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Sustainability of crop and livestock dominant dryland systems of Alentejo region: differences in economic returns and environmental consequences

Sustentabilidade dos sistemas dominantes de produção agrícola e pecuária em sequeiro na região Alentejo: diferenças nos resultados económicos e efeitos ambientais

Maurícia Rosado[1]*, Carlos Marques[2] e Rui Fragoso[2]

[1] University of Évora, Department of Animal Science, ICAAM, Apartado 94, 7002-554 Évora, Portugal. E-mail: *mmcr@uevora.pt, author for correspondence
[2] University of Évora, Department of Management, CEFAGE-UE, Apartado 94, 7000 Évora, Portugal. E-mails: cmarques@uevora.pt; rfragoso@evora.pt

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ABSTRACT

This paper presents a case study with two traditional Mediterranean-type farming systems: cropping dominant and grazing or livestock dominant. Traditional farming systems from the Mediterranean area in the Alentejo, southern region of Portugal, are compared in terms of economic returns, environmental impacts and trade-offs. A linear programming model that considers the economic and environmental issues for each farming system was developed. The models maximize farm profit subject to managerial, resource and environmental constraints. Environmental impacts were evaluated from cradle-to-grave and assessed following an input-output (I/O) analysis of environmental accounts and a Life Cycle Assessment (LCA) methodology. Results are used for economic evaluation and environmental impacts of farming systems. Results show that livestock predominant farming has larger environmental impact and lower net farm income than the crop farming system. Shadow prices of environmental constraints are compared for both systems to evaluate cost and efficiency of policies that constrains environmental consequences and promote sustainability. Costs required to compensate farmers for reductions of environmental impacts are lower for livestock predominant farming than for crop farms. Therefore, policy priorities should be targeted firstly to livestock predominant farming system effects. Subsidies represent a substantial part of the net farm income in both cases. Hence, in both cases, but particularly with the livestock predominant farming, there is considerable margin to improve policy effectiveness to control environmental impacts.

Keywords: economic returns, environmental impacts, farming systems, LP models, tradeoffs.

RESUMO

Este artigo apresenta um estudo de caso com dois sistemas agrícolas tradicionais característicos da área Mediterrânea, no Alentejo, região sul de Portugal. Um sistema agrícola tradicional dominante na produção de culturas e, um segundo sistema agrícola tradicional vocacionado para a produção de pastagens e forragens dominante em produção animal. Para cada sistema de produção foi desenvolvido um modelo de programação linear que considera os aspetos económicos e ambientais. Os modelos maximizam o lucro da exploração sujeito a restrições de recursos, de implementação das rotações e restrições ambientais. Estes sistemas tradicionais da área Mediterrânea, foram comparados em termos de resultados económicos, impactes ambientais e "trade-offs". Os impactes ambientais foram avaliados do "berço ao túmulo" seguindo uma análise de input-output (I/O) do azoto e da energia utilizada e uma metodologia do ciclo de vida (ACV) para os gases de efeito de estufa, acidificação, eutrofização e um indicador agregado de impacte ecológico. Os resultados mostram que o sistema predominante em pecuária tem impacte ambiental maior e rendimento líquido mais baixo do que o sistema predominante em culturas. Os preços sombra das restrições ambientais foram comparados em ambos os sistemas para avaliar os potenciais custos e eficiências de políticas ambientais que promovem a sua sustentabilidade. Os custos requeridos para compensar os agricultores por reduções de impacte ambiental são mais baixos para o sistema predominante em animais que para o de culturas. Por isso as prioridades políticas deverão ser dirigidas mais para o sistema predominante de animais do que para o de culturas. Os subsídios representam uma parte substancial do rendimento líquido em ambos os casos. Assim, em ambos os casos, mas particularmente em explorações predominantes de animais há uma margem considerável para melhorar a eficácia das políticas de redução dos impactes ambientais.

Palavras-chave: resultados económicos, impactes ambientais, sistemas agro-pecuários, programação linear, custo-benefício

Introduction

The concept of sustainable development emerged in the late nineteenth century, when fossil fuel energy demand exceeded its ecological limits and society looked for a concept that reconcile ecological, economic and social objectives of the present with those of future generations. Managing the present and future in a sustainable way is a task that will accompany humanity into the future (Schlör *et al.*, 2013).

