

ECONOMICAL AND ENVIRONMENTAL TRADE-OFFS OF TRADITIONAL MEDITERRANEAN DRY FARMING SYSTEMS IN THE ALENTEJO REGION OF PORTUGAL

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Abstract

This paper aims assessing the economic and environmental trade-offs of traditional Mediterranean dry farming systems in the Alentejo region, southern Portugal. An environmental analysis using environmental indicators, such as the nitrogen balance, energy input, greenhouse gas emissions, acidification, eutrophication impacts, as well as an aggregated eco-indicator were developed. For assessing economic returns of farming systems, a budgeting analysis was carried out. Then the environmental and economic analysis was integrated in a linear programming model which was developed for a regional farm type. This model was used to assess the farm net profit under different policy measures, as well as to obtain the economic trade-off of each environmental indicator through its dual solution regarding the respective shadow prices. Results show that farm net profit greatly varies among crops for the different policy scenarios considered and the economic and environmental trade-offs highlights the important role other crops than cereals in rotations for promoting the sustainability of Mediterranean crop system.

Key Words: Trade-offs; Economic and environmental analysis; linear programming; shadow prices.

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1. Introduction

The concept of sustainable development arose at the end of the last century, when the demand for fossil fuel energy exceeded its ecological limits and society looked for a concept that reconciled the ecological, economic and social goals of the present with those of future generations. Nowadays, managing the present and future in a sustainable way is a task that will accompany humanity into the future (Schlör et al., 2012). To address this challenge in a global and interconnected world, the world's agriculture must be competitive but also sustainable. European agriculture is, obviously, no exception. Public policies, such as the Common Agricultural Policy (CAP) in the European Union (EU), must deal with this challenge and provide guidance. That is their major role.

There is evidence and public concern about the environment, 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 environmental and natural resources, play a role in producing public goods and services that markets undersupply (Cooper et al., 2009; Marques, 2010). The introduction of sustainability objectives requires the redefinition of reference values for agricultural activities, which must be based not only on the recognition of multifunctional land use but also on the complex role that agriculture plays in society (Gomiero et al., 2006, Newman et al., 2013).

CAP has extended its first and foremost 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, support and orientation for farmers is expected to be closely tied to the environmental performance of their farming systems, which requires effective integrated economic and environmental evaluation (Pacini et al., 2004; Van Ittersum et al., 2008). Indeed, in the current CAP reform, part of 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 accurate and transparent environmental assessment (Joumard, R., 2011). To meet this challenge, evaluation of the sustainability of 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. This requires an integrated economic and environmental evaluation of agricultural systems (Pacini et al., 2004; Van Ittersum et al., 2008).

Facing to those challenges, this paper presents the case study of the Alentejo region, southern Portugal, in which a comparison between two traditional Mediterranean dry land farming systems is done based on an integrated economic and environmental analysis. Thus, the contrast between a traditional dry land farming system and an extensive livestock mixed farming system in the Alentejo region seeks to explore and analyze economic, production and environmental trade-offs. Another question that the paper treats is the relationships between environment and policy measures, such that results can be used to guide CAP instruments.

The paper is organized in three more sections. The following section describes the material and methods. First a general overview about the analytical framework used is done and then the tow traditional Mediterranean farming systems are presented, as well as, the linear programming models developed. Section 3, regards to environmental and economic results and trade-offs are analyzed and explored. In the final section the major conclusions and future research implications are presented.

2. Material and methods

Analytical systems and methodologies for obtaining quantitative descriptions of the trade-offs between different objectives, such as gross margin, greenhouse emissions and the energy input use in farm, has been developed (Ten Berge et al., 2000). Linear programming models applied at farm level allows integrate economic, production and environmental issues based on micro accounting data and technical knowledge of farming systems.

