Exploring the Relationship between Agricultural Productivity and Land Degradation in a Dry Region of Southern Europe

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Abstract

This paper explores the possible relationship between Agricultural Productivity (AP) and Land Degradation (LD) in Italy by addressing the importance of socio-environmental conditions on sub-regional scale. Multivariate analyses were carried out in the early 1990s and early 2000s on 784 Local Labour System (LLS) districts exposed to different levels of land vulnerability to degradation. In the early 1990s, AP in northern Italy was positively correlated with labour productivity in agriculture, share of agriculture in total product, and land vulnerability to degradation. During the following years, however, the increase in AP resulted not to be correlated to LD. A reverse pattern was observed in southern Italy, thus suggesting that the growth in AP was accompanied by an increasing level of land vulnerability. Based on these results, specific agro-environmental measures aimed at mitigating LD are discussed.

Keywords: Land Degradation, Agricultural Productivity, Local Labour Systems, Multivariate Analysis, Italy.

Résumé

Ce papier explore l'existence d'une possible relation entre la Productivité Agricole et la Dégradation du Sol en Italie en soulignant l'importance des conditions socio-environnementales à l'échelle sous-régionale. D'analyses multidimensionnelles ont été exécutées au début des années 1990 et au début des années 2000 dans 784 Systèmes Locaux du Travail exposés à différents niveaux de vulnérabilité du sol aux phénomènes de dégradations. Au début des années 1990, il y avait une corrélation positive entre la productivité agricole italienne et la productivité du travail dans le secteur agricole, la quote-part dans la production agricole totale, et la vulnérabilité du sol à la dégradation. En tout cas, au cours des années suivantes, l'augmentation de la productivité agricole s'est avérée ne plus être corrélée avec la dégradation du sol. De plus, nous avons enregistré une tendance opposée en Italie du Sud, ce qui nous a suggéré que l'augmentation de la productivité agricole était accompagnée d'une vulnérabilité du sol de plus en plus croissante. Sur la base de ces résultats, des mesures agro-environnementales spécifiques ont été proposées pour atténuer les phénomènes de dégradation du sol.

Mots clés: *Dégradation du Sol, Productivité Agricole, Systèmes Locaux du Travail, Analyse Multidimensionnelle, Italie.*

1. Introduction

In southern Europe, the impact of climate change in agriculture mainly regards the reduction of land productivity and the consequent changes in the geographical distribution of crops because of the lack of water and the ever more frequent heat waves (Olesen and Bindi, 2002). Moreover, increasing drought severity and worsening climate aridity may drive a progressive reduction in irrigated areas in regions where the agriculture is most heavily affected by competition with industrial and urban uses of water (Rodriguez Diaz *et al.*, 2007). Land could also suffer from negative impacts in the form of erosion and hydro-geological damage for the increased rainfall intensity, and in terms of salinization, as a result of the excessive extraction of water from underground. Some of the low input farming systems currently located in marginal areas of the Mediterranean may therefore be the most severely affected by climate change (Sivakumar, 2007). Coupled with climate changes, Land Degradation (LD) is a complex phenomenon that includes the aforementioned processes and others of socio-economic origin. LD occurs in many forms including soil salinization, erosion, compaction, pollution, and sealing. It often induces deforestation, degradation of rangelands, and other ecological problems (Le Houerou, 1993; Veron *et al.*, 2006; Montanarella, 2007). Following a general increase of both climate aridity and human pressure, a growing land vulnerability to degradation has been observed in the Mediterranean basin over the last few decades. Under these conditions, there is certainly scope to extensively study the impact of LD on the economy. The relationship between Agricultural Productivity (AP) and LD, assessed in some previous studies at farm scale (e.g. Boellstorff and Benito, 2005; Atis, 2006; Hein, 2007), needs to be explored also at regional scale.

Several papers addressing the problem of LD at national, regional, and local scales provide a basis to investigate the impact of this environmental phenomenon on the primary sector (e.g. Tanrivermis, 2003).