To address this challenge in a global and interconnected world, world's agriculture must be competitive but also sustainable. There is evidence and public concern about the environmental issues, namely regarding loss of biodiversity, climatic change and air, soil and water degradation, and the recognition that farmers, due to the specific characteristics of their activity and connection with environment and natural resources, play an important role for producing public goods and services that markets undersupply (Cooper *et al.*, 2009; Marques, 2014). Public policies, such as the Common Agricultural Policy (CAP) in the European Union (EU), must deal with this challenge and provide guidance.

The introduction of sustainability objectives requires the redefinition of reference values for agricultural activities, which must be based not only on the recognition of the multifunctional land use but also on the complex role that agriculture plays in society (Gomiero *et al.*, 2006). CAP has extended its first and main objective of agriculture as that of supplying food to include policies relating to environmental effects and concerns, namely by decoupling, promoting agro-environmental policy measures and adopting ecological cross compliance requirements. Thus, it is expected that support and orientation for farmers may be closely tied to the environmental performance of their predominant farming systems, which requires an effective integrated economic and environmental evaluation (Pacini *et al.*, 2004; Van Ittersum *et al.*, 2008). Indeed, in the current CAP reform, part of the farm support payments already includes a required greening to implement this orientation.

The environmental component of sustainable development is usually addressed in a very general way and the variety of impacts is rarely considered. However, it is essential to consider the full range of impacts for an accurate and transparent environmental assessment (Joumard, 2011). To meet this challenge, evaluation of the sustainability of the agricultural systems and methods to determine those with greater yields relative to their resource use and environmental degradation have been proposed (Martin *et al.*, 2006). To provide effective guidance and deliver public results, policies must be based in real and appropriated evaluation of farmer actions and their environmental contribution.

Facing this challenge, this paper presents the case study of the Alentejo region of southern Portugal, for which a comparison between two traditional Mediterranean dryland agricultural systems is based on an integrated economic and environmental analysis. Thus, it is intended in this article to analyze two Mediterranean farming systems, one crop predominant and other livestock predominant, from the point of view of their environmental and economic performance. The aim is to discuss the relationship between the economy and the environment of these systems and their relationship with the policy instruments applied in such a way that the results can be used to guide the CAP measures.

Material and methods

The traditional dry land crop farming system is based on a typical farm of 250 hectares, of arable land without trees, with clay soils, in the Beja district (Rosado, 2009). This farming system is based on a crop rotation of four years (sunflower – durum wheat1 – green pea – durum wheat2) in which cereal alternates with sunflower and pea. The crop rotation is established to achieve high production levels of cereal, namely durum wheat, which used to have specific subsidies till changes in agricultural support policy towards decoupling. For soil preparation deep plough is followed by two harrowing soil mobilization, during winter, and one before sunflower seeding, in March, which begins the crop rotation. Sunflower does not receive fertilization or herbicide treatment. The soil for durum wheat1 is prepared with chisel plough followed by harrow and a seed density of 200 kg per hectare and a fertilization level of 300 kg per hectare (N-P-K respectively 20-20-0) was used. A chemical weeding followed by nitrogen fertilization with 150 kg per hectare (N 27%) was done. For the green pea a harrow and two chisel plough operations are done for soil preparation and the seeding was 150 kg per hectare. Weeding and fertilization treatments were not used in green pea. The durum wheat2 ends the crop farming rotation with the same annual calendar and technology used for durum wheat1.

The second system studied is a dryland traditional Mediterranean grassland-based agro-pastoral system that integrates crop and livestock, where animals use dryland extensive pasture system, fodder crop and more fibrous resources as feed, transforming raw material efficiently and directly into useful goods for humans and so contributing to enhance sustainability of the system (Bocquier and González-Garcia, 2010). This livestock predominant farming system is also carried out in a typical farm of 250 ha, with Mediterranean soils. Five annual crops in rotation (wheat - oat x vetch – oat - durum wheat - ryegrass) occupy 68% of the total farm area. Natural grassland occupies 22% of the total farm area (ha) under dispersed tree cover of corkoak and holmoak "montado", the typical Mediterranean forest. This natural grassland consist of annual grasses and some leguminous. The remaining 10% of the total farm area is dedicated to natural pasture improved with fertilizer.