In order to meet the purpose of this paper a linear programming model was developed to analyze the economic, production and environmental trade-offs in the Alentejo region, located in southern Portugal between Tagus River and Algarve. The analysis was based on two traditional Mediterranean farming systems: a dry land cropping system; and an extensive livestock mixed system. The model maximizes the farm profit in the long term (net margin) and was developed at the farm level for each one of the two farming systems studied, considering land as a fixed resource and that the farmer's behaviour is subjected to crop area in the rotation. The environmental analysis is integrated with economic analysis considering in the model counter equations to model the input-output relationships between production and environmental impacts. Therefore, the farmers' behaviour regarding crops and production technologies is based on farming system profit and after has been taken the decision the model allows to assess its environmental impacts. In this structure is easy considering several indicators and for each one is possible to have a shadow price, which represents the trade-off between economic profit and environmental impact.

Among the agro-environmental issues and respective indicators that have been proposed to evaluate environmental effects of production system technologies at farm level, nutrient (Simon et al., 2000; Bassanino et al., 2007), pesticide use (Padovane et al., 2004), energy (Pervanchon et al., 2002; Koga, 2008), soil organic matter (Ernest, Siri-Prieto, 2009), soil preparation and sowing (Borin et al., 1997; López-Fando and Pardo, 2009) and biodiversity (Manhoudt et al., 2005) are frequently used and reported in the literature. The agro-indicators selection depends upon project objectives, data availability, policy options and scenarios.

Rosado et al. (2012) presents a critical review of methods and different evaluations reported in scientific literature for crops under different systems and conditions (Tsatsarelis, 1993; Nguyen and Haynes, 1995; Legendre, 1997; Moerschner and Gerowitt, 2000; Mattson, 2003; Loges et al., 2005; Nemeck and Baumgartner, 2006; Charles et al., 2006; Koga, 2008), 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 (Hernández 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 gas emissions, acidification and eutrophication effects and a composite eco-indicator impact factor calculated with SimaPro 6.0 software.

The nitrogen indicator evaluation is based on Simon et al. (2000), with inputs coming from fertilizer contents, biological incorporation of legume crop and atmospheric deposition, and output calculated from crop production quantities and nitrogen content tables (Soltner, 2004).

The energy input analysis includes the use of direct and indirect energy (Hulsbergen 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 (Safe, 2003), fertilizers (Hulsbergen et al., 2001), pesticides (Green, 1987) and machinery (Rosado, 2009)

Total absolute values for greenhouse gas emissions, acidification, eutrophication and composite eco-indicator were based in coefficient unit values of SimaPro software package of life cycle analysis. Output file of SimaPro provides data on eleven environmental indicators (including those three), and a composite weighted and normalised single value indicator of global environmental effect (Eco95).

A description of the traditional Mediterranean dry land farming system and of the traditional Mediterranean extensive livestock mixed system and corresponding models are presented follows..

2.1. The traditional Mediterranean dry land farming system

The traditional dry land farming system is based on a typical farm of 250 hectares, with clay soils and without tree, in the Beja district (Rosado, 2009). This farming system is based on a crop rotation of four years (sunflower – durum wheat – green pea – durum wheat) in which cereal alternates with sunflower and pea. The crop rotation are established to achieve high production levels of cereal, namely durum wheat that have had specific grants in the past support policy.

Soil conventional preparation with deep plough, in October, 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 and it is harvested in August. The soil for durum wheat is prepared during November with chisel plough followed by harrow. Seeding occurs in December with a seed density of 200 kg per hectare and fertilization levels of 300 kg per hectare (N-P-K respectively 20-20-0). During February a chemical weeding is followed by a nitrogen fertilization with 150 kg per hectare (N 27%). The harvesting (3 tons per hectare of wheat and straw) is in July. The green pea seeding occurs next in January with 150 kg per hectare. After a harrow and two chisel plough operations are done for soil preparation. As with sunflower, pea does not require weeding nor fertilization treatments. The harvest of 1100 kg of pea, per hectare, is also in July. The durum wheat ends crop farming rotation exactly with the same annual calendar as wheat but with expected productivity of 2.9 tons per hectare.

The unitary environmental impacts for crops and for the all farming system are presented in Table 1.

