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Sustainable technical index for bio-economic farm models in Pampean region Argentine

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Abstract

An index of sustainable technical development, based on agrosystem properties (productivity, stability, and sustained growth) and its trade off is proposed. First, system´s relative energy is modelled using a Cobb-Douglas function, incorporating physical, technical, and economic variables, for nineteen periods. Level of productivity is analyzed using Greene's absolute frontier, stability and sustained growth using Marshack-Andrews frontier. The results enable the establishment of a scale of sustainable development with two levels. Level A, sustainable farms with 62.22% productivity, 85.90% stability and a sustained growth of 14.40%. Analyzing the trades off, it is observed an inverse relationship between productivity and stability as between stability and sustained growth. Not sustainable farms are grouped in level B, with the following attributes: productivity (48.62%), stability (98.16%) and sustained growth (10.84%). From trade off´s analysis we see a direct proportional relationship among productivity, stability and sustainability. We also observe that sustainability index depends, considering time and space, on risk and uncertainty existing.

Objective

The aim of this study is to propose indicators of sustainable development, attempting to cover multiple specifications. First, incorporating the theory of agrosystems and their properties (productivity, stability, and sustained growth or growth over time).

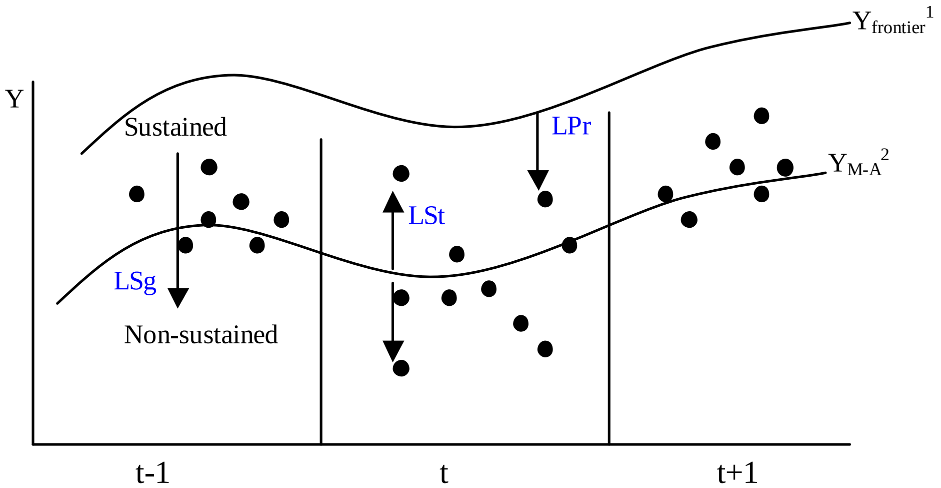
Material and Methods

System modelling

As agrosystems have a multiproduct character (beef production and cropping activities) it is necessary to model the system relative energy (Y: mcal/ha) in accordance with Viglizzo and Roberto (1989) and Ghersa et al. (2002). This energy model is calculated with Cobb-Douglas function, which incorpore physical, technical, and economic variables (Xj). Further, Marshack-Andrews function (1994) and Greene's absolute frontier (1980) are used.

Figure 1 shows the three proposed indicators. The level of productivity (LPr) establishes a unidirectional scale for the set of farms. The level of stability (LSt) establishes a bidirectional scale and the level of sustained growth (LSg) behaves similarly to productivity.

The sustainable technical development is estimated from the three proposed indicators using a sustainable development scale with different levels; so the zone with higher sustainable development shows farms with a maintained growth in time (LSg>0), with high productivity a stability. On the contrary the no sustainable development zone groups farms without a maintained growth (LSg<0), and a low level of productivity and stability.



$^{1}Y_{frontier}$: Greene´s absolute frontier, $^{2}Y_{M-A}$: Marshack-Andrews frontier, LPr: Level of productivity, LSt: Level of stability, LSg: Level of sustained growth.

Figure 1. Indicators of the Agrosystem.

Results and Discussion

The analysis involved 46 farms, cattle fattening in winter, wintering and cropping activities, located in the semi-arid Pampas of Argentina, during the period 1982-2000 (19 years) and a total of 425 analyses of management (not all the records were available in each period). Management reports incorporate more than 80 variables grouping physical, technical, and economic aspects of each activity.

Energy model

The proposed model includes relative energy production (EP:Mcal/ha per year) as explicative and endogenous variable, and the following explicative or exogenous variables: percentage of area devoted to livestock, sunflower, and maize (SL, SSF, and SMA respectively); set stocking (SS:kg/ha); average daily weight gain (ADG:g/d); direct farming costs (DFC:$/ha); cost of supplementation (CSU:$/ha); yield on total capital (YTC:%) and period (T:year). Following, frontier function is calculated adding the maximum positive residual (0.60641).

The quantification of the indicators is established using results from the log-linear and its equivalent Cobb-Douglas models. Log-linear model shows a small range of variation typical of the logarithmic scale, and are very close to 100%, and are not in agreement with those obtained from the Cobb-Douglas model.