Natural grassland and improved natural pasture is directly grazed by farm animals. Vetch x oat as well as ryegrass is used for hay production for animal feeding. Oat grains and cereals straws and stubbles are also used for animal feeding. The wheat and durum wheat grain is marketed as well as part (77.3%) of the durum wheat straw produced. The livestock is based on beef cattle in extensive systems to address the weaknesses of the soil, as well as nature conservation which seem to be increasingly valued by landowners (Menezes *et al*., 2010).

For soft wheat, soil conventional preparation is made with two disc harrowing soil mobilizations, followed by one soil mobilization with a double cultivator. Seeding with a drill lines and a roller coupled, use a seeding density of 180 kg per hectare and fertilization levels of 250 kg per hectare (N-P-K respectively 18-46-0). A weed spraying and a covering fertilization using 190 kg per hectare (Urey 46%) is made. The production technology used for the durum wheat is identical to the one used in the soft wheat with the exception of the seeding density, which is 200 kg per hectare in the former and 180 kg per hectare in the later.

Soil conventional preparation for the oat is made with disc harrowing and two crossed soil mobilizations, followed by seeding, with a drill lines and a roller coupled and using 150 Kg per hectare of oat seed and 190 kg fertilizer per hectare (N:P:K respectively 7-14-14). Cover fertilization is done with 100 kg of fertilizer per hectare (Urey 46%).

Oat x vetch soil preparation is done with harrowing mobilization followed by cultivator. Seeding is made with a drill lines and a roller coupled using 140 kg of seed per hectare (80 kg oat and 60 kg of vetch), simultaneously is carried out a fertilization using 150 kg of fertilizer (N-P-K respectively 18-46-0). A fertilization is made with 100 kg of fertilizer per hectare (N: 27%) using a centrifugal distributor. The forage is cut using a mower conditioner and, two days later, a gleaner turns the cut material towards a faster drying of the green material. After drying, the hay is balled, collected and stored for animal feed.

Soil preparation for ryegrass sowing is done with a double cross harrowing, followed by seeding with a drill lines to which it is coupled a roller. The seeding density is 25 kg per hectare and fertilizer application is of 130 kg of fertilizer (N-P-K respectively 15-15-15) per hectare. In the 2nd half of December the animals (beef cattle) graze this ryegrass (cutting teeth), after which it is done a fertilization with 110 kg of fertilizer (N: 27%) using a centrifugal distributor. The forage is cut, in May, using a mower conditioner. In the following days the forage is turned with a gleaner in order to be sufficiently dried to be baled.

Natural grassland improvement is done using 220 kg of superphosphate fertilizer per hectare. The natural pasture availability varies throughout the year, as well as, the chemical composition and nutritive value. Hence, it was considered five periods with different quantities produced and nutritional value through the year (Rosado, 2009).

Livestock activity is based on the production of beef cattle in extensive system. The breeding stock includes crossbred cows, replacement heifers and two bulls (one Charolaise and other Limousin). The mating is concentrated between November and December and during this time the bulls accompany the cows grazing. For the reproductive parameters it was considered a fertility rate of 90% and a mortality rate up to calves weaning of 3%. Annually all the male calves born and part of female calves born are sold after weaning, with an average live weight of 245 kg and 220 kg, respectively. The replacement of the males is done with animals purchased outside the farm.

The food requirements of different categories of animals on the farm were calculated based on tables from INRA (Soltner, 2004), depending on the weight of the animal and his physiological state.

Analytical systems and methodologies for obtaining quantitative descriptions of the trade-offs between different objectives, such as gross margin, greenhouse gases emissions and the energy input use in farm, have been used from the literature (Ten Berge *et al*., 2000). Linear programming models applied at farm level are one of the least complex and most extensively used methodologies that allows to integrate economic, production and environmental issues based on microeconomic budgeting accounting data and technical knowledge of farming systems (Marques, 2012). Economic indicators for the two considered production systems include total production costs, gross and net margins and are estimated through budget accounting of different production activities of each system.