Table 1: Environmental effects for crop activities and system

Environmental indicators	Sunflower	Durum Wheat 1	Green Peas	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 and energy accounts and SimaPro output

The mathematical structure of the linear programming model developed to assess this farming system is presented follows:

$$\text{Max } Z = \sum_p p_j X_j \quad (1)$$

Subject to

$$\sum_j X_j \leq s \quad (2)$$

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

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

where, X_j is the decision variable regarding the area of crop j ; E_i is the endogenous variable that measures the environmental impact respecting to indicator i ; s and x_j^0 are

the exogenous parameters of available land and maximal crop area in the rotation, respectively; p_j is the net margin by crop j ; finally, e_{ij} is the technical coefficient that measures the unitary environmental impact of crop j regarding indicator i .

The expression (1) is the objective function and corresponds to maximizing the farm net margin. The 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.

2.2. The traditional Mediterranean extensive mixed farming system

The second system studied is an integrate crop-livestock production system, where animals use plants 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-García, 2010).

This crop-livestock system is carried out in a typical farm of 189 ha, with Mediterranean soils in the Évora district. Cropping options at this farm has five annual crops in rotation (wheat – oats – vetch oat - durum wheat – ryegrass), occupying an area of 110 hectares, this is, twenty two hectares per culture. Natural grassland occupies 53.7 hectares in sub-covert of dispersed tree cover of cork and holmoak “montado”, the typical Mediterranean forest. The natural pastures consist of annual grasses and some legumes. There are also twenty five hectares of natural pasture improved with fertilizer, and an olive grove that occupies 23.3 hectares but that will not be subject of the present study.

Vetch oat and ryegrass are for hay production for animal feeding, as well as, oats grains and cereals straws and stubbles. The wheat and durum wheat grain is marketed as well as part (77,3%) of wheat durum straw produced is marketed. Natural grassland and improved pasture will be directly grazed by farm animals. The livestock is based on beef cattle in very extensive systems to addressing the weaknesses of the soil, as well as nature conservation that appears progressively valued by landowners (Menezes et al, 2010).

Soil conventional preparation for the soft wheat is made in the early November with two disc harrowing soil mobilizations, followed by one soil mobilization with a double cultivator. Seeding occurs, in November 15, with a drill lines and a roller

coupled, using a seeding density of 180 kg per hectare and fertilization levels of 250 kg per hectare (N-P-K respectively 18-46-0). Weed spraying is in middle February, and the covering fertilization using 190 Kg (Urey 46%) is at first half of March. The wheat harvesting (2.1 tons per hectare of wheat and straw) is in July. The production technology used for the durum wheat is identical to soft wheat with exception of seeding density, which is 200 Kg per hectare in former and 180 Kg per hectare in the later.

Soil conventional preparation for the oats is made in middle October with disc harrowing and two soil mobilization crossed, followed by seeding, with a drill lines and a roller coupled and using 150 Kg of oat seed and 190 Kg fertilizer per hectare (N:P:K respectively 7-14-14). Cover fertilization is in middle February with 100 Kg per hectare (Urey 46%). Oats harvest is in middle June with grain productivity of 1800 Kg per hectare and 1800 Kg of straw per hectare.

Oat vetch soil preparation occurs in the 1st half of October with harrowing mobilization followed by cultivator. Seeding is made with a drill lines and a roller coupled using 140 kg of seeds per hectare (80 kg oats and 60 kg of vetch), simultaneously is carried out a fertilization using 150 kg of fertilizer (N-P-K respectively 18-46-0). In the 2nd half of January the oats vetch fertilization is made with 100 Kg fertilizer per hectare (N: 27%) using a centrifugal distributor. In the second half of May, 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 baled, collected and stored and the yield of 4500 kg per hectare is intended for animal feed.

Ryegrass soil preparation sowing occurs in the 1st half of October with a double cross harrowing. Seeding takes place in the 1st half of October, 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 proceeds to a fertilization with 110 kg of fertilizer (N: 27%) using a centrifugal distributor. In the 1st half of May the forage is cut using a mower conditioner. In following days the forage is turning with a gleaner to forage dry enough to be baled.

The average yield per hectare is 4000 Kg of hay and is intended entirely for the livestock feeding.

At natural grassland improvement it is only proceed to fertilizer application in final of the 2nd half of September, applying 220 kg of superphosphate per hectare.

The natural pasture is intended to feed livestock and its availability varies throughout the year, as well as, the chemical composition and nutritive value. Hence, it was considered in the model five periods, which regard different quantities produced and nutritional value through the year (Rosado, 2009).

