Land Use Policy xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Land Use Policy

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

Agricultural "greening" and cropland diversification trends: Potential contribution of agroenergy crops in Capitanata (South Italy)

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A R T I C L E I N F O

Keywords:
Agricultural landscape
Land use change
Shannon's index
Crop diversity
Land planning

A B S T R A C T

Cropland diversity was the focus of this work to support regional policy in a land planning perspective for the development of both the agriculture and renewable energy sectors. Considering the *Capitanata* region (South of Italy) as a case study, the land share-out in agricultural crops have been assessed by using two different approaches: a) multi-year census data and b) land use/land cover digital maps through GIS assisted techniques. In the first case, the smallest land unit was the administrative municipality while in the second, it was the cell of a grid having a regular sized mesh (3 km) superimposed to the digital map. The share of the cultivated surfaces among the main crop categories was computed with reference to the region as a whole and its geographical sub-regions, the latter statistically determined according to the main characters in their crop composition. Thereafter, the Shannon's Diversity Index was applied to the crop share of cultivated areas. Finally, a potential scenario of possible land use changes due to the introduction of energy crops was presented, according to defined land conversion criteria, in order to improve the crop spatial diversity, particularly in those sub-regions where lower diversity levels were previously detected.

An attempt in describing and explaining the dynamic traits of cropland diversity was performed. The essential elements resulting from the analysis were: 1) The stronger the environmental constraints, the narrower is the crop choice and the consequent crop diversity. 2) By eliminating the link between support payments and production, the EU-CAP "decoupling" scheme had positive effects in terms of cropland diversity. Further reinforcing effects are probably expected by strengthening the CAP rural development and the agro-environmental measures. The "greening" scheme applied in the last CAP programming period (2014–2020) is probably acting in the same direction. 3) Through a simulated new planning scenario, a limited but well-targeted agroenergy land conversion may produce a significant improvement in cropland diversity even though not necessarily translated in a lower environmental burden due to agriculture, at least immediately.

Diversification is the sign of a progressive reorientation of agriculture towards a multifunctional activity that combines producing quality food, maintaining rural livelihoods and landscapes, promoting environmental stewardship, preserving biodiversity, establishing a better agro-ecosystem functioning. In this respect, the scope of the work was to provide a planning case study at regional scale in order to promote a reconciling approach between productive and ecological services of agriculture, coming from a diversified and multifunctional agricultural system made of both food- and energy-crops.

1. Introduction

Agriculture is the dominant land use in Europe. According to Eurostat (2015), utilized agricultural area (UAA) accounted for the 40% of the total land area of the EU-28 in 2013. This is approximately the same proportion of land covered by forests and other wooded land. A further 9% of the land belongs to agricultural holdings. Therefore, in the long run, agriculture largely contributed in shaping the landscape and it is still a major factor in driving its transformation. Deep changes in agriculture are taking place and a large part of the European rural landscape is being transformed (van der Ploeg, 2008). Changes in agricultural land use has shown diverging trends: agricultural specialization, concentration and intensification, on the one hand (Paulo et al., 2016); farmland marginalization and abandonment, on the other (Terres et al., 2015). This trends are frequently observed as dynamic patterns in structural farm adjustment (Meert et al., 2005; Moreno-Pérez et al., 2011). Economic, political, and social drivers play a relevant role in affecting the agricultural landscape and land use. In the

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http://dx.doi.org/10.1016/j.landusepol.2017.10.038
Received 28 January 2017; Received in revised form 17 July 2017; Accepted 20 October 2017
0264-8377/

Please cite this article as: Monteleone, M., Land Use Policy (2017), http://dx.doi.org/10.1016/j.landusepol.2017.10.038

last decades, agricultural changes were also driven by the EU reforms of the common agricultural policy (CAP) at farm level and, consequently, at landscape scale. The CAP 'first pillar' promoted a market-oriented vision with subsidies to farmers decoupled from production and addressed to a direct payment. Within this frame, an increased attention to environmental concerns was turned into a set of "good agricultural and environmental conditions" (GAEC) which regulate access to EU payment to farmers. With the so-called "cross-compliance" scheme (EC Council Regulation 73/2009), soil and water quality, soil carbon stocks and landscape maintenance are specifically considered. On the other hand, CAP has been re-oriented towards a wider rural policy perspective, aiming at integrating environmental issues and rural development. On this respect, a large set of "agro-environmental" measures and rural development instruments are the essential ingredients of the CAP 'second pillar'.

The new CAP (2014–2020) confirms and further develops this strategy. Indeed, 30% of the total amount of resources assigned to farmers as direct payments is linked to three mandatory prescriptions: a) maintaining on-farm permanent grassland, b) diversifying arable crops, and c) devoting a minimum amount of the utilized agricultural area to "ecological focus areas". From this set of conditional requirements, it is clear the attempt to remunerate public goods provided by farmers (i.e. positive environmental externalities). In other words, the so-called "green payment" is a share of the total payment that farmers may receive from the CAP in recognition of an overriding public interest (Cimino et al., 2015). In this perspective, "greening" is applied to farming units but is intended to be effective at a larger spatial dimension, that of the overall landscape at regional level (Mahé, 2012), to promote diversification and protect agricultural biodiversity.