Among the agro-environmental issues and respective indicators that have been proposed to evaluate environmental effects of production system technologies at farm level, nitrogen balance (Simon *et al*., 2000; Bassanino *et al*., 2007), pesticide use (Padovane *et al*., 2004), energy input (Pervanchon *et al*., 2002; Koga, 2008), soil organic matter (Ernest and Siri-Prieto, 2009), soil preparation and sowing (Borin *et al*., 1997; López-Fando and Pardo, 2009) and biodiversity (Manhoudt *et al*., 2005) are used and reported in the literature.

The agro-indicators selection depends upon project objectives, data availability, policy options and scenarios. Rosado *et al*. (2012) present a critical review of methods and different evaluations reported in scientific literature for crops under different systems and conditions, including prior evaluations for the different Portuguese systems and regional conditions, namely for Alentejo crop activities, such as wheat and sunflower (Teixeira *et al*., 2008), as well as for similar conditions in regions of Spain (Hernánz *et al*., 1995).

Selected indicators in this study include nutrient balance for nitrogen, input level for energy and life cycle assessment (LCA) approach for greenhouse gases emissions, acidification, eutrophication effects and a composite eco-indicator impact factor calculated with SimaPro 6.0 software.

The nitrogen indicator evaluation is based on the work of Simon *et al.* (2000), with inputs coming from fertilizer contents, biological incorporation of nitrogen by legume crop and atmospheric deposition, and outputs calculated from crop production quantities and nitrogen content tables (Soltner, 2004). The energy input analysis includes the use of direct and indirect energy (Hülsbergen *et al*., 2001). Direct energy is related to the consumption of fossil fuels and lubricants in cropping operations (Audsley, 2000). The indirect energy includes the energy associated with seeds (Sauvenier *et al*., 2005), fertilizers (Hülsbergen *et al*., 2001), pesticides (Green, 1987) and machinery (Rosado, 2009). Total absolute values for greenhouse gases emissions, acidification, eutrophication and composite eco-indicator (Eco95) were based in coefficient unit values of SimaPro 6.0 software package of the Life Cycle Analysis. Eco95 is a composite weighted and normalized single value indicator of global environmental effect of eleven environmental indicators.

A linear programming model was developed for each one of the two farming systems in order to analyze the economic returns, environmental impacts and trade-offs. The model maximizes farm profit in the long term (net margin), subject to the total land availability and maximum crop areas of the rotation. The environmental analysis is integrated considering in the model counter equations that model environmental coefficients of production activities. Therefore, the model assumes that the farmer's decision is based on farming system profits, and technical coefficients for each environmental indicator permit to assess the environmental impact of the alternative systems. With this model structure it is possible to have a shadow price for each environmental indicator, which represents the trade-off between economic profit and environmental impact.

The mathematical structure of the linear programming model developed to the traditional dryland crop dominant farming system is as follows:

$$Max\ Z = \sum_{p} p_j X_j \quad (1)$$

Subject to

$$\sum_{j} X_j \leq s \quad (2)$$

$$X_j \leq x_j^0 \quad (3)$$

$$\sum_{j} e_{ij} X_j \leq x_j^0 \quad \forall i \quad (4)$$

substitute *xj0* by *Eimax*

where, *Xj* is the decision variable regarding the area of crop *j* and *pj* is the net margin of crop *j*; *s* and *xj0* are the exogenous parameters of available land and maximal crop area in the rotation, respectively; finally, *eij* is the technical coefficient that measures the unitary environmental impact of crop *j* regarding indicator *i* and *Eimax* is the maximum level of environmental of indicator *i* set at marginal terms.

Equation (1) is the objective function and corresponds to maximizing the farm net margin. Equation (2) represents the land constraint in the model. Equations (3) and (4) relate to crop sheets in rotations and input-output relations between production and environment, respectively.

