Journal of Environmental Management 145 (2014) 299–306

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Zero Net Land Degradation in Italy: The role of socioeconomic and agro-forest factors

Luca Salvati [a,*], Margherita Carlucci [b]

[a] Consiglio per la Ricerca e la sperimentazione in Agricoltura, Centro per lo studio delle Relazioni Pianta-Suolo (CRA-RPS), Via della Navicella 2-4, I-00184 Rome, Italy
[b] Dipartimento di Scienze Sociali ed Economiche, 'Sapienza' Università di Roma, Piazzale A. Moro 5, I-00185 Rome, Italy

ARTICLE INFO

Article history:
Received 2 January 2014
Received in revised form
10 June 2014
Accepted 4 July 2014
Available online

Keywords:
Land degradation
Sensitivity
Agro-forest systems
Policies
Local community
Italy

ABSTRACT

In 2012, the United Nations Convention to Combat Desertification has launched a policy strategy called 'Zero Net Land Degradation' (ZNLD), which aims to prevent the degradation of productive land and restore already degraded land. In Europe, and especially in Mediterranean Europe, land degradation is a complex phenomenon affecting both depopulated, marginal agro-forest regions and affluent agricultural areas. In an effort to develop a ZNLD strategy in Italy we identified the socioeconomic variables associated with environmental conditions leading to a long-term (1960–2010) reduction in land sensitivity to degradation. Our results show an increase in ZNLD areas in the last ten years. Rural municipalities classified at ZNLD showed an economy based on services, an agriculture sector oriented towards quality productions and more sustainable cultivation practices, a balanced population structure and the prevalence of a mixed farmland/woodland land-use structure. These results may inform a country-scale ZNLD strategy targeting complex human–natural degradation processes in ecologically-fragile Mediterranean areas.

1. Introduction

Land degradation (LD) is one of the most relevant environmental problems on a global scale. LD occurs in large areas of the world where soils exhibit a loss in biological and economic productivity. As clearly stated by United Nations Convention to Combat Desertification (UNCCD, 2012), LD resulted from various factors, including climatic variations and human activities. It has been estimated that around 20% of global land area is presumably already degraded (Imeson, 2012), exhibiting a persistent decline in land productivity as well as in the provision of other ecosystem services (food, water, climate security, biodiversity, recreational and cultural values). On a global scale, the surface of affected and vulnerable land was found increasing in the last decades (Geist and Lambin, 2004; Gisladottir and Stocking, 2005; Romm, 2011).

Empirical evidence indicates that unsustainable land management is one of the key drivers of land degradation (e.g. Briassoulis, 2011). For example, agriculture was regarded either as an aggravating factor resulting in land over-exploitation or a mitigating one e.g. in areas characterized by high erosion risk (Cawley, 1994; Caraveli, 2000; Wilson, 2008). On the one hand, the intensification of agriculture usually determines an increase in crop surface and greater technical skills that could be a factor of LD (Rubio and Bochet, 1998; Hubacek and van der Bergh, 2006; Wang et al., 2006). On the other hand, the abandonment of marginal and mountainous lands may seriously alter soils – possibly because of the increased erosion risk – and the structure of resident population (Iosifides and Politidis, 2005; Danfeng et al., 2006; Corbelle-Rico et al., 2012). Managing land resources in a sustainable manner is a prerequisite to effective mitigation policies against LD (Montanarella and Vargas, 2012). Sustainable land management requires the adoption of legal frameworks enforcing the implementation of good practices for land protection by landowners and major stakeholders (Bowyer et al., 2009).

Policies may induce land users to take decisions that either protect the land against desertification or expose it to stronger degradation forces (Imeson, 2012). Sector policies have often increased desertification problems. Agricultural policies and subsidies focussing on single crops or products stimulate conversion of traditional, sustainable multi-functional land-use systems into intensive ones, such as mono-cultural systems that are not adjusted

* Corresponding author. Tel.: +39 06 700 54 13; fax: +39 6 700 57 11.
E-mail addresses: luca.salvati@entecra.it, bayes00@yahoo.it (L. Salvati), margherita.carlucci@uniroma1.it (M. Carlucci).

http://dx.doi.org/10.1016/j.jenvman.2014.07.006
0301-4797/

to the local environmental conditions (Juntti and Wilson, 2004). For example, in marginal lands European Union subsidies have been found to stimulate agriculture with low profits and negative impacts on land quality (Onate and Peco, 2005).

Given the increasing pressure on land from agriculture, forestry, pasture, energy production and urbanization, urgent action is needed to halt LD. The need for quantitative policy targets was recently discussed in the framework of the UNCCD. A new goal of sustainable development agreed at Rio+20 is the reduction of LD rate to achieve LD-neutrality, which is being referred to as 'Zero Net Land Degradation' (ZNLD). ZNLD can be achieved when, over a given period of time, non-degraded land remains healthy and already degraded land is restored, thus reducing to zero the net rate of loss in productive land. The proposed goal is underlined by the following targets: (i) zero net LD by 2030, (ii) zero net forest degradation by 2030 and (iii) drought preparedness policies implemented in all drought-prone countries by 2020 (UNCCD, 2012). Sustainable land management, arresting further degradation and restoring/rehabilitating degraded land, avoiding degradation of non-degraded lands, improving community-based and traditional approaches and, finally, implementing a payment system for ecosystem services were considered as reliable pathways for achieving ZNLD (Imeson, 2012).

Southern Europe offers intriguing case studies to explore the relationship between the socioeconomic context and long-term (or medium-term) changes in land sensitivity to degradation with the final objective to inform effective ZNLD strategies at various spatial scales. Mediterranean rural areas show a wide diversity in agricultural systems, socioeconomic characteristics, land-uses and land tenure regimes, ranging from affluent areas with high value-added agriculture and a mixed industrial/service economy to semi-arid disadvantaged areas with a low-income, agriculture-oriented socioeconomic structure (Salvati and Bajocco, 2011). In this region, LD has been considered a typical phenomenon associated with rural landscapes (Basso et al., 2000). Both disadvantaged, marginal agro-forest regions in mountain areas and high-value added agricultural areas in lowlands are affected by LD processes (Garcia Latorre et al., 2001; Helldén and Tottrup, 2008; Mancino et al., 2013). Southern Europe can be thus a candidate for the application of effective ZNLD policies due to the complex relationship between socioeconomic and environmental factors shaped by the millenary human–nature interactions (Salvati et al., 2013a).