Mesoscale approaches, even if empirical and cross-sectional, may stimulate further studies designed to address, at a fine scale, the complexity of the environment-agriculture relationship in a LD context. The aim of this paper is therefore to integrate the environmental information on LD collected in Italy in the last few years with disaggregated economic data recorded over the same period. Even if this study preliminarily provides further information to make hypotheses on the possible impact of LD on rural development at regional scale, it also stimulates the integrated analysis of crucial variables from different ecological and socio-economic themes in order to

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link/de-link agricultural productivity to the increasing land vulnerability to degradation. Strategies aimed at reducing the impact of agriculture on the Mediterranean landscape were finally discussed.

2. Methods

2.1. Study area, data, and indicators

The analysis presented here was based on a cross section of environmental and economic indicators estimated on 784 Local Labour System (LLS) districts covering the entire Italian territory. They were identified on the basis of data relative to daily labour mobility utilising the 1991 Population Census data and reflecting economically homogeneous areas (ISTAT, 1997).

Land vulnerability to degradation was estimated here through the Environmental Sensitive Area Index (ESAI). In this model, climate, soil quality, and vegetation variables produce a composite index called ESAI (Basso *et al.*, 2000). Following the indications provided by Jollands (2006), selected variables were chosen according to a number of requirements influencing the reliability of the outcome. Climate was described by rainfall, temperature, and reference evapotranspiration. Climatic values of such variables for the period 1961-2000 were calculated using daily data measured at about 500 stations belonging to the national meteorological networks (Venezian-Scarascia *et al.*, 2006). To obtain a regional distribution and spatial coverage of the three variables over the investigated periods (1961-1990 and 1971-2000) kriging and cokriging (with elevation, latitude, and distance to the sea as ancillary variables) procedures were applied to precipitation and temperature respectively. The average annual reference evapotranspiration rate was calculated using the Penman-Montieth formula (Salvati *et al.,* 2008). Soil data were taken from an Italian database of agricultural soil characteristics, with additional information collected from ecopedological and geological maps of Italy, the EU soil quality map, and a Digital Elevation Model at 20 m resolution (Salvati and Zitti, 2008). Variables depicting soil properties like texture, depth, slope, and the available water capacity were selected. According to Basso *et al.* (2000), soil quality can be considered static over the investigated period as the considered variables change slowly or rarely and by their nature are infrequently measured or mapped.

The impact of land-cover changes was assessed by way of four standard ESAI variables: fire risk, protection from soil erosion, drought resistance of vegetation, and plant cover. These indicators were obtained through elaboration of Corine Land Cover maps available for the whole Italian territory in the early 1990s and early 2000s. Finally, the impact of human pressure on land use and thus on LD was expressed, at its simplest level, in terms of population density, measured at the municipality level in 1991 and 2001 by the National Census of Household. A demographic variation index calculated for a period of ten years (1981-1991 and 1991-2001) was further defined at the same geographical scale. Lastly, an estimation of the agricultural intensification developed from Corine Land Cover maps (Salvati *et al.,* 2007) was considered in the analysis.

A score system based on the degree of correlation that the various classes have with LD was applied to each variable. Three partial indicators, depicting environmental quality in terms of climate, soil quality, and land use, were estimated as the geometric means between the different scores of each variable. ESAI was thus estimated as the geometric mean of the three partial indicators. Areas were classified as not affected (ESAI < 1.17), potentially affected (1.17 < ESAI < 1.225), fragile (1.225 < ESAI < 1.375), and critical (ESAI > 1.375). ESAI was computed at the LLS level separately for the two study periods. Computation was based on the use of original ESAI raster maps: an average ESAI score was attributed to each LLS by 'zonal statistics' tool provided by ArcGIS software (Salvati and Zitti, 2008).

Economic indicators were estimated in the early 1990s and early 2000s at the same district scale. Original data (derived from national accounting and agriculture censuses and provided by Italian National Institute of Statistics) included per capita income (INC), share of agriculture (AGR) and industry (IND) in total product, agricultural productivity (AP), and labour productivity (FP) of the agriculture. AP and FP were respectively obtained as the agricultural value added per hectare of utilised agricultural area (UAA) and the ratio of agricultural value added to work units (Trisorio, 2005).

