Prob	ton/ha	Prob	ton/ha
10%	2,8	3,0	2,8	3,0	15%	2,0	15%	1,3	5%	1,4	10%	2,0
15%	3,3	3,5	3,8	4,0	20%	4,5	20%	1,8	15%	2,0	25%	6,0
50%	4,4	4,5	5,4	5,5	35%	6,5	40%	2,4	45%	2,8	40%	1,2
25%	5,2	5,2	6,5	6,5	20%	8,0	15%	2,8	20%	3,2	15%	1,5
					10%	10,0	10%	3,0	10%	3,8	10%	2,0

Prob: Probability; Conv: conventional tillage; DS: direct seeding

In addition to the described cattle activities defined in the model, sale of weaned calves (170 kg/head for females and 180 kg/head for males) and a short fattening period for heifers with spring supplementation (to be sold in October weighting 280 kg/head) are included. For cow replacement, two alternatives are considered: 15-month or 27-month heifers both produced internally.

Forage supply is modeled through independent activities according to soil quality requirements and seasonal production of each type of pasture crops. Table 5 shows the effects of variability in pasture productivity on weight sale of the marketed animals.

Table 5. Sale Weights: minimum, most likely and maximum values (Kg/head).

	Steers		Heifers		Light Cow	Fattened Cow
Sale Month	January	March - April	January	October	March-Sept.	June - November
Minimum	290	320	270	250	360	400
Most likely	340	380	310	280	380	420
Maximum	370	410	330	300	390	450

Simulation of output and input prices is based on triangular probability distributions. The most likely (mode), minimum and maximum values are set based on the typical sale (purchase) months for each output (input) between 1992 and 2009 (Table 6). Distribution parameters for input purchases are based on the typical purchase month between 2001 and 2009 (Table 7). All prices are expressed as April 2009 pesos (Wholesale Domestic Prices Index, basis 1993=100[1]).

Table 6. Outputs Prices: minimum, most likely and maximum values.

	Wheat	Corn	Sunflower	Soybeans	Calf female	Calf male	Steer		Heifer		Cull Cow Light		Cull Cow Heavy	
Sale Months	Jan-Feb-Mar	May-Jun-Jul	Apr-May-Jun	Apr-May-Jun	Feb-Mar		Jan	Apr	Jan	Oct	Mar	Sep	Jun	Nov
	$/ton				$/kg									
Minimum	315	269	458	481	2.38	2.75	2.50	2.52	2.50	2.51	0.96	1.17	1.57	1.59
Most likely	470	375	747	745	3.11	3.38	2.92	2.96	2.93	2.95	1.38	1.57	1.98	2.11
Maximum	758	566	1145	1007	3.94	4.16	3.35	3.76	3.38	3.33	1.98	1.98	2.87	2.72

Table 7. Inputs prices: minimum, most likely and maximum value.

Prices	Phosphate diammonium ($/ton)	Urea ($/ton)	Glyphosate ($/l)
Minimum	1475.8	1122.0	14.0
Most likely	4195.5	2703.4	22.0
Maximum	950.8	609.0	9.0

[1] Instituto Nacional de Estadísticas y Censos - Argentina

Prices are simulated considering correlation between them. Sale prices of calves, heifers and steers showed a high positive correlation (higher than 75 %) although their relation with the different cow categories was lower. In grains, a high correlation between wheat and corn (80%) was found.

Land rent is considered as a discrete variable tied to different soybeans price ranges because of the high correlation between these two variables. Wheat-soybeans double cropping leasing fees are also simulated according to soybeans prices, but double cropping land renting fee is set as 50 US$/ha above the renting fee for soybeans production. The remaining cost items are considered constant and valued according to 2008 price average.

Both matrix specifications consider the existence of physical limitations to the expansion of production activities (maximum area according to availability, soil occupation times, and soil aptitude). Matrix specifications differ in the inclusion of agronomic restrictions of maximum area for summer crops (225 ha) and for winter crops (225 ha). These restrictions aim at reducing soil degradation.

Results Analysis

Production plans that consider conservationist land use restrictions and conform the efficient E-A set are presented on Table 8. Production plans tend become more diversify as risk and expected total margin (ETM) decreases.

Table 8. E-A Efficient Plans Agronomic restricted MOTAD Model. Agricultural Land Utilization.