In Italy, Salvati et al. (2013b,c) showed that land sensitivity to degradation increased over the last fifty years with the largest growth concentrating on areas with specific socioeconomic characteristics. Salvati and Bajocco (2011) identified per-capita income, agricultural intensification and topography as crucial variables determining the level of land sensitivity at the regional scale. Salvati et al. (2011) suggest that a number of social and economic factors (among which the structure of the economic system, human capital, population dynamics, territorial characteristics and agricultural practices are supposed to be the most relevant) influence the level of land sensitivity in a non-linear way. Salvati and Carlucci (2011) identified local districts with high-quality, traditional productions (e.g. vine, olive, fruit crops and rain-fed cereals) and with specific demographic, social and economic features (intermediate population density, balanced demographic structure, moderate-to-low internal migration, diversification of the economic structure) as areas with the highest long-term reduction in the level of sensitivity to LD.

Based on these premises, the present study is aimed at assessing the socioeconomic characteristics of local communities that are associated with environmental conditions possibly leading to a medium- or a long-term reduction in the level of land sensitivity to degradation. In an effort to implement a ZNLD strategy in Italy, the study introduces an original approach to identify ZNLD areas and to profile them based on a large indicators' set. We adapted a consolidated assessment procedure (the Environmentally Sensitive Area scheme: see Salvati et al., 2013a) to the diachronic (1960–2010) monitoring of land sensitivity to degradation (Salvati and Bajocco, 2011) with the aim to identifying ZNLD municipalities according to an original, objective criterion. The territorial profile of ZNLD municipalities in Italy was determined through the multivariate analysis of more than 120 socioeconomic indicators. An *in-depth* knowledge of the economic, demographic, social and institutional characteristics of sensitive and ZNLD areas may inform integrated policy strategies on a country scale targeting complex human–natural degradation processes in ecologically-fragile Mediterranean areas.

2. Methodology

2.1. Study area

The investigated area covers the Italian territory extending for nearly 302,070 km^2 (23.2% lowlands, 41.6% hills and 35.2% mountainous areas). Italy shows significant disparities in climate, soil, vegetation, population structure, settlements and income distribution between northern and southern regions which possibly influence the size of land sensitivity to degradation (Salvati and Bajocco, 2011). In the present study local municipalities were chosen as the elementary spatial unit of analysis. Municipalities are a relevant spatial unit for environmental reporting of land sensitivity to degradation and to inform sustainable management of rural land (Abu Hammad and Tumeizi, 2012; Briassoulis, 2011; Salvati and Carlucci, 2011). Municipality data provide a reliable description of the local socioeconomic context in countries with considerable territorial disparities, such as Italy. Fig. 1 reports a flow-chart illustrating the main steps of the present study.

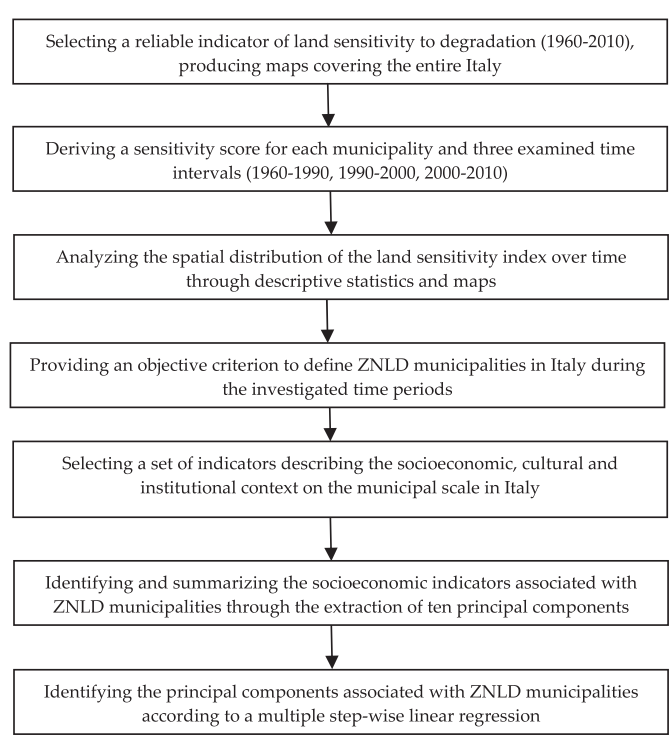

Fig. 1. Flow-chart describing the main steps of this study.

2.2. Estimating changes in land sensitivity to degradation

According to UNCCD (2012), land degradation is intended here as a temporary (possibly leading to a permanent) decline in the productive capacity of the soil, that can be referred to a loss of biomass, a reduction in actual (or potential) productivity, a change in vegetation cover or a loss in land fertility. Sensitive lands, rather common in various countries of the northern Mediterranean basin, such as Spain, Italy and Greece, are regarded as areas where soil degradation processes (e.g. erosion, salinization, compaction, contamination, sealing, loss in organic matter: see Montanarella, 2007 for a review) are locally active in conjunction with biophysical and/or socioeconomic factors leading to landscape degradation (Salvati et al., 2013a).

The concept of 'land sensitivity to degradation' used in the present study (the degree to which a land system undergoes changes due to natural forces, human intervention or a combination of both, see Kosmas et al., 2003) refers to the logical framework developed in the MEDALUS international project (Salvati et al., 2013b). Instead of a process-based evaluation, the MEDALUS approach identifies areas where several factors – alone or in cooperation – increase the probability of LD processes. Land sensitivity to degradation can therefore be considered as a comprehensible concept for stakeholders and a traditional policy target in southern Europe (Salvati and Zitti, 2009).

The level of land sensitivity to degradation in Italy was measured at four points in time (1960, 1990, 2000 and 2010) following the Environmental Sensitive Area (ESA) scheme (Basso et al., 2000; Salvati et al., 2013a). Based on simplified indicators and quantitative tools, this methodology has become a standard procedure to assess the level of land sensitivity to degradation (Kosmas et al., 2003) and was applied to a number of case studies in Mediterranean Europe, northern Africa and the middle East (see Ferrara et al., 2012 for a review). The outcomes of the ESA scheme have been extensively validated at several sites in Spain, Italy and Greece (Basso et al., 2000). Ferrara et al. (2012) assessed the reliability of the ESA index using sensitivity analysis. Their results show that the ESA index is statistically-stable and not affected by spatial and temporal heterogeneity in the composing indicators.