2.2. Statistical analyses

Exploring the relationship between AP and LD should take into account different driving forces (Mendelsohn and Dinar, 2003). On the one hand, rural development influences the environmental quality (Mendelsohn *et al.*, 2007) because income growth in agriculture is generally accompanied by crop intensification (Cacho, 2001) with increasing environmental pressure (through mechanisation, poor water management, and soil pollution risk due to pesticides and fertilisers). On the other hand, the role of LD in the primary sector is also multiple (Pender, 1998; Cuffaro, 2001; Pender *et al.,* 2004). LD acts as a negative externality reducing output and productivity of man-made capital and labour in agriculture, which is sensitive to losses in soil fertility and water shortage (Shortle and Abler, 1999). However, the relationship between LD and rural development would be also influenced by exogenous variables such as traditional production factors, policies, and site-specific variables. Based on a simplified Ricardian model we specified two equations for AP as follows:

$$\log (AP_t) = a + b_1(AGR_t) + b_2 \log(FP_t) + b_3 \log(ESAI_t) + \mathbf{e} \quad (1)$$

$$\log (AP_{t+1}/AP_t) = a + b_1(AGR_{t+1} - AGR_t) + b_2 \log (FP_{t+1}/FP_t) + b_3 \log(ESAI_{t+1}/ESAI_t) + \mathbf{e} \quad (2)$$

Due to the restricted availability of economic data at the spatial level used in this paper, in these specifications AP at the initial time and its change in output are function of an indicator of labour productivity and, indirectly, of the technological progress in the primary sector (FP), its share in total product taken as a *proxy* of the level of per capita income (AGR), and land vulnerability to degradation (ESAI), which specifies the aggregated, average effect of climate variability, soil quality, and other ecological variables on AP (Mendelsohn and Dinar, 2003).

Equations were separately estimated in three geographical areas (northern, central, and southern Italy) by using the stepwise linear regression.

Weighted regression analysis was applied in order to take into account the different surface areas of the LLS districts. Predictors entered each model according to the results of *F* test with a probability level fixed to 0.01; **e** represents the error term. Results report the variables entered each model with significant coefficients. Collinearity among variables was checked throughout by way of variance inflation factor and condition index.

A Principal Component Analysis (PCA) was performed in order to detect changes of the agricultural productivity in the Italian region where LD is potentially more severe.

The procedure was separately applied for the two study years to the matrix composed by 6 variables (INC, AGR, IND, AP, FP, and ESAI) measured on the most vulnerable area of the country (365 districts from southern Italy). Six dummies identifying the NUTS-2 region of each district (Abr: Abruzzo; Mol: Molise; Cam: Campania; Apu: Apulia, Bas: Basilicata; Cal: Calabria; Sic: Sicily; Sar: Sardinia) were included as supplementary variables. The dataset structure was explored by computing loadings (i.e. the correlation between the original variables and the factors extracted by PCA).

Finally, a SWOT analysis (Hill and Westbrook, 1997) was implemented for two partitions of the whole investigated area that are contrasting in both socio-economic and environmental terms (i.e. northern/central *vs.* southern Italy). The SWOT framework is a strategic planning method used to evaluate the strengths, weaknesses, opportunities, and threats of a defined territorial context. It involves specifying the objective of the study and identifying the internal/external forces that are favourable/unfavourable to achieving that objective (in this case, the sustainable development of the Italian regions). Strengths and Weaknesses are attributes of the system that are respectively helpful or harmful to achieve the objective. Opportunities and threats are external conditions that are respectively helpful or harmful to achieve the objective.

3. Results

The analysis of economic indicators by regions reveals that a complex pattern of rural development exists in Italy (Table 1). In southern regions, the importance of agriculture in the whole economy is locally high, but low profitability of the production factors suggests that the efficiency of this sector could improve in the short-term. The opposite condition was observed in northern and central Italy. This is likely a result of the different development paths that have characterised the two areas in the last fifty years.