Livestock activity is based on the production of beef cattle with an extensive system. The breeding stock includes 80 crossbred cows with similar characteristics to Charolaise, twelve 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 was considered a fertility rate of 90% and a mortality rate up to calves weaning of 3%. Annually born thirty-five male calves and thirty-five female calves. All the males calves and twenty-three female calves are sold after weaning with live weight of 245 kg and 220 kg, respectively. The replacement of the males is done with animals purchased from abroad the farm. The food requirements of different categories of animals on the farm were calculated based on tables INRA (Soltner, 2004), depending on the weight of the animal and his physiological state.

The unitary environmental impacts for crops and for the all mixed farming system are presented in Table 2.

Table 2: Environmental effects for crop activities and system of crop-livestock

Environmental indicators	Wheat	Durum Wheat	Oat	Vetch x oat	Rye grass	Crop 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 (kg CO ₂ eq./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

In this case, the dry farming model presented before was transformed in order to consider livestock production and their complementarities with crop system, namely,

with forage crops and pastures. The mathematical structure of the linear programming model developed for the mixed farming system is presented follows:

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

Subject to

$$\sum_j X_j \leq s \quad (6)$$

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

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

$$\sum_l n_{lt} X_l + \sum_f W_{ft} - r_t Y \geq 0 \quad \forall t \text{ and with } l \text{ and } f \in j \quad (9)$$

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

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

where, indexes k, l and f are respect to selling crops, pastures and forage crops, respectively; Y is decision variable corresponding to the level of livestock activity; W_{ft} is an endogenous activity that measures the consumption of forage f in the year period t; n are the nutritional coefficient parameters of pasture l or forage f in the period t; r_t are the livestock nutritional requirements in each period t; and x^0 is the up boundary of livestock activity Y.

Face to the former model presented to dry land cropping system, this model 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 one regards the balance feed according to the year period. The second assures that forages consumption does exceed the production. The last one bounds livestock activity to the observed levels in the farm.

3. Results

Economic and environmental results for the dry land farm cropping system model are presented in Table 3. Farm results 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 62.5 and durum wheat 125 hectares. Global environmental impacts obtained in absolute values are 4.2 tons of nitrogen, 1.6 GJ of energy, 333.2 tons of CO₂ eq., 4.4 tons of SO₂ eq., 1.4 tons of PO₄ 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.

Dual prices 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 CO₂eq. To reduce this value by a ton of CO₂eq., a 0.3 % reduction on the farm emission level, requires a cost in farm return of 244 Euros. The same applies to each agri-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.

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

Rows	Values	Dual Prices
Net Farm Income (€)	81 336	d.a.
Subsidies (€)	72 630	d.a.
Land (ha)	250	326 (€/ha)
Rotation implementation 1 st (ha)	0	169 (€/ha)
Rotation implementation 2 ^{sd} (ha)	0	28 (€/ha)
Rotation implementation 3 th (ha)	0	157 (€/ha)
Nitrogen Balance (Kg N)	4 203.75	19.35 (€/KgN)
Energy input (GJ)	1 655	49.15 (€/GJ)
Emissions Green house (Kg CO ₂ eq.)	333 175	0.244(€/KgCO ₂ eq.)
Acidification (Kg SO ₂ eq.)	4 458.75	18.24(€/Kg SO ₂ eq.)
Eutrophication (Kg de PO ₄ eq.)	1 450,63	56.07 (€/Kg PO ₄ eq.)
Eco 95 (Pt)	1 307.5	62.21 (€/Pt)

d.a.= doesn't apply

Source: LP model results

Another way to compare results for alternative environmental effects is to compute the environmental effects for the same reduction in costs. For example, with one Euro reduction in the costs the greenhouse gas emissions can be reduced by 4.1 Kg CO₂eq. and the acidification by 0.05 Kg SO₂eq.