The ESA index (the so called ESAI) was composed by 14 elementary variables grouped in four thematic indicators: (i) climate quality, including average annual rainfall rate, aridity index and aspect; (ii) soil quality quantified by soil depth and texture, slope and the nature of the parent material; (iii) vegetation and land-use quality, based on the degree of vegetation cover, fire risk, protection offered by vegetation against soil erosion and the degree of resistance to drought shown by vegetation and (iv) a human pressure index including population density, annual population growth rate and an indicator of land-use intensity taken as a proxy for land management quality (Salvati and Bajocco, 2011). All variables have been derived from official data sources (population and agricultural censuses, meteorological statistics, Corine Land Cover maps and a soil quality map provided by the European Joint Research Centre) at the lowest available spatial resolution (see Salvati et al., 2013c for technical details on variables and data sources).

Indicators of land sensitivity were obtained by applying a standard weighting system (ranging from 1 to 2) to each considered variable (see Salvati and Bajocco, 2011 for the full table of weights). The scoring system was based on the known relationship between each factor and LD processes (Basso et al., 2000; Kosmas et al., 2003; Salvati et al., 2013b). Based on this weighting system, the ESAI was estimated in each spatial unit and year as the geometric mean of the variables described above, obtaining a score ranging from 1 (the lowest sensitivity to degradation) to 2 (the highest sensitivity to degradation). Three classes of land sensitivity were identified that reflect the classification thresholds shown in Salvati and Bajocco (2011): (i) areas unaffected or only potentially affected by LD (ESAI < 1.225), (ii) 'fragile' areas (1.225 < ESAI < 1.375) and (iii) 'critical' areas (ESAI > 1.375). Based on the spatial resolution of the available layers, maps have been produced at 1 km^2 pixel resolution (Salvati et al., 2013c). The elementary spatial unit has been selected according to Basso et al. (2000) and is coherent with the resolution of the single layers.

To our knowledge these layers are the most homogeneous, reliable and spatially detailed data currently available for the diachronic assessment of the ESAI in Italy (Salvati et al., 2011). The time interval considered is sufficiently long to assess medium- and long-term changes in the level of sensitivity both on a local and regional scale, according to the resolution of the considered variables. The restricted data availability for some input variables in the ESA scheme prevented us to estimate the level of land sensitivity to degradation in intermediate points in time between 1960 and 1990.

An average ESAI was estimated in each of the 8100 Italian municipalities (2001 boundaries) for 1960, 1990, 2000 and 2010 by using the 'zonal statistics' tool provided with ArcGIS software (ESRI Inc., Redwoods, USA) after the overlap between each of the four ESAI raster files and the shape file describing the municipalities' boundaries. The 'zonal statistics' procedure computes a surface-weighted average of the raster values recorded on each elementary pixel and belonging to each spatial unit (Salvati et al., 2013b). Annual changes in the level of land sensitivity to degradation were estimated over three different time intervals indicating (i) long-term changes (1960–2000) and (ii) medium-term changes (1990–2000) preceding the year when the socioeconomic context was assessed (2000) as well as (iii) medium-term changes (2000–2010) after the same year. Municipalities with a negative (or null) change in the ESAI, indicating a decrease in the level of land sensitivity over time, were considered as at ZNLD.

2.3. Socioeconomic indicators

The socioeconomic factors potentially influencing land sensitivity to degradation were studied by means of 111 indicators (listed in Appendix 1), chosen to be not redundant with the biophysical variables used in the computation of the ESAI, populated with data on the municipal scale provided by national statistical sources (primarily from the Italian National Statistical Institute, ISTAT) and mainly referring to 2000 or 2001. Data refer to five research fields (Demographic and territorial characteristics, Labour market and human capital, Economic specialization and competitiveness, Quality of life, Rural development and water management) in turn subdivided into 13 thematic dimensions (human settlements: 6 indicators; population structure: 7; job market: 14; educational level: 6; productive structure: 17; tourism specialization: 7; living standards: 17; crime and society: 4; land tenure: 5; land use: 8; production intensity: 4; quality and innovation in agriculture: 9; human capital in agriculture: 5; water management: 6).

Twelve supplementary indicators were used for the explanatory analysis of the territorial gradients possibly affecting land sensitivity to degradation. These indicators refer to (i) environmental characteristics (mean elevation, a dummy for latitude (0: northern and central Italy, 1: southern Italy and the two main islands of Sicily and Sardinia), two dummies for lowland and mountainous municipalities, the average ESAI score, a dummy for seismic risk) and (ii) the spatial organization of the investigated area (total resident population, municipal surface, population density, annual population change, a dummy for urban municipalities and the percentage of compact and dense urban settlements on the total municipal area). The final data matrix contains 123 variables including both active and supplementary indicators made available in each of the 8100 Italian municipalities.

The selection of the variables, the definition of the indicators and the identification of the thematic dimensions adequate to describe the socioeconomic context influencing LD processes on a local scale have been set up following the suggestions provided by Trisorio (2005). Although these indicators cannot be considered an exhaustive description of the socioeconomic context, since the restricted data availability on a municipal scale prevented us to include other – possibly relevant – variables in the analysis, they provide a broad qualification of the economic structure and social characteristics of each examined municipalities. Moreover, the dataset developed in the present study includes indicators available at the most recent observation year for comparison on the desired geographical scale.

2.4. Statistical analysis

A Principal Components Analysis (PCA) was undertaken on the data matrix described in Section 2.3 (111 active variables and 12 supplementary variables) to identify latent factors representing the different socioeconomic contexts in Italy (Salvati and Carlucci, 2011). To identify the socioeconomic context associated to ZNLD conditions, the principal components extracted were correlated to the observed changes in land sensitivity to degradation. As the PCA was based on the correlation matrix, the number of significant axes (m) was chosen by retaining the components with eigenvalue > 3. The Keiser–Meyer–Olkin (KMO) measure of sampling adequacy, which tests whether the partial correlations among variables are small, and Bartlett's test of sphericity, which tests whether the correlation matrix is an identity matrix, were used to assess the quality of PCA outputs. These tests evaluate the appropriateness of the factor model to analyze the original data. Each component with eigenvalue > 3 was characterized using active and supplementary variables with loadings > |0.3| and computing the percentage of variables with loadings > |0.3| by each thematic dimension considered (Salvati and Zitti, 2009).