Table 1: *Economic and environmental indicators by geographical area in Italy (2000).*

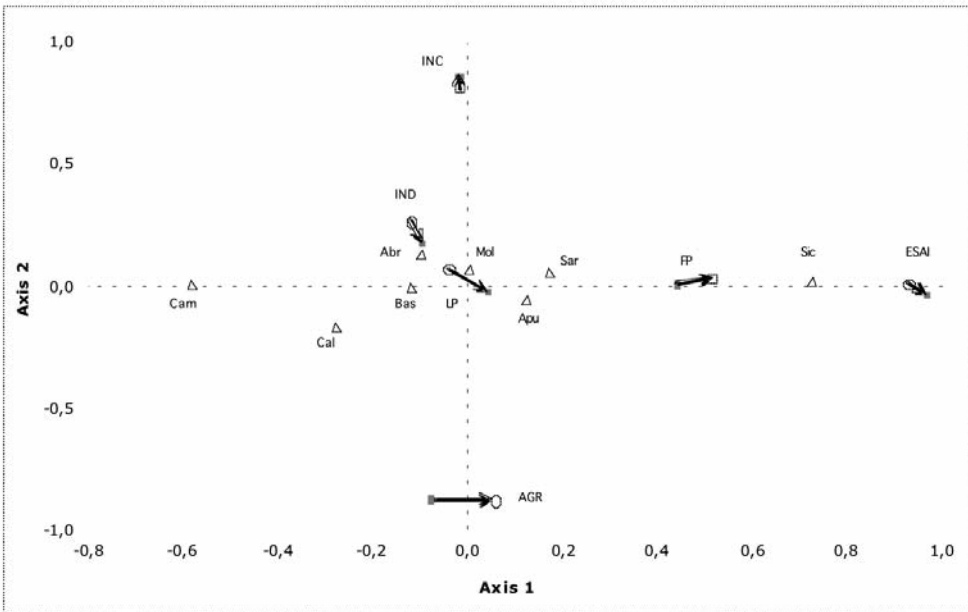
	North-west	North-east	Centre	South
Agricultural productivity (1.000 euros *per* ha of UAA)	2.8	2.8	1.6	1.9
Agricultural productivity (1990-2000, %)	3.0	2.0	1.4	2.7
Labour productivity of agriculture (1000 euros *per* work unit)	29.7	26.6	25.1	17.9
Labour productivity of agriculture (1990-2000, %)	4.3	5.3	3.0	4.5
Agriculture's share in total product (%)	1.8	3.1	1.9	4.6
Population living in rural municipalities (%)	26.6	13.7	12.6	56.7
Agriculture's workers (%)	2.7	5.3	3.6	9.4
Crop intensification (1990-2000, %)	0.2	-0.1	1.2	2.5
ESAI (average score)	1.22	1.23	1.25	1.28
ESAI (1990-2000, %)	2.3	2.2	2.5	2.3

The estimates of equations 1 and 2 are reported in Table 2. At the beginning of this study, AP was positively associated to FP in all geographical areas and the regression coefficient increased from north to south. In northern and central Italy, LP positively correlated with AGR; only in northern Italy a higher level of AP was also associated to a higher vulnerability to LD. Increasing levels of LP were throughout associated to a consistent increase of FP and AGR over the study period. In southern Italy only, increasing AP was also associated to a consistent increase in LD. In other words, increasing agricultural productivity is obtained in both northern and southern Italy by a contemporary in-

Table 2. *Estimates of stepwise regressions among AP (as the dependent variable) and some economic-environmental variables in Italy by geographical area (standard errors are reported in brackets; one and two stars indicate significance at $p < 0.01$ and $p < 0.001$, respectively).*