Results for the extensive mixed farming system farm model are presented in table 4. All the land available is used with the rotation, which means that each crop included, soft wheat, oats, oats and vetch, durum wheat, ryegrass, natural pasture and improved area use 35,7 ha of land. Feedstuff produced under this rotation is able to meet nutritional requirements of a herd of 118 breeding cows. Mixed system farm economic result is approximately 42.8 thousand hectares. However, subsidies to cereals and to cows received of almost 64 thousand euros, value above net farm income, indicating that farm social return is negative and that without heavy policy support this mixed farming system without adjustments is not sustainable.

Table 4 – Environmental effects and economic trade-offs for mixed system farm

Rows	Values	Dual Prices
Net Farm Income (€)	42 791	d.a.
Subsidies (€)	63 955	d.a.
Land (ha)	250	171 (€/ha)
Rotation implementation 1 st (ha)	0	3,9 (€/ha)
Rotation implementation 2 nd (ha)	0	17,3 (€/ha)
Rotation implementation 3 th (ha)	0	0 (€/ha)
Rotation implementation 4 th (ha)	0	246,3(€/ha)
Rotation implementation 5 th (ha)	0	236,2(€/ha)
Rotation implementation 6 th (ha)	0	146,5(€/ha)
Rotation implementation 7 th (ha)	0	35,3(€/ha)
Animal Nutritional Balance 1 st (FU)	0	0,147(€/FU)
Animal Nutritional Balance 2 nd (FU)	0	0,147(€/FU)
Animal Nutritional Balance 3 th (FU)	0	0,147(€/FU)
Animal Nutritional Balance 4 th (FU)	0	0,147(€/FU)
Animal Nutritional Balance 5 th (FU)	0	0,147(€/FU)
Nitrogen Balance (Kg N)	8 075.4	5.30(€/KgN)
Energy input (GJ)	1 813.6	23.60 (€/GJ)
Emissions Green house (Kg CO ₂ eq.)	395 621	0.11(€/KgCO ₂ eq.)
Acidification (Kg SO ₂ eq.)	4 584.3	9.61(€/Kg SO ₂ eq.)
Eutrophication (Kg de PO ₄ eq.)	1 737.9	24.62 (€/Kg PO ₄ eq.)
Eco 95 (Pt)	1 378.6	31.05 (€/Pt)

d.a.= doesn't apply

Source: LP model results

Global environmental impacts obtained in absolute values are 8 tons of nitrogen, 1.8 GJ of energy, 395.6 tons of CO₂ eq., 4.6 tons of SO₂ eq., 1.7 tons of PO₄ eq. and an overall eco-indicator impact of 1 379 points. Dual prices of environmental effects indicate trade-offs between economic and each environmental criteria. Values vary from 0.11 Euros per €/KgCO₂eq to 24.62 euros per kg of PO₄eq. In aggregate terms costs

with these effects are evaluated by Eco 95. To reduce ecological farm impact (Eco 95 indicator) by one point, a 0.0073 percent decrease (because farm score is 1378.6 points), requires a cost of 31.05 Euros.

4. Conclusions

The Economic and environmental evaluation of dryland cropping systems of the Alentejo agriculture was performed using economic and agri-environmental indicators and the trade-offs between economic and environment criteria were explored. The systems are rotationally based so the contribution of the different included crops was also evaluated.

Economic results for the crop system farm show the importance of cereals in the rotation mechanism. This is also due to subsidies that benefit this crop system since they represent 89 per cent of farm net income and are particularly tied 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. 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 costs 62 Euros in the farm profit. Unit costs, for each environmental issue, vary from 244 Euros for a ton. of CO₂eq, of greenhouse emissions, to 56 thousand Euros for a ton of PO₄eq., in terms of eutrophication. To have a relative evaluation of the different environmental issues, trade-offs results should be compared with their weights in the composite ecological indicator.

Mixed system farm net returns are half of net returns of the crop system farm. Economic results for the mixed system farm indicate that subsidies are even more important in relative terms in mixed system farming because of high levels set for breeding cows. In total they represent 150 percent of farm net returns hence indicating farm social net returns negative. Relatively to crop system farm subsidies for mixed

system farm represent 88 percent. Although an extensive production technology is adopted for breeding cows including natural and improved pasture areas complemented with hay and straw forage crops, environmental total impact of the mixed system farm is higher than of 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, mixed system farm 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 on 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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