The components extracted by PCA have been subsequently correlated to the medium- and long-term changes in the level of land sensitivity to degradation observed in each municipality. Three separate regression models were developed using the percent change in the ESAI (δESAI) observed in (i) 1960–2000, (ii) 1990–2000 and (iii) 2000–2010 as dependent variables and the scores of each selected principal component as descriptors. A forward stepwise linear regression approach was used to identify and rank the most significant descriptors determining variations in each dependent variable using an F-to enter p-value of 0.01. Results of each regression model were presented using standardized coefficients and tests of significance (an F-statistic testing for the null-hypothesis of non significant model and a t-statistic testing for the null-hypothesis of non significant regression coefficient). These outputs were also used to rank the importance of the different descriptors extracted by the stepwise procedure. A Durbin–Watson statistic was applied separately to the residuals from the three least squares regressions, testing for the null hypothesis that the errors are serially uncorrelated against the alternative that they follow a first order autoregressive process. Although serial correlation does not affect the consistency of the estimated regression coefficients, it does affect our ability to conduct valid statistical tests. For example, the F-statistic to test for overall significance of the regression may be inflated under positive serial correlation because the mean squared error will tend to underestimate the population error variance. Values of Durbin–Watson statistics close to 2 indicate no auto-correlation.

A two-step multivariate strategy including PCA and a multiple stepwise regression model was preferred to econometric approaches because of the high number of (possibly correlated) variables considered in the present study. The PCA was used to remove the partial correlation among variables and to incorporate significant information in a restricted number of independent components used as descriptors in the subsequent regression model. Statistical analyses have been carried out using STATISTICA package (Tulsa, Oklahoma).

3. Results

3.1. Identifying ZNLD areas in Italy

The distribution of areas classified as 'critical' (i.e. with ESAI > 1.375) at both the beginning and the end of the observation period (1960 and 2010) is shown in Fig. 2 (upper panel) together with ZNLD areas characterized by a decrease in the level of sensitivity observed during three time intervals (1960–2000, 1990–2000 and 2000–2010; lower panel) reflecting periods characterized by different socioeconomic conditions in the country. While 'critical' areas increased markedly during the last fifty years (expanding especially in the lowland areas of northern Italy and in restricted areas of central Italy, e.g. Tuscany and Latium, and southern Italy, e.g. Apulia, Basilicata and Sardinia), the geography of ZNLD areas changed even more rapidly during the investigated time interval. ZNLD areas during 1960–2000 concentrated in marginal areas along northern and central Apennines being more scattered in southern Italy. The analysis carried out in the 1990–2000 time window shows a moderate increase in the surface area classified at ZNLD conditions. Southern Italy and, in part, central Italy were characterized by a huge increase in ZNLD areas in the most recent period of investigation (2000–2010) while areas classified at increasing land sensitivity concentrated in northern Italy and in the most accessible lowland districts of central Italy.

Based on the statistics illustrated in Table 1, the surface area classified at ZNLD in Italy grew markedly between the first examined time interval (35% of the country's surface in 1960–2000) and the most recent decade (47% in 2000–2010). The population residing in ZNLD municipalities followed the same pattern shifting from 27% to 41%. However, this increase was not homogeneous in the three geographical areas being remarkable only in southern Italy (land classified at ZNLD passed from 26% to 74% of the regional surface). On the contrary, ZNLD areas remained quite stable at 36% in central Italy and decreased in northern Italy (from 45% to 25%), with stable population living in ZNLD municipalities.

3.2. Principal Components Analysis

Summary results of the Principal Components Analysis carried out on the matrix relative to the 8100 Italian municipalities and the 111 active variables are reported in Table 2 and Appendix 2. The Keiser–Meyer–Olkin measure of sampling adequacy and Bartlett's test of sphericity ($p < 0.001$) indicate that the selected model is appropriate to analyze the original data matrix. The PCA extracted ten components with absolute eigenvalues higher than 3 and accounting for a cumulated variance summarizing 48% of the total variance, which is considered a relatively high proportion of variance in respect to the number of input variables. Component 1 explained 14% of the total extracted variance and was found to be associated to living standards and environmental variables. These variables depict a gradient based on differences in income and wealth conditions between northern and southern regions. The gradient also reflects diverging conditions in the labour market and