Indicators of the agroecosystem

Productivity is lower than 57% in Cobb-Douglas model for each period. The explanation for the low results is that these are low-input agroecosystems, with predominantly grazing feeding. According to Castaldo (2003), pastural systems are situated in a phase of increasing yields with respect to the technology used. These results of stability, upper 90% in each of the periods, coincide with those of Viglizzo and Roberto (1989) and Cervini and Demarco (2003).

Figure 2 shows the agrosystem trade-offs. High correlation coefficients ($r=0.98$; $P<0.01$) between productivity and sustained growth are observed; and low correlation ($r=-0.09$; $P<0.05$) for both stability-productivity and stability-sustained growth. The mean rates of sustained growth, -6.26% and 7.23%, determine the four zones of sustained growth which are described.

Index of sustainable technical development

Having structured the system according to the lines of sustained growth, the indicators of the agrosystem are calculated for each of the four zones. The index of sustainable technical development of the agrosystems is established using the indicators (Table 2). Level A is established for the sustainable agrosystems and level B for the non-sustainable ones, each with two sublevels: 1 and 2.

Finally, the sustainable development index is compared with the classification of pastural winterings of the semi-arid Pampa (Castaldo, 2003), made trough cluster analysis.

Sustainability index B: This embodies non-sustainable farms, with low levels of productivity (lower than 55%) and a directly proportional and increasing relationship between productivity, stability, and sustained growth. Sublevel B2, with low productivity, stability and sustained growth, corresponds to the systems described by Viglizzo and Roberto (1989) with slow winterings of around 24 months, average daily gain of less than 390 g and without supplementation. Sublevel B1 improves indexes and corresponds to winterings with some degree of technification, where feeding is based on pastures and seasonal forage, and supplementation is employed. In these cases the daily mean gain is less than 450 g, and wintering lasts 22 months.

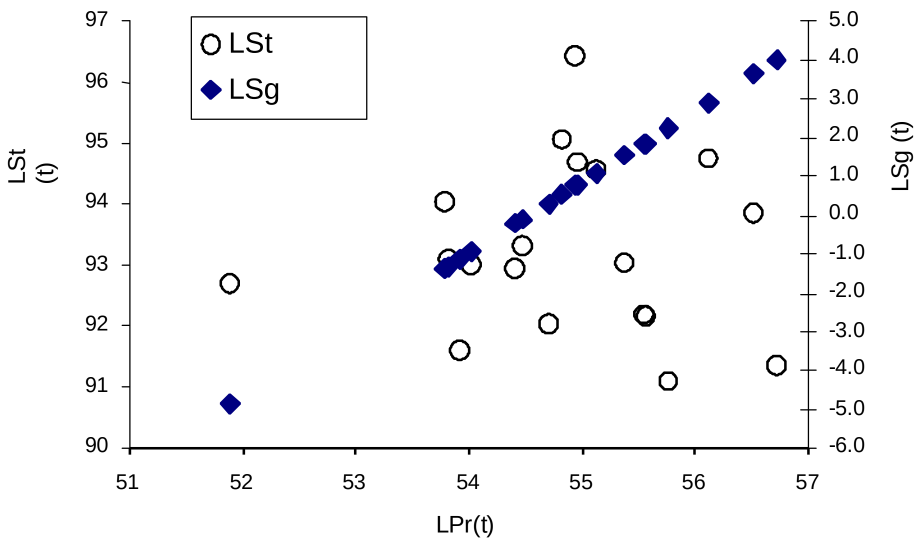


Figure 2. Relationships between Productivity, Stability, and Sustained Growth.

Sustainability index A: This embodies sustainable farms, with medium levels of productivity (between 55 and 66%). Where there are inverse relationships between productivity and stability and between stability and sustained growth. The farms of group A1 perform similarly to those of B1, although they have higher levels of supplementation and adequate pasture management, and achieve gains of between 450 and 500 g/d, with steers at 20 months. Groups A1 and B1 make up the greater part of the farms analysed, and employ an economic criterion of minimum cost in accordance with Castaldo *et al.* (2003) and Pariani (2004). Group A2 comprises pastural farms with a higher degree of intensification and dependence on external inputs. They present winterings with daily gains of between 500 and 600 g, and the cycle is finalized after 15 to 17 months. Their resource management seeks to maximize the financial profitability of the process, at the same time these take on a high risk because the output price is set by the internal market, while the price of inputs depends on the international market (Martos *et al.*, 2004; Castaldo *et al.*, 2003).

Table 1. Index of Sustainable Technical Develpoment.

Sustainability index	Zones of sustained growth (RSg)	Productivity (%)	Stability (%)	Sustained growth (%)
A_2	4 (RSg≥7.23)	62,22	85,90	14,10
A_1	3 (0≤RSg<7.23)	56,28	96,79	3,21
B_1	2 (-6.26≤RSg<0)	52,96	97,04	-2,96
B_2	1 (RSg<-6.26)	48,62	89,16	-10,84

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