ETM Reduction	ETM (1000 $)	A: Risk Measure (1000 $)	Rent land (ha)		Activities on rent land (ha)					Activities on suitable annual crop Own land (ha)						
			Single Crop	Double Crop	Wheat			Soybeans		Wheat			Sun-flower	Soybeans		PP
					Bt SD	Bt Conv	Trad Conv	Single Crop	Double Crop	Bt SD	Bt Conv	Trad Conv		Single Crop	DoubleCrop	
				250		250			250		225			225	213	
2.5%	755,0	266.1	106	144		196		54	144		225			225	134	
5.0%	735.6	233.0	250		69	85		96			225			225	132	
7.5%	716.2	214.4	250		92		63	94			185	40	28	197	131	
10.0%	696.9	201.2	250				141	109		75	127	23	50	167	118	8
12.5%	677.5	188.5	221				117	104		70	121	33	52	159	101	14
15.0%	658.2	175.8	178				95	83		67	113	45	47	163	97	15
17.5%	638.8	163.2	136				73	63		64	105	56	42	167	94	16
20.0%	619.5	150.5	93				50	43		61	96	68	37	172	90	16
22.5%	600.1	137.8	51				28	23		57	88	80	32	176	86	17
25.0%	580.7	125.2	8				6	2		55	80	90	27	180	83	17
27.5%	561.4	113.1								39	71	101	39	177	39	24
30.0%	542.0	102.3								21	59	115	52	165	1	38
32.5%	522.7	93.9									48	145	71	126		61

A: Absolute media deviation of total margin
Trad: traditional; Bt: baguette; Conv: conventional tillage; DS: direct seeding; PP: perennial pasture.

Reaching the maximum ETM implies expanding baguette wheat-soybeans double-crop to the maximum allowed limit (whether owned or rented land). Nevertheless, rented land for double–cropped is included in the solutions only at highest levels of benefit but also at the highest levels of risk. On the other hand, soybeans single crop has relatively low variability and high-expected unitary margin (EM) which makes it the unique summer crop even in those solutions with the lower risk levels.

In the farmer's own land, single crop soybeans and baguette wheat are allocated the majority of cropping area in every efficient plan. Nevertheless, with an ETM reduction equal to or large than 7% plans become more diversified including sunflower and pasture. As risk and total benefit decrease, crop combinations maintain a similar proportion between regular soybeans and sunflower while double-cropped soybeans reduces progressively its participation.

Pastures are included in efficient E-A solutions when the maximum ETM reduces by 10% or more. However, pastures occupy significant amounts of farmland only in plans with low risk levels.

Together with the incorporation of pastures, feeder cattle is also included on high quality land. Plans with ETM reductions of 30% or more increase and diversify fattening activities.

Predictably, when the model that free of crop rotation constraints achieves the maximum ETM solution allocating all suitable land to the activity with the highest expected margin: baguette wheat-soybeans double-crop (Table 9).

This double crop occupies more than 85% of the owned land suitable for annual crops up to a 15% reduction of maximum ETM. For further ETM reductions, the model allocates more land to regular soybeans. In these efficient plans the area of pastures increases slightly respects those with land use restriction.

Like in plans with agronomic restriction the double crop in rented land is present only at high-risk levels. The payment of a premium for the longer period of land use makes double crop more risky than single crop soybeans. In the own land double crop uses an important proportion of area in most efficient E-A plans.

Table 9. E-A Efficient Plans Agronomic Unrestricted MOTAD Model. Agricultural Land Utilization.

ETM Reduction	ETM (1000 $)	A: Risk Measure (1000 $)	Rent land (ha)		Activities on rent land (ha)			Activities on suitable annual crop Own land (ha)						
			Single Crop	Double Crop	Wheat	Soybeans		Wheat			Sun-flower	Soybeans		PP
					Bt Conv	Single Crop	Double Crop	Bt SD	Bt Conv	Trad Conv		Single Crop	Double Crop	
Optimum	849684	404684		250	250		250		450				438	
2.5%	828442	356263	103	147	147	103	147		450				438	
5.0%	807200	312540	232	18	59	191	18		450				438	
7.5%	785958	277400	250			250		8	414			27	358	
8,9%	774314	261038	250			250		70	328			52	303	
10.0%	764716	251070	250			250		120	240	31		60	285	
12.5%	743474	234501	250			250		95	194	103	4	54	235	
15.0%	722232	218614	250			250		85	178	125	20	41	163	
17.5%	700989	203368	230			230		75	140	130	20	62	147	23
20.0%	679747	189439	197			197		64	132	129	20	75	135	29
22.5%	658505	175582	171			171		57	122	140	26	78	123	28
25.0%	637263	161747	127			127		53	110	134	29	99	113	26
27.5%	616021	147920	83			83		50	97	127	28	126	103	22
30.0%	594779	134171	40			40		49	85	116	26	153	93	21
32.5%	573537	120540						41	81	101	24	183	72	20

A: Absolute media deviation of total margin
Trad: traditional; Bt: baguette; Conv: conventional tillage; DS: direct seeding; PP: perennial pasture.