In the case of the traditional livestock dominant farming system, the farming model presented before was transformed in order to consider livestock production and their complementarities with forage crops and pastures, namely to model the livestock feed mix problem. The mathematical structure of the linear programming model developed for this farming system is as follows:

$$Max\ Z = \sum_{k} p_k X_k + pY \quad \text{with } k \in j \quad (5)$$

$$\sum_{j} X_j \leq s \quad (6)$$

Subject to

$$X_j \leq x_j^0 \quad (7)$$

$$\sum_{j} e_{ij} X_j \leq x_j^0 \quad \forall i \quad (8)$$

idem to last model

$$\sum_{l} n_{lt} X_l + \sum_{f} W_{ft} - r_t Y \geq 0 \quad (9)$$

$\forall t$ and with l and $f \in j$

$$\sum_{t} \frac{W_{ft}}{n_{ft}} \leq X_f \quad \forall f \quad (10)$$

$$Y \leq y^0 \quad (11)$$

where, indexes *k*, *l* and *f* respect to selling crops, pastures and forage crops, respectively; *Y* is the decision variable corresponding to the level of livestock activity; *Wft* is an endogenous activity that measures the consumption of forage *f* in the year period *t*; *nlt* ou *nft* are the unitary nutritional coefficient parameters of pasture *l* or forage *f*, respectively, in the period *t*; *rt* are the livestock nutritional requirements in each period *t*; and *y0* is the up boundary of livestock activity *Y*.

Relatively to the former model, this has as main changes the addition of livestock activity profits in the objective function (5) and the new equations (9), (10) and (11). The first respects to feed balance for each period of the year considered indicating that nutrients available of pastures plus nutrients consumed of forages must meet minimum livestock nutritional requirements. The second assures that livestock nutrients from forage consumption divided by the unitary nutritional coefficient parameter per hectare of forage doesn't exceed the forage production area. The last one bounds livestock activity to the observed levels in the farm.

Results

Environmental effects for crop dominant and grazing dominant farming systems are presented in Table1 and Table 2, respectively. Overall the level of the environmental indicators of the two farming system studied are below average of values reported in the literature. Globally, results show that cereals originate higher environmental impacts than forage for all environmental indicators, except for nitrogen balance in green pea in the crop dominant system.

Environmental impacts for all type of indicators of the livestock dominant system are larger than for the crop dominant system. In relative terms this magnitude is 2.4 times larger for nitrogen balance and energy input and between 1.30 and 1.54 for greenhouse gas emissions and eutrophication, respectively. The eco-indicator, a weighted average of the latter environmental effects, indicates that the livestock dominant system environmental impact is estimated to be 1.33 times larger the crop dominant system.

Economic and environmental results for the crop system farm model are presented in Table 3. Farm economic returns reflect a substantial contribution of subsidies in farm income, making up almost 73 in a total net return of 81 thousand Euros, representing 89 percent of farm net return. Total area of 250 hectares is fully used with the four crops rotation imposed by the rotational restriction which indicates that sunflower and green peas use each 62.5 hectares and durum wheat 125 hectares.

Global environmental impacts obtained in absolute values are 4.2 tons of nitrogen, 1.6 thousand Gj of energy, 333.2 tons of CO_2 eq., 4.4 tons of SO_2 eq., 1.4 tons of PO_4 eq. and an overall eco-indicator impact of 1 308 points. These total absolute estimates are particularly important for comparing impacts and trade-offs of different crops, production technologies and farming systems and hence for indicating potential reductions of environmental impacts. Shadow prices for rotation implementation lines indicate losses of 169, 28 and 157 Euros per hectare for different crops relatively to highest crop net income return due to rotational requirements imposed for technical reasons.

Dual prices of each environmental indicator represent marginal costs of environmental effects and indicate trade-offs between economic and each environmental criteria. For instance, farm total greenhouse gas emissions is estimated to be around 333 tons CO_2eq. To reduce this value by a ton of CO_2eq., a 0.3 % reduction on the farm emission level, requires a cost in farm return of 244 Euros. The same applies to each agro-environmental indicator selected. In aggregate terms of these effects, to reduce ecological farm impact (Eco 95 indicator) by one point, a 0.0076 percent decrease (because farm score is 1307.5 points), requires a cost of 62.21 Euros/Pt. Another way to compare results for alternative environmental effects is to compute the environmental effects for the same reduction in income, i.e., eventually policy costs to compensate farmers. For example, with one euro reduction in the costs the greenhouse gas emissions can be reduced by 4.1 Kg CO_2eq. and the acidification by 0.05 Kg SO_2eq.

Results of the farm model for the extensive mixed farming system are presented in Table 4.