	Northern Italy		Central Italy		Southern Italy	
	Eq. 1	*Eq. 2*	*Eq. 1*	*Eq. 2*	*Eq. 1*	*Eq. 2*
log(FP)	4.11(0.73)		4.81(1.18)		7.51(1.58)	
Δ log(FP)		4.09(0.49)		2.45(0.55)		8.01(0.56)
AGR	0.55(0.21)		3.29(0.87)			
Δ(AGR)		1.89(0.25)		0.78(0.23)		0.48(0.10)
log (ESAI)	2.60(0.50)					
Δ log(ESAI)						2.73(0.61)
Intercept	-0.09(0.04)	-0.01(0.00)	-0.03(0.01)	-0.01(0.00)	0.07(0.03)	-0.02(0.00)
Adjusted R^2	0.27*	0.41*	0.16*	0.24*	0.07	0.55*
N	**283**		**136**		**365**	

Figure 1. *Principal component analysis of the economic and environmental indicators in southern Italy as revealed by the loading plot.*



crease in land vulnerability. However, gaining productivity at the expenses of land quality was observed later in the southern region compared to the northern one. This is likely due to the different path of economic growth occurred in the two regions.

Figure 1 showed the main results of PCA (i.e. indicator's loadings with the two principal axes). Factor 1, accounting for 16% of the total variance, depicted a gradient of LD based on ESAI. Regions positively associated to this axis included Apulia, Sicily, and Sardinia, where land vulnerability to degradation is more evident. Factor 2, which accounted for 15% of the total variance, was regarded as a *proxy* of regional development. Notably, INC was associated to the positive values of this axis and AGR, a variable related to disadvantaged economic conditions, showed the reverse pattern. Arrows indicate, on a time basis, the most important indicator's changes on the factorial plane. ESAI showed a positive shift along the first axis going towards the positive values. This indicated that the ecological conditions determining LD became worse over the last few years especially in the more vulnerable districts. AP movements were consistent with ESAI, confirming the outputs of the regression analysis. Finally, AGR showed a similar pattern by moving towards the positive values of the first axis. This suggests that the agriculture's share in total products maintained high in the more vulnerable southern areas, while decreasing in less vulnerable and more developed districts.

4. Discussion

The results of the present study suggest that a complex relationship exists between agricultural productivity and land vulnerability to degradation in Italy. It was likely due to the different impact of the environmental drivers of LD acting in northern and southern regions. This claims important implications for rural development of especially disadvantaged (and more vulnerable) regions (Hein, 2007). As observed during the early nineties in northern Italy, a higher agricultural productivity is compatible with increasing LD in the short term. This could be possible thanks to good natural capital in term of climate and soil as well as to the technological progress. As a matter of fact, evidences from previous studies indicate that LD occurred in northern and central Italy only over limited surfaces of rural areas depending on human causes, as ecological conditions are generally good in terms of both climate and soil quality (Salvati and Zitti, 2008). Moreover, as expected for a developed area, the agricultural share in total product is considerably low in northern and central Italy and thus, negative effects of LD on AP through losses in soil fertility are difficult to assess at the aggregate scale (Tanrivermis, 2003). Although in the seventies and eighties the lowlands in northern Italy experienced a process of agricultural intensification that contributed to the increase of land vulnerability, increasing levels of AP were observed during the most recent years without any significant relation with LD severity (Salvati *et al.,* 2007).

A different economic path was observed in southern Italy, one of the less developed areas in the European Union with important land surfaces prone to LD risk (Wilson and Juntti, 2005). Increasing land vulnerability was especially observed in the driest zones of Apulia, Sardinia, and Sicily. In these areas (i) the level of agricultural intensification is generally lower than in northern Italy; (ii) labour productivity of agriculture is correlated to AP; (iii) both the agricultural share in total product and the percent of workers in the agricultural sector are higher than those observed in northern and central Italy; and, finally, (iv) increasing AP is associated, on average, to a significant increase in land vulnerability to degradation over the study period (see Table 3). Under this condition, agricultural intensification may accelerate LD through multiple impacts, ranging from heavy mechanisation and irrigation spreading to unsustainable water management and growing livestock density. These processes may increase the risk of soil salinization, erosion, compaction, and pollution (Simeonakis *et al*., 2007). Coupled with high population density, urban sprawl, industrial concentration, and tourism growth along the ecologically