Figure 1 shows that in absence of land use restriction the maximum ETM (point b) is 9% higher than the restricted maximum ETM (point a). However, reaching the unrestricted maximum involves a more than proportional increase of 25% in the absolute media deviation (A). However, if conservationist restrictions are ignored (i.e., unrestricted model specification) it is possible to reach an ETM equal to the maximum restricted ETM, but reducing the risk level by 15% (point a´). In the production plan corresponding to point a’ single crop soybeans in the own land is replaced by baguette wheat using a higher proportion of its stubble to increase cattle rearing, the lower risk level activity

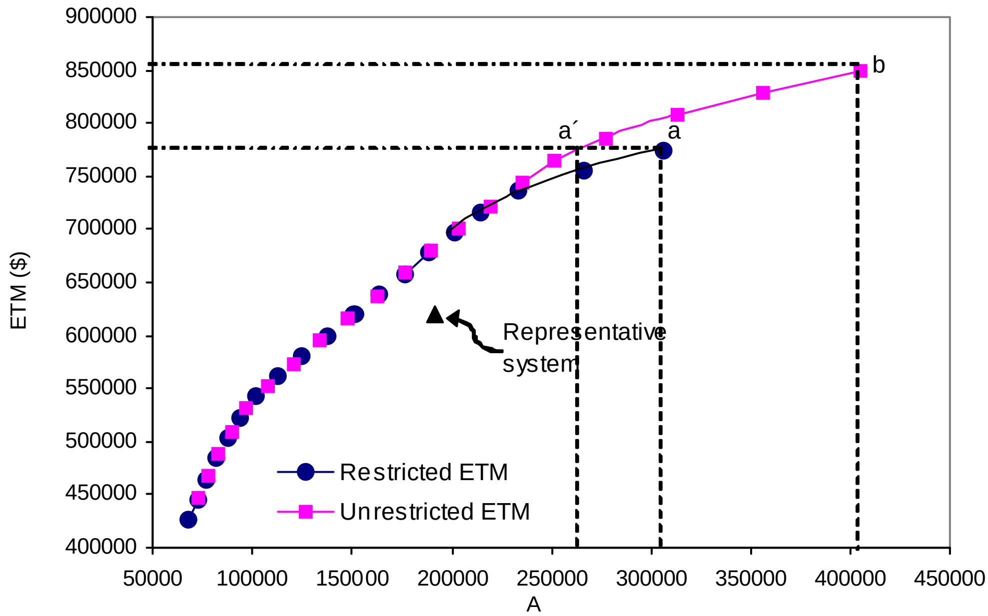

Figure 1. E-A Efficient Set of Plans for Agronomic Restricted and Unrestricted MOTAD Model.

Comparisons of efficient A-E solutions with the representative system

The productive plan of the modal farm agreed by the panel of experts is shown in Figure 1 according to its expected total margin and absolute media deviation. The productive plan followed by this representative farm yields a lower ETM and is riskier than the plans included in the efficient set. The modal farm could benefit by reducing its level of risk by 21% while maintaining the same ETM ($620600) or by increasing its ETM by 10% while maintaining the same risk exposure.

However, the combination of activities of the representative farm is similar to restricted plan yielding $619.500 (Table 8). There are two notorious differences between efficient and representative plan. First, while the representative plan grows the wheat-soybeans double crop on rented land, the efficient plan uses the rented to produce single crop soybeans. High gross margin variability of soybeans in the double crop explains the higher risk taken by the representative farmer. The second difference is that the efficient plan tends to be more specialized in crop activities increasing wheat area, while the representative plan allocates more land to pastures and cattle fattening activities.

On the other hand, efficient plans tends to be more specialized in crop activities increasing wheat surface, while pastures and cattle fattening activities get an important place in the representative farm plan.

Conclusions

The analysis of efficient return-risk solutions shows that relaxing land use restriction allows obtaining expected profits similar to those of the restricted maximum, but whit a lower level of risk. However, these solutions are more specialized than those with crop restriction even at intermediate or low risk level.

This result is against the assumption that uncertainty in yields and/or prices leads to more diversified production plans. Strategies to reduce risk may not be necessary consistent with conservationist practices.

Comparative analysis of the representative production plan with the efficient plans places the farmer within a range of intermediate profit-risk levels solutions. Differences found between representative farm and efficient plans, may be partially explained because the model does not consider some particular considerations, such as financial and labor restrictions. However, the most important cause may be that still farmers' decisions are motivated by soil conservation goals. It is also likely that farmers having medium or large scale consider the inclusion of pastures in rotation, despite the revenue decrease.

Results of this paper provide additional elements to explain the observed tendency towards the specialization in annual cash crops and suggest that such tendency will continue, unless substantial efforts are made to promote sustainable land management practices. These promotion efforts should focus at farmers with different production scales and degrees of risk aversion.

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