All the land available is used with the crops in rotation (soft wheat- oats- oats x vetch-durum wheat- ryegrass) and with natural grassland and improved natural pasture mainly to feed livestock the predominant production of the farming system. Feedstuff produced under this rotation is able to meet nutritional requirements of a herd of 118 breeding cows. Total net farm income under this farming system is approximately 42.8 thousand Euros, almost half (52.6%) of the return of the farm under the crop farming system. However, subsidies received to cereals and to cows are almost 64 thousand euros, value above net farm income, indicating that farm social return is negative and that without heavy policy support this livestock farming system without adjustments is not sustainable. Global environmental impacts obtained in absolute values are 8 tons of nitrogen, almost twice the value of the crop farming system (192.1%), 1.8 thousand Gj of energy (109.6%), 395.6 tons of CO_2 eq. (118.7%), 4.6 tons of SO_2 eq. (102.8%), 1.7 tons of PO_4 eq. (119.8%) and an overall eco-indicator impact of 1 379 points (105.4%).

Dual prices of environmental effects indicate trade-offs between economic and each environmental criteria. Values vary from 0.11 €/KgCO2eq to 24.62 euros per kg of PO_4eq. In aggregate terms costs with these effects are evaluated by Eco 95 indicator. To reduce ecological farm impacts (Eco 95 indicator) by one point, a 0.0073 percent decrease (because the farm score is 1378.6 points), requires a cost of 31.05 Euros.

Table 1 - Activities and average environmental effects for crop predominant farming system

Environmental indicators	Sun-flower	Durum wheat1	Green pea	Durum wheat 2	Crop system
Nitrogen balance (kg/ha)	-17.0	22.9	35.7	25.7	16.8
Energy input (GJ/ha)	2.93	11.37	3.81	9.60	6.93
Greenhouse gas emissions (kg CO_2 eq./ha)	369	2514	186	2262	1333
Acidification (kg SO_2 eq./ha)	3.45	33.36	3.21	31.32	17.84
Eutrophication (kg PO_4 eq./ha)	0.62	10.74	1.47	10.38	5.80
Eco-indicator 95 (pt/ha)	1.92	9.13	1.77	8.10	5.23

Source: Nitrogen, energy accounts and SimaPro output

Table 2 - Activities and average environmental effects for livestock predominant farming system

Environmental indicators	Wheat	Durum wheat	Oat	Vetch x oat	Rye-grass	Livestoc k system
Nitrogen balance (kg/ha)	75.7	79.7	23.4	20.4	2.3	40.3
Energy input (GJ/ha)	11.52	11.99	8.45	6.59	5.02	16.8
Greenhouse gas emissions (kgCO_2eq./ha)	2516	3095	1344	698	1016	1734
Acidification (kg SO_2 eq./ha)	35.9	43.7	19.0	10.0	12.6	24.2
Eutrophication (kg PO_4 eq./ha)	11.6	13.1	7.6	6.1	6.4	8.96
Eco-indicator 95 (pt/ha)	9.94	11.31	5.97	3.49	4.15	6.97

Source: Nitrogen and energy accounts and SimaPro output

Table 3 - Farm environmental effects and economic trade-offs for the crop system farm

	Values	Dual Prices
Net farm income **(€)**	81 336	d.a.
Subsidies (€)	72 630	d.a.
Land (ha)	250	326 (€/ha)
Rotation implementation 1st (ha)	0	169 (€/ha)
Rotation implementation 2^{sd} (ha)	0	28 (€/ha)
Rotation implementation 3th (ha)	0	157 (€/ha)
Nitrogen balance (kg N)	4 203.75	19.35 (€/kgN)
Energy input (GJ)	1 655	49.15 (€/GJ)
Emissions greenhouse gas (kg CO_2eq.)	333 175	0.244(€/kg CO_2eq.)
Acidification (kg SO2eq.)	4 458.75	18.24(€/kg SO_2eq.)
Eutrophication (kg de PO_4eq.)	1 450.63	56.07 (€/kg PO_4eq.)
Eco 95 (Pt)	1 307.5	62.21 (€/Pt)

d.a.= doesn´t apply. Source: LP model results

Table 4 - Environmental effects and economic trade-offs of the crop-livestock mixed farm system