Table 3. The agriculture system in a LD context: an example of SWOT analysis in Italy

Northern/ central Italy	**Strengths**	**Weaknesses**
	High per-capita income	Increasing soil pollution, sealing, and compaction
	High crop productivity	Increasing urban sprawl
	High technological progress	Increasing severe droughts
	Increasing multi-functional farms	
	Opportunities	**Threats**
	High-quality natural capital	Worsening LD conditions associated to land productivity
Southern Italy	**Strengths**	**Weaknesses**
	Increasing crop productivity	Low per-capita income
	High proportion of rural population	Low crop productivity
	High employment rate in the primary sector	Low technological progress
		Limited water availability
	Opportunities	**Threats**
	Low crop intensity	Starting desertification processes over defined hot-spots
	High potential for tourism development	
	Increasing population	
	High share of agriculture in total product	

fragile coastal areas, this factor exacerbates the environmental conditions in terms of water shortage and soil degradation, reflecting a reduction of land productivity in the short-term (Tanrivermis, 2003; Atis, 2006; Hein, 2007).

Based on these considerations, the process of agricultural intensification observed in the few last years in some southern areas could be only partially sustainable in the long term. In fact, two contrasting paths are possible in the near future: (i) land extensivation (Olesen and Bindi, 2002) with considerable income loss and growing marginalisation of inland and rural districts, and (ii) further intensification of low-sustainable crops, based for instance on water over-exploitation. Both paths, if poorly controlled, may enhance environmental degradation. Multi-scale monitoring, based on scenario analyses at the country scale, quantitative panel models at the regional scale, and qualitative social enquiries at local scale (Makhzoumi, 1997; Iosifides and Politidis, 2005; Onate and Peco, 2005) are needed to disentangle the most probable economic path and the possible interrelations with the environment.

In the present context, policy is increasingly concerned with reducing the generation of negative agricultural externalities (Hubacek and van der Bergh, 2006). Traditional agricultural policies, however, have attempted to achieve objectives related to farm income, agricultural price, and trade (Shortle and Abler, 1999). A production context favourable to LD implies that actions are taken to increase current agricultural production at the expense of future soil productivity and thus future production, as the analyses carried out in this paper suggest. Considering that LD is a dynamic environmental process, the matter is to assess if this strategy is sustainable from the environmental and economic points of view in both the short- and the long-term. In fact, a possible downward spiral between agricultural productivity and LD in the more fragile dry areas should be avoided (Pender, 1998; Shortle and Abler, 1999). This paper provides first evidences that a risk to enter this spiral exists for southern Italy. Some facts tend to support such an hypothesis. First, LD is locally severe and has been increasing over the last few years; second, agricultural intensity is lower (but rapidly increasing) than in northern and central Italy; third, the sensitivity of AP to FP is the highest observed in Italy; and forth, increasing AP negatively impacts, on average, on land vulnerability.

European agricultural policies have partially encouraged the flexibility of land use, crop production, and farming systems. Further efforts are needed by considering more strictly the multifunctional role of agriculture and by striking a variable balance between economic, environmental, and social functions at both regional and local scales. The possible strategies to be undertaken in order to mitigate possible externalities of the agriculture causing LD include both *in situ* actions and measures applicable at regional level (Zalidis *et al*., 2002; 2004). The former group includes technical and biological measures (e.g. crop rotation, tillage techniques, diversification of irrigation methods) that will be useful in addressing the problems of soil salinization (Atis, 2006; Perez-Sirvent *et al.*, 2003). Improving technical skills of farmers through adequate education scheme can also play a role in motivating conservation of land resource at farm level (Tanrivermis, 2003). The latter group includes financial resources which should be provided to encourage the active involvement of farmers in soil conservation, especially in marginal, inland areas subjected to erosion (Hein, 2007). Penalties to discourage unsustainable soil conservation practices are finally important incentives to motivate efforts against LD.

These measures can mitigate desertification by contributing to the different causal chains which characterise this complex environmental phenomenon.

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