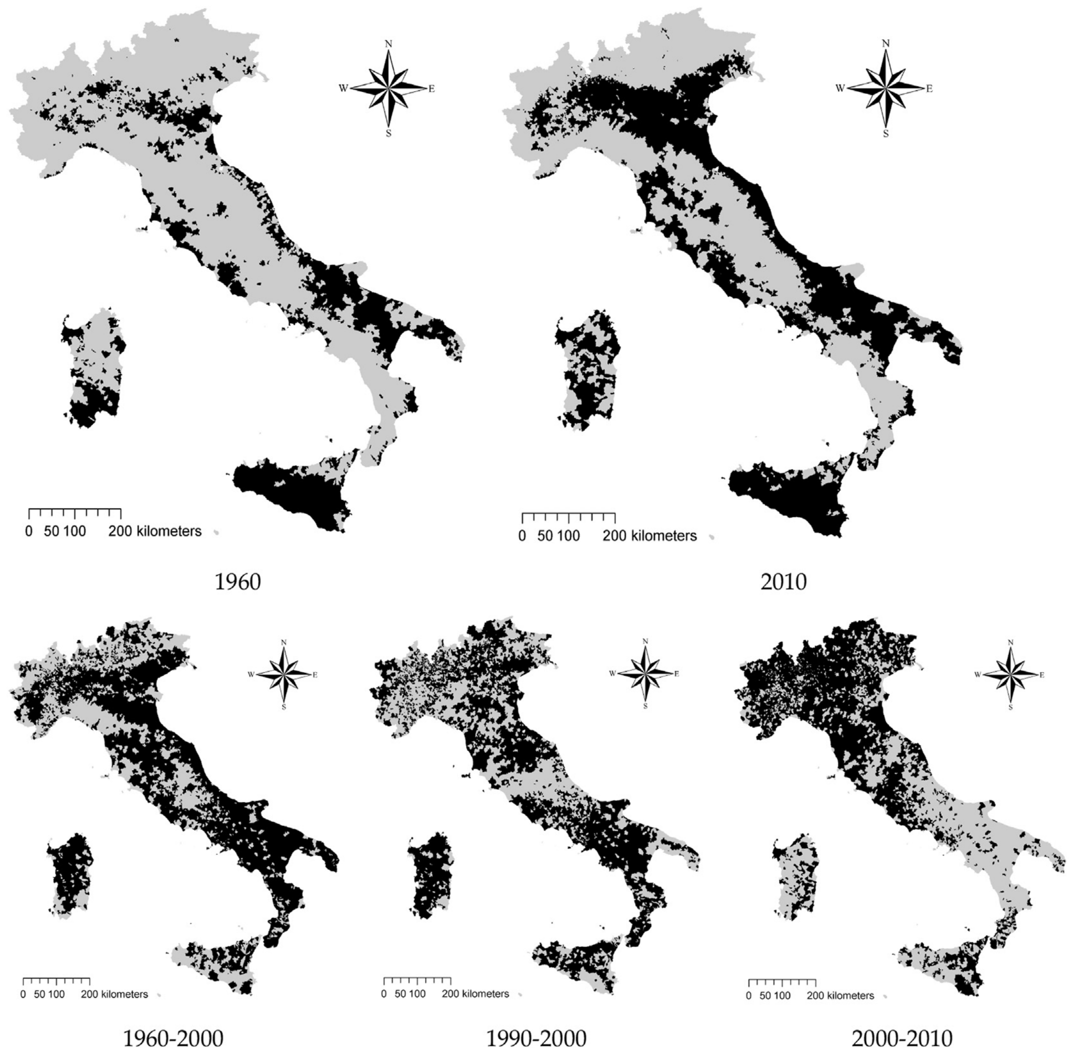

Fig. 2. The distribution of 'critical' areas to LD (with ESAI score > 1.375, see classification in Section 2.2) in 1960 and 2010 (upper panel) and changes in the level of land sensitivity (lower panel) by time period in Italy (black tone respectively indicates 'critical' areas and areas with increase in the level of sensitivity to degradation; ZNLD areas are illustrated in soft grey).

educational level of resident population (see component loadings reported in Appendix 2).

Component 2 explained more than 9% of the total variance and was found associated to variables describing population structure, crop intensity, water management in agriculture and supplementary variables, being also correlated negatively with the ESAI score. This component could be seen as an LD severity gradient based on disparities in the level of land sensitivity to degradation on both regional (e.g. differences observed between northern and southern Italian regions) and local scales (e.g. differences observed between

Table 1
Surface area and resident population of local municipalities under ZNLD conditions in Italy by time interval and geographical area.

Area	1960–2000		1990–2000		2000–2010	
	Surface area (%)	Population (%)	Surface area (%)	Population (%)	Surface area (%)	Population (%)
North	44.5	31.7	47.2	54.8	24.8	31.3
Centre	36.4	17.1	40.2	28.5	35.7	20.8
South	25.8	25.9	32.1	37.8	73.6	64.1
Italy	**35.3**	**26.8**	**39.7**	**43.7**	**46.8**	**41.0**

Table 2
Percentage of variables with loadings > |0.3| by thematic dimension and principal component (* indicates supplementary variables).

Thematic dimension	Principal component									
	1	2	3	4	5	6	7	8	9	10
Human settlements	33	67	50	33	0	0	0	0	17	17
Population structure	43	71	0	86	0	0	0	0	0	0
Job market	64	36	0	7	0	0	7	14	0	0
Educational level	67	50	33	33	0	0	0	0	33	0
Productive structure	29	12	18	0	6	0	18	6	0	6
Tourism	14	29	29	0	0	0	0	0	0	0
Living standards	92	38	54	38	0	0	8	0	0	0
Crime and society	25	25	25	0	0	0	25	0	0	0
Land tenure	20	60	20	0	40	40	0	0	20	0
Land-use	0	50	38	13	25	13	0	0	13	0
Production intensity	25	75	25	25	25	50	25	0	0	0
Quality/innovation in agriculture	0	0	0	11	56	11	0	0	0	33
Human capital in agriculture	20	20	40	0	0	20	0	0	0	0
Water management	0	83	50	0	0	0	0	50	0	0
*Environment**	83	83	0	0	0	0	0	0	0	0
*Spatial organization**	50	67	33	17	0	0	0	0	17	17

Table 3
Results of stepwise multiple regression analysis with δESAI as the dependent variable and the ten components extracted by PCA (see Table 2 and Appendix 2) as independent variables.

Variable	Beta		
	Coefficient	t	p-Level
Dependent variable: δESAI (1960–2000)			
Summary statistics: adjusted $R^2 = 0.256$, $F(8,7971) = 342.5$, $p < 0.0001$, std. error of coefficients 0.0097, Durbin–Watson test: 1.99			
Intercept		49.58	0.0000
Component 2	0.4284	44.34	0.0000
Component 1	−0.1602	−16.58	0.0000
Component 6	0.1262	13.06	0.0000
Component 3	0.1230	12.73	0.0000
Component 10	0.0845	8.75	0.0000
Component 8	0.0559	5.78	0.0000
Component 5	0.0537	5.56	0.0000
Component 4	0.0492	5.09	0.0000
Dependent variable: δESAI (1990–2000)			
Summary statistics: adjusted $R^2 = 0.058$, $F(7,7972) = 71.2$, $p < 0.0001$, std. error of coefficients 0.0109, Durbin–Watson test: 1.97			
Intercept		19.94	0.0000
Component 4	0.1471	13.54	0.0000
Component 2	0.1417	13.04	0.0000
Component 1	0.0821	7.56	0.0000
Component 7	−0.0640	−5.89	0.0000
Component 3	−0.0495	−4.55	0.0000
Component 6	0.0442	4.071	0.0000
Component 9	0.0437	4.02	0.0001
Dependent variable: δESAI (2000–2010)			
Summary statistics: adjusted $R^2 = 0.235$, $F(8,7971) = 308.2$, $p < 0.0001$, std. error of coefficients 0.0098, Durbin–Watson test: 1.99			
Intercept		25.55	0.0000
Component 1	−0.4197	−42.87	0.0000
Component 9	−0.1143	−11.68	0.0000
Component 2	−0.1086	−11.10	0.0000
Component 7	0.1064	10.87	0.0000
Component 4	0.1047	10.70	0.0000
Component 6	−0.0876	−8.95	0.0000
Component 8	−0.0522	−5.33	0.0000
Component 5	−0.0507	−5.18	0.0000

lowland and mountain areas in the same region). The gradient was mainly associated with population density, average family size, elevation, the agricultural intensity index and the percent area of pastures and meadows.