	Values	Dual Prices
Net Farm Income (€)	42791	d.a.
Subsidies (€)	63955	d.a.
Land (ha)	250	171 (€/ha)
Rotation implementation 1st (ha)	0	3.9 (€/ha)
Rotation implementation 2sd (ha)	0	17.3 (€/ha)
Rotation implementation 3th (ha)	0	0 (€/ha)
Rotation implementation 4th (ha)	0	246.3(€/ha)
Rotation implementation 5th (ha)	0	236.2(€/ha)
Rotation implementation 6th (ha)	0	146.5(€/ha)
Rotation implementation 7th (ha)	0	35.3(€/ha)
Animal Nutritional Balance 1st (FU)	0	0.147(€/FU)
Animal Nutritional Balance 2sd (FU)	0	0.147(€/FU)
Animal Nutritional Balance 3th (FU)	0	0.147(€/FU)
Animal Nutritional Balance 4th (FU)	0	0.147(€/FU)
Animal Nutritional Balance 5th (FU)	0	0.147(€/FU)
Nitrogen Balance (kg N)	8 075.4	5.30(€/kg N)
Energy input (GJ)	1 813.6	23.60 (€/GJ)
Emissions Greenhouse (Kg CO2eq.)	395 621	0.11(€/kg CO2eq.)
Acidification (kg SO2eq.)	4 584.3	9.61(€/kg SO2eq.)
Eutrophication (kg de PO4eq.)	1 737.9	24.62 (€/kg PO4eq.)
Eco 95 (Pt)	1 378.6	31.05 (€/Pt)

d.a.= doesn´t apply
Source: LP model results

Conclusions

The economic and environmental evaluation of dryland crop and livestock dominant farming systems of the Alentejo agriculture was performed using economic and agro-environmental indicators and the trade-offs between economic and environment criteria were explored. These systems are rotationally based so the contribution of the different included crops to sell and to feed livestock was also evaluated. Economic results for the crop system farm show the importance of cereals in the rotation. This is also due to subsidies that benefit this crop system since they represent 89 per cent of farm net income that were particularly coupled to durum wheat. Durum wheat has net profits two to three times higher than sunflower and green peas. Hence, they have, in relative terms, a negative impact in the average economic results of the crop system. However, in environmental terms these crops have a substantial positive effect in average environmental impact. Environmental estimates indicate that sunflower and green pea effects are 4.5 and 4.9 times lower than the durum wheat's and they reduce the magnitude of the environmental impact of the crop system by almost 40 per cent. Farm economic and environmental effects and trade-offs were estimated for composite eco-indicator and for each environmental issue. Composite ecological impact reduction by one unit requires a 62 Euros decrease of farmer profit. To have a relative evaluation of the different environmental issues, trade-offs results should be compared with their weights in the composite ecological indicator. Unit costs for each environmental issue vary from 244 Euros for a ton of CO_2eq. of greenhouse gas emissions to 56 thousand Euros for a ton of PO_4eq. in terms of eutrophication.

Net farm income of livestock dominant system is half of the total net return of the crop system farm. Economic results for livestock dominant system indicate that subsidies are even more important in relative terms in livestock production system farming because of high levels set for breeding cows. In total they represent 150 percent of farm net returns hence indicating that farm social net returns are negative. Relatively to crop system farm subsidies for livestock dominant system represent 88 percent. Although an extensive production technology is adopted for breeding cows including grassland and improved natural pasture areas complemented with hay and straw forage crops, environmental total impact of the livestock dominant system is higher than of the crop system farm in all items, varying from 102 to 192 percent for acidification to nitrogen balance, respectively, and in aggregated terms, with an overall ecological indicator score 5.4 percent higher. However, livestock dominant system costs to reduce environmental impact are lower than for crop system farm, since they relate with returns sacrifice that are lower for this farm, ranging from 27 to 52 percent for nitrogen balance and acidification, respectively, and 50 percent lower in aggregated ecological terms.

Economic and environmental results presented in this paper for these two system farms in Alentejo may be very helpful to calibrate the effectiveness of environmental policies since they are trade-offs that indicate farmer costs with environmental reduction per item and in aggregated terms. Results also suggest that the relative importance of past subsidies to support these dry land system farms can be more effectively used in future agricultural policy to play an important role combining economic and environmental concerns and promoting these systems farm sustainability.

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