Considering the specific topic of this work, here agricultural *diversification* refers to the shift from the dominance of one or just a few crops (i.e. crop specialization and, at least, monoculture) to the cultivation of a larger number of species. Other and broader definitions of agricultural diversification are available in the literature, mainly related to the economic and structural interpretation of farming (Bradshaw, 2004; Dries et al., 2012).

In ecological terms, crop diversity positively affects agro-ecosystem functioning (Davis et al., 2012). Conversely, it is widely accepted that monoculture in arable systems has a deleterious effects on soil quality and on farming ecological conditions. The more diverse and heterogeneous is the landscape, the more it can potentially contribute to offer ecological services (Liebman and Schulte, 2015).

Concerning the EU target of "greening", energy crops (i.e. those species grown to be used in energy conversion processes) could be a further option in farming diversification within the multifunctional frame assigned to agriculture (Popp et al., 2014).

The production of biomass on agricultural land has raised a number of interrelated controversies (Shortall, 2013) and a "land use issue" progressively grew in the last decade, from the side of both policy makers and public opinion. Competition for land between energy and food is considered very risky in decreasing food security while increasing food price volatility (Allen et al., 2014). Moreover, starting from the seminal papers by Searchinger et al. (2008) and Fargione et al. (2008), the supposed environmental advantages due to fossil displacement in the use of renewable energy sources, based on assuming carbon neutrality, frequently revealed to be untrue or largely overestimated (Mohr and Raman, 2013). Risks linked to direct and indirect land use changes, crop management intensification, soil fertility exploitation and its carbon stocks reduction, increased N_2O emissions, higher pressure on biodiversity, are well documented today. (Don et al., 2012; Pedroli et al., 2013). On the other side, according to Tilman et al. (2009), to rethink bioenergy from an agro-ecological perspective means to consider the benefitting of a bioenergy "done right". Farming technical operations reducing the use of pesticides, irrigation water and fertilizers, preserving soil organic carbon content, locally centered and based on distributed energy facilities, are essential conditions for a sustainable bioenergy supply-chains (Dale et al., 2016; Monteleone et al., 2009).

In this respect, a land planning procedure performed at regional scale is a valuable approach to identify possible land use conflicts between different utilization options (food vs. energy) and to apply a rational and comprehensive procedure that properly matches "land capability" with "crop suitability" in an accurately designed bioenergy supply system (Tenerelli and Monteleone, 2008a, 2008b).

Cropland diversity was the focus of this work to support regional policy in a land planning perspective for the development of both agriculture and renewable energy sectors. Considering the *Capitanata* region (South of Italy) as a case study, the first objective was determining the share-out of the cultivated surfaces among the main crop categories. According to the census data, relatively homogeneous subregions in their crop composition were statistically identified; then, agricultural long-term diversification trends were detected and commented. As a parallel procedure, regional and sub-regional cropland composition was also spatially determined by processing digital land use maps. By interpreting the "greening" purposes of the CAP, the second objective was to arrange a potential scenario of agroenergy land use change, i.e. to present possible land conversions from conventional food/feed crops to energy crops. Conversion criteria have been applied in order to improve cropland diversity, specifically in those sub-regions where lower diversity levels were previously detected.

While the first objective was purely explanatory, the second was intended to work out a possible approach to the transformation of the agricultural landscape, measuring the outcomes in terms of cropland diversity. More generally, the scope of the work was to provide a planning case study at regional scale in order to promote a reconciling approach between productive and ecological services of agriculture, coming from a diversified and multifunctional agricultural system made of both food- and energy-crops.

2. Materials and methods

2.1. Overview of the applied methods

Capitanata is the investigated area, about 720,000 ha in surface. Administratively it corresponds to the province of Foggia, placed in the southeast part of Italy (Fig. 1).

Fig. 2 shows the sequential steps of the entire analysis. The analysis was performed along two parallel lines (Fig. 2A and B respectively). The first approach is based on the interpretation of the long-term agricultural census data (over the years 1982, 1990, 2000, and 2010). Discrete land units of minimum extension corresponding to the 63 municipalities of the *Capitanata* region were considered in the first approach. Differently, in the second approach, a spatially (GIS assisted) procedure was applied, taking into account the digital land use/land cover maps of the same region.

Initially, the share-out of the cultivated surfaces among the most relevant census categories of agricultural crops was computed for the entire region and the whole census dataset. Long-term dynamics of cropland composition was consequently detected (Fig. 2A1). The 2010 census dataset was used to statistically perform a zoning procedure identifying groups of municipalities with a rather homogeneous internal crop composition thus forming distinctive geographical sub-regions. In parallel, the digital land use maps of *Capitanata* were processed to obtain a land partitioning into regular grid-cells, each cell having its specific crop composition. Based on this land grid partition, a potential scenario of agroenergy land use change was arranged according to specific land evaluation criteria and land conversion rules. Thereafter, an adaptation of the Shannon's Diversity Index (SDI) was applied to the share-out of crop surfaces (cropland composition) within each land unit. The SDI was assumed as an indicator of cropland diversity and used to assess, characterize and compare the agricultural diversity of *Capitanata* and its sub-regions, considering both the census