Component 3 explained 6% of the total variance and was found to be correlated with indicators of human settlements, living standards and water management in agriculture. Variables such as per-capita apartment size, landscape diversity index, per-capita water consumption, density of bank deposits and hotel occupancy rate showed the highest component loadings possibly indicating an urban-to-rural gradient. Component 4 explained more than 3% of the total variance and was found associated with indicators describing the structure of resident population. The component identifies areas with young population (especially urban, peri-urban and lowland areas with a dynamic economic structure and high accessibility) and aged population (especially rural and marginal areas with low accessibility, poor infrastructures and a static job market).

Component 5 explained more than 2.5% of the total variance and correlated with quality and innovation processes in agriculture and specific land tenure conditions. This axis indicates the increasing polarization in dynamic rural areas (mainly characterized by organic or high-value added crops, productions – especially wine – with quality designations and the prevalence of the property land tenure) and marginal/disadvantaged areas with farmer ageing, small farms, extensive crops and the prevalence of rented land as tenure system. Component 6 accounted for nearly 2.5% of the total variance and was correlated with indicators describing regional disparities in crop intensity, land tenure and human capital. Basically, this axis represents the agricultural specialization of Italian municipalities (according to the share of cropland in the total municipal area) in turn associated to specific characteristics of the production systems, e.g. irrigation, rural landscape, land fragmentation and farm-holders' regime.

Component 7 accounted for more than 2% of the total variance and was found to be associated with social and economic structure variables. Variables such as crime index, number of work accidents, density of workers in the industrial sector and the share of workers in commercial activities indicate areas devoted to industrial development, mainly located in northern and central Italy. Component 8 explained 2% of the total variance and it was associated with water management and job market variables. Components 9 and 10 accounted for less than 2% of variance and correlated respectively with land-use and land tenure variables and with indicators of quality and innovation in agriculture, human settlements and the economic structure.

3.3. Identifying socioeconomic contexts characterizing ZNLD areas

Three separate regression models were estimated for the time intervals investigated (Table 3). According to the adjusted R^2 statistics, the models referring to 1960–2000 and 2000–2010 were statistically significant, with R^2 higher than 0.23, which is a relatively high score in respect to the huge number of observations (i.e. municipalities) analyzed. Durbin–Watson statistic was always close to 2, indicating the presence of negligible, if any, autocorrelation in the residuals of the three regression models. The stepwise model incorporating δESAI (1960–2000) as the dependent variable showed an adjusted R^2 approaching 0.26 with a highly significant F-statistic and identified eight principal components (t-test, $p < 0.0001$) as the most correlated to the dependent variable. Component 2 contributed the most to the variability of δESAI and suggests the importance of the latitude gradient (together with variables describing socioeconomic development) to determine conditions of stable (or reversing) land sensitivity over time. Component 1, the second most important variable in the stepwise regression, highlights the importance of population structure, crop intensity, water management and water use in agriculture (e.g. sustainable irrigation practices). Components 3 and 6 contributed to δESAI with standardized coefficients (beta) > 0.1 and pointed out the role of agricultural specialization and human settlement variables. Taken together, these findings identified ZNLD municipalities as areas with low anthropogenic pressure, extensive agriculture, medium–high living standards and a balanced population structure.

The stepwise regression analyzing δESAI (1990–2000) as the dependent variable produced a model with the adjusted R^2 approaching 0.06 and significant F-statistic. Seven principal components were selected (t-test, $p < 0.001$) with only two components (2 and 4) showing beta > 0.1. These components incorporate the effect of population structure and dynamics, agricultural intensification, water management and use variables, partly confirming the results obtained in the model described above. However, although significant p-values and remarkably good Durbin–Watson statistics, these findings should be considered as only moderately reliable because of the low R^2 value.

Finally, the stepwise model analyzing δESAI (2000–2010) as the dependent variable produced an adjusted R^2 approaching 0.24 with a highly significant F-statistic. Eight principal components (t-test, $p < 0.0001$) entered the stepwise regression with five components showing beta > 0.1. Results of this model are quite different from those obtained for the period 1960–2000 and confirm the changes in the geography of ZNLD areas. The stepwise regression identified Component 1 as the most important variable followed by Components 9, 2, 7 and 4. These incorporate the effect of diverging living standards between northern and southern Italy, population structure and dynamics, crop intensity, water management, land-use and land tenure and the socioeconomic structure. Taken together, these findings identified ZNLD municipalities as areas with moderate (or even increasing) anthropogenic pressure, intermediate living standards (income and consumption level), sustainable agricultural practices (especially in the use of water), a relatively balanced population structure, a socioeconomic structure oriented to services, the prevalence of property farms and a land-use structure oriented towards mixed farmland/woodlands and compact urban settlements.

4. Discussion

The present study investigates the socioeconomic variables mostly associated with the environmental conditions determining a reduction in land sensitivity to degradation at the local scale in Italy during the last fifty years. A non-increasing rate of land sensitivity to degradation over time was considered as a criterion to identify ZNLD areas on a local scale. Based on a large set of indicators describing social, demographic, economic, political, institutional and cultural analysis domains, focus was given to the most prominent factors triggering (or, conversely, mitigating) land degradation over time (Rubio and Bochet, 1998) and space (Safriel and Adeel, 2008; Amiraslani and Dragovich, 2011; Yang and Wu, 2012). Multidimensional statistics allowed us to evaluate the importance of the socioeconomic local context predisposing land to degradation or reversing its level of sensitivity.

Although several Mediterranean countries experienced an impressive economic development in the last decades, disparities still exist between urban and rural areas, coastal and inland areas, lowland and mountain areas, especially where rural areas show a level of per-capita income significantly lower than the European average. In southern Europe disadvantaged, marginal and dry areas with limited chances of growing rapidly, exhibit critical ecological conditions, thus requiring renewed policy interventions. Because of the heterogeneity of cause–effect relationships, few studies attempted to identify ZNLD areas and to evaluate the contribution of biophysical and socioeconomic factors to the expansion of these areas (Salvati and Zitti, 2009; Salvati et al., 2013b).

The present study shows that ZNLD areas have expanded in the most recent time horizon especially in southern Italy. This region, considered as the most sensitive in Italy because of climate aridity, soil vulnerability, poor vegetation cover affected by fires, overgrazing and informal urban expansion (Salvati et al., 2013c), was supported in the last two decades by specific conservation policies developed in the framework of the Italian National Action Plan (NAP) to combat Desertification. These findings proved the effectiveness of (at least some of) the measures against land degradation promoted by the Italian NAP (see Briassoulis, 2011 for a description of the NAPs in Italy and in the other European Mediterranean countries).

Moreover, multivariate analysis documents the complexity of the socioeconomic profile of ZNLD municipalities. While land degradation in the Mediterranean region is characterized by the long-term interaction between the biophysical and the human dimensions (Helldén and Tottrup, 2008), Vogt et al. (2011) demonstrated that a number of socioeconomic factors impact (and possibly degrades) the land acting in close synergy and determining non-linear and un-predictable effects. The dynamic interplay between socioeconomic and ecological factors determines non-linear development paths and often implicates feedback relations with exogenous variables (Patel et al., 2007). The unpredictability of territorial actors' behaviour with its consequences on decision variables, among which prices, investments, institutions and services are particularly important, adds entropy to an already articulated territorial system (Onate and Peco, 2005). In Italy, this framework was complicated by the rapid modifications recently observed in the socioeconomic structure which altered the spatial organization of entire regions (see, as instance, Salvati et al., 2011). This could have played a role in the changing geography of ZNLD areas.

These changes are reflected in the diverging results produced by the regression models analyzing two time intervals (1960–2000 and 2000–2010). While in the long term (1960–2000) ZNLD areas have been associated with environmental conditions characterized by permanently-low anthropogenic pressure, in the most recent period rural municipalities classified at ZNLD showed moderate-to-high population density, an economic structure centred on services, a dynamic agriculture sector oriented towards quality productions and more sustainable cultivation practices (with special regards to sustainable water management and reduced irrigation consumption), a balanced demographic structure and the prevalence of a mixed farmland/woodland land-use structure. These results confirm the importance of specific socioeconomic factors characterizing rural areas in terms of sustainability and competitiveness (Salvati and Carlucci, 2011). A balanced socioeconomic context with intermediate population density, an environmentally-sustainable and economically-viable agricultural system coupled with a dynamic tertiary sector, a moderate land consumption rate and a diversified landscape structure are the most relevant attributes characterizing ZNLD municipalities in Italy.

Although rural development variables play a pivotal role in discriminating ZNLD municipalities, demographic processes (e.g. population structure and dynamics, ageing, family size) and wealth indicators (e.g. disposable income, revenues from taxes, infrastructures) proved to be also important in a divided country such as Italy. As a matter of fact, socioeconomic disparities between northern and southern regions were only partly reduced during the last fifty years. However, the rapidly-changing disparities in the geography of ZNLD areas during the three time interval examined here suggest that environmental regulations, land protection measures, policies mitigating land mismanagement and orienting rural development towards the pillar of environmental sustainability (Trisorio, 2005), all included under Italian NAP's umbrella, contributed to shape the (changing) level of land sensitivity to degradation especially in the southern part of the country.

5. Conclusions

An analysis of a comprehensive set of socioeconomic indicators highlighting links with the most relevant environmental factors, has been implemented in the present study to evaluate the complexity of the local context determining land degradation in Italy. By developing a diachronic approach that assesses the evolution of local communities, the methodology proposed here identifies the variables characterizing ZNLD areas to inform effective local and regional scale mitigation policies. The use of administrative spatial partitions allowed us to investigate the local socioeconomic context indirectly evaluating the possible responses implemented by rural communities to contrast land degradation. Although the National Action Plans to combat desertification in northern Mediterranean countries assigned to larger regions (i.e. administrative regions and river basin authorities) to boost land conservation and soil restoration, municipalities are important spatial units for regional planning and land management.

The analysis of socioeconomic profiles of ZNLD municipalities may thus inform sustainable land management policies against land degradation. Such analyses could be improved incorporating projections on climate changes, urbanization, demographic trends, socioeconomic restructuring and considering the links between current and past land-uses and territorial contexts in a multi-temporal perspective. Scenario analyses at the local scale will also be necessary to define a specific ZNLD policy strategy aimed at improving the environment conditions according to the bargaining power of the social actors concerned about land degradation.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jenvman.2014.07.006.

References

Abu Hammad, A., Tumeizi, A., 2012. Land degradation: socioeconomic and environmental causes and consequences in the eastern Mediterranean. Land Degrad. Dev. 23, 216–226.
Amiraslani, F., Dragovich, D., 2011. Combating desertification in Iran over the last 50 years: an overview of changing approaches. J. Environ. Manag. 92 (1), 1–13.
Basso, F., Bove, E., Dumontet, S., Ferrara, A., Pisante, M., Quaranta, G., Taberner, M., 2000. Evaluating environmental sensitivity at the basin scale through the use of geographic information systems and remotely sensed data: an example covering the Agri basin – Southern Italy. Catena 40, 19–35.
Bowyer, C., Withana, S., Fenn, I., Bassi, S., Lewis, M., Cooper, T., Benito, P., Mudgal, S., 2009. Land Degradation and Desertification. Policy Department, Economic and Scientific Policy. European Parliament, Bruxelles.
Briassoulis, H., 2011. Governing desertification in Mediterranean Europe: the challenge of environmental policy integration in multi-level governance contexts. Land Degrad. Dev. 22 (3), 313–325.
Caraveli, H., 2000. A comparative analysis on intensification and extensification in Mediterranean agriculture: dilemmas for LFAs policy. J. Rural Stud. 16 (2), 231–242.
Cawley, M.E., 1994. Desertification: measuring population decline in rural Ireland. J. Rural Stud. 10 (4), 395–407.
Corbelle-Rico, E., Crecente-Maseda, R., Santé-Riveira, I., 2012. Multi-scale assessment and spatial modelling of agricultural land abandonment in a European peripheral region: Galicia (Spain), 1956–2004. Land Use Policy 29, 493–501.
Danfeng, S., Dawson, R., Baoguo, L., 2006. Agricultural causes of desertification risk in Minquin, China. J. Environ. Manag. 79, 348–356.
Ferrara, A., Salvati, L., Sateriano, A., Nolè, A., 2012. Performance evaluation and costs assessment of a key indicator system to monitor desertification vulnerability. Ecol. Indic. 23, 123–129.
Garcia Latorre, J., Garcia-Latorre, J., Sanchez-Picon, A., 2001. Dealing with aridity: socio-economic structures and environmental changes in an arid Mediterranean region. Land Use Policy 18, 53–64.
Geist, H.J., Lambin, E.F., 2004. Dynamic causal patterns of desertification. Bioscience 54, 817–829.
Gisladottir, G., Stocking, M., 2005. Land degradation control and its global environmental benefits. Land Degrad. Dev. 16, 99–112.
Helldén, U., Tottrup, C., 2008. Regional desertification: a global synthesis. Glob. Planet. Change 64, 169–176.
Hubacek, K., van den Bergh, J.C.J.M., 2006. Changing concepts of ‘land’ in economic theory: from single to multi-disciplinary approaches. Ecol. Econ. 56, 5–27.
Imeson, A., 2012. Desertification, Land Degradation and Sustainability. Wiley, Chichester.
Iosifides, T., Politidis, T., 2005. Socio-economic dynamics, local development and desertification in western Lesvos, Greece. Local Environ. 10, 487–499.
Juntti, M., Wilson, G.A., 2004. Conceptualising desertification in southern Europe: stakeholders interpretations and multiple policy agendas. Eur. Environ. 15, 228–249.
Kosmas, K., Tsara, M., Moustakas, N., Karavitis, C., 2003. Identification of indicators for desertification. Ann. Arid Zones 42, 393–416.
Mancino, G., Nolè, A., Ripullone, F., Ferrara, A., 2013. Landsat TM imagery and NDVI differencing to detect vegetation change: assessing natural forest expansion in Basilicata, southern Italy. Iforest Biogeosci. For. 7, 75–84.
Montanarella, L., Vargas, R., 2012. Global governance of soil resources as a necessary condition for sustainable development. Curr. Opin. Environ. Sustain. 4 (6), 559–564.
Montanarella, L., 2007. Trends in land degradation in Europe. In: Sivakumar, M.V., N'diangui, N. (Eds.), Climate and Land Degradation. Springer, Berlin, pp. 83–104.
Onate, J.J., Peco, B., 2005. Policy impact on desertification: stakeholders' perceptions in southeast Spain. Land Use Policy 22, 103–114.
Patel, M., Kok, K., Rothman, D.S., 2007. Participatory scenario construction in land use analysis: an insight into the experiences created by stakeholder involvement in the Northern Mediterranean. Land Use Policy 24, 546–561.
Romm, J., 2011. Desertification: the next dust bowl. Nature 478, 450–451.
Rubio, J.L., Bochet, E., 1998. Desertification indicators as diagnosis criteria for desertification risk assessment in Europe. J. Arid Environ. 39, 113–120.
Safriel, U., Adeel, Z., 2008. Development paths of drylands: thresholds and sustainability. Sustain. Sci. 3, 117–123.
Salvati, L., Bajocco, S., 2011. Land sensitivity to desertification across Italy: past, present, and future. Appl. Geogr. 31 (1), 223–231.
Salvati, L., Bajocco, S., Mancini, A., Gemmiti, R., Carlucci, M., 2011. Socioeconomic development and vulnerability to land degradation in Italy. Reg. Environ. Change 11 (4), 767–777.
Salvati, L., Carlucci, M., 2011. The economic and environmental performances of rural districts in Italy: are competitiveness and sustainability compatible targets? Ecol. Econ. 70 (12), 2446–2453.
Salvati, L., De Zuliani, E., Sateriano, A., Zitti, M., Mancino, G., Ferrara, A., 2013a. An expert system to evaluate environmental sensitivity: a local-scale approach to land degradation. Appl. Ecol. Environ. Res. 11 (4), 611–627.
Salvati, L., Tombolini, I., Perini, L., Ferrara, A., 2013b. Landscape changes and environmental quality: the evolution of land vulnerability and potential resilience to degradation in Italy. Reg. Environ. Change 13 (6), 1223–1233.
Salvati, L., Zitti, M., Perini, L., 2013c. Fifty years on: understanding the long-term spatio-temporal patterns of sensitivity to desertification across Italy. Land Degrad. Dev. http://dx.doi.org/10.1002/ldr.2226.
Salvati, L., Zitti, M., 2009. The environmental ‘risky’ region: identifying land degradation processes through integration of socio-economic and ecological indicators in a multivariate regionalization model. Environ. Manag. 44 (5), 888–899.
Trisorio, A., 2005. The Sustainability of Italian Agriculture. Italian National Institute of Agricultural Economics (INEA), Rome.
UNCCD (United Nations Convention to Combat Desertification), 2012. Policy Brief: Zero Net Land Degradation. UNCCD, Bonn. http://www.unccd.int/Lists/SiteDocumentLibrary/Rio+20/UNCCD_PolicyBrief_ZeroNetLandDegradation.pdf (accessed at June 2014.).
Vogt, J.V., Safriel, U., Bastin, G., Zougmore, R., von Maltitz, G., Sokona, Y., Hill, J., 2011. Monitoring and assessment of land degradation and desertification: towards new conceptual and integrated approaches. Land Degrad. Dev. 22 (2), 150–165.
Wang, X., Chen, F., Dong, Z., 2006. The relative role of climatic and human factors in desertification in semiarid China. Glob. Environ. Change 16, 48–57.
Wilson, G.A., 2008. From ‘weak’ to ‘strong’ multifunctionality: conceptualising farm-level multifunctional transitional pathways. J. Rural Stud. 24 (3), 367–383.
Yang, L., Wu, J., 2012. Knowledge-driven institutional change: an empirical study on combating desertification in northern china from 1949 to 2004. J. Environ. Manag. 110, 254–266.