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Crop Production and Crop Diversity in France: A Spatial Analysis

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ABSTRACT

This paper aims to provide empirical evidence of the effect of crop diversity on crop production and spillover effect. Based on the estimation of production functions with spatial concerns on an original and rich dataset, results of the study suggest that crop diversity has a positive and significant effect on crop production. Its marginal contribution is substantial when rainfall is low in the agroecosystem. Furthermore, spatial dependence is a major issue and could be explained by topographic, climatic and agronomic constraints.

Contents

1. Introduction

After an initial period when the Common Agricultural Policy (CAP) was aimed at European food security and based on increasing agricultural productivity, the second pillar of the CAP introduced other objectives, including rural development and the production of goods which are sustainable and environmentally friendly (Bureau and Toyer, 2014). Nevertheless, the negative ecological impact of agricultural development constitutes one of the major criticisms of the CAP. Following public awareness and scientific-based evidence of the function of ecosystem services, the role of ecosystems in crop production has increasingly been a focus of interest.

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Ecosystem services are defined as “the conditions and processes through which natural ecosystems, and the species that make them up, sustain, and fulfill human life” (Daily, 1997, p. 6). They contribute to the essential ecological functions on which agriculture depends, including erosion control, sediment retention, soil formation, genetic resources, water regulation and supply (Costanza et al., 1997). They also offer a wide variety of aesthetic, recreational and cultural services to human welfare. As outlined by Gardiner et al. (2009), Kremen et al. (2004), Altieri (1999), ecosystems within agricultural lands could provide services of biological pest control and pollination, as well as improvement of soil fertility that may promote agricultural production.[1]

The link between biodiversity and ecosystem services remains confused in scientific literature and in national or regional ecosystem assessments. Biodiversity can be considered in many different ways: as a regulator of ecosystem processes, final ecosystem service or good (Mace et al., 2012). As complex as this relationship could be, many authors have shown that biodiversity contributes to determining the quantity, quality and reliability of ecosystem services (Harrison et al., 2014; Luck et al., 2009). We consider that biodiversity[2] is a pillar of ecosystem services as it constitutes the ecological underpinnings of service provision. It is often seen as a public good which means that individuals cannot be effectively excluded from use (non-excludable) and where use by one individual does not reduce availability to others (non-rivalrous). We focus here on a subset of biodiversity, a part produced by the agroecosystem: crop diversity. It refers to “all diversity within and among wild and domesticated crop species […] and in many situations, provides the link between stress and loss of resilience” (Di Falco and Chavas, 2008, p. 83).

Hence, markets do not reflect the full social costs or benefits of biodiversity and their management may be complex. Nevertheless, biodiversity valuation can help scholars and policymakers deal with this market failure by assigning a monetary value that reflects the social importance of biodiversity. This could help in designing effective tools for their management. From an economic viewpoint, assessing the value of biodiversity may be done with a variety of valuation approaches (Barbier, 2007; De Groot et al., 2002; Farber et al., 2002; TEEB, 2010). In this study, we use the production function-based approach where we assume that crop diversity is an input in the production process of agricultural goods, which are themselves marketed, and we attempt to assess its contribution to agricultural production while accounting for spatial dependence. Furthermore, crop diversity could play an important role in ecosystem resilience. Resilience refers to an ecosystem's capacity to recover from disturbances or unexpected shocks and maintain its essential functions (Holling, 1986). In the agroecosystem, when rainfall is scarce, crop diversity can act as a catalyzer to agricultural production.

At farm scale, crop diversity tends to increase the yield of each crop, although its impact on overall production is likely to be negative and its effect on profit unclear (Davis et al., 2012; Deytieux et al., 2012; Iverson et al., 2014; Lechenet et al., 2014). One of the explanations for the yield effect is the synergy obtained by rotating crops on a given field (Carrouée et al., 2012; Doré et al., 2011). Brisson et al. (2010) explored the stagnation of wheat yield in France, distinguishing agronomic, environmental (climate) and economic factors. They concluded that the change in rotation and decrease of legumes in practices are involved in this stagnation. In another analysis of yield evolution at global level, Ray et al. (2012) suggested that in many countries an increase in the number of crops per cropping cycle or intercropping with other crops could increase net food supply and farmer incomes. However, to the best of our knowledge, there is very little research conducted at a national level and we do not know of any study in France which examines the effect of crop diversity on crop production. Another important shortcoming in the literature is the scarcity of studies which integrate spatial dependence in the analysis.

Spatial dependence of agricultural production may be spearheaded by agronomic, environmental and economic factors. Indeed, the cluster pattern of agricultural production may be explained by some natural, historical, socio-cultural and institutional factors. The choice of the spatial unit is crucial, but the choice of homogeneous agronomic areas does imply neither that all agronomic characteristics are controlled nor that these areas belong to the same supply or consultancy networks. In particular, farmers can be part of a large network and exchange information on agricultural practices that could improve their productivity. Thus, due to exchanges of information in the network, copy-catting and learning effect, the levels of agricultural production in an area may be influenced by those in neighboring areas. Therefore, not accounting for spatial dependence may bias the estimates and lead to erroneous policy recommendations. Hence, this paper contributes to existing knowledge by shedding some light on the effect of crop diversity on crop production in France with some significant spillover effects across neighborhood. From a policy perspective, a better understanding of the factors that may influence agricultural productivity could give more insight into how policymakers could intervene via some incentives to protect both agricultural lands and biodiversity.

The overall objective of the study is to examine the effects of crop diversity and other factors on agricultural production while accounting for spatial dependence. More specifically, we aim, via econometric tools, to measure the impact of crop diversity on major crop production (cereals, oilseeds and protein crops) in a given Small Agricultural Region[3] (SAR) and other contiguous SARs. Using a rich dataset constructed with matching methods that allow for analysis at a national level, results of the study suggest that crop diversity has a positive and significant effect on crop production and its marginal contribution is substantial when rainfall is low in the agroecosystem. More importantly, spatial dependence is not at odds with the data. Our results suggest that, holding all other things constant, a 1% increase of labor (capital) will lead to an increase in crop production of 0.20% (0.24%). Similarly, a 1% increase of fertilizer will yield an increase of 0.57% in crop production.

The paper is structured as follows. In Section 2, we review the literature on the relationship between crop production and crop diversity. Section 3 provides the econometric model and discusses the data while Section 4 presents the results of the study. We conclude the study in Section 5 with some policy recommendations.

2. Literature Review

The relevance of biodiversity in the provision of ecosystem services has been fully documented in the literature. Tilman et al. (2005) demonstrated that plant diversity (number of plant species added to plots) improves plant primary productivity. Reich et al. (2001) found that higher plant diversity leads to greater carbon (CO_2) storage in plants and lower levels of nitrate in ground waters. Hajjar et al. (2008) gave an exhaustive survey of the links between crop genetic diversity and ecosystem services such as: (i) pest and disease management, (ii) enhancement in pollination services and soil processes and (iii) providing continuous biomass cover, aid in carbon sequestration and prevention of soil erosion. The debate has focused on the principle mechanisms

[1] From the 2005 report of the Millennium Ecosystem Services (MA, 2005), there are four types of ecosystem services: provisioning services: products obtained from ecosystems (food, raw materials etc.), regulating services: benefits obtained from the regulation of ecosystem processes (pest and disease control, carbon sequestration, etc.), cultural services: intangible benefits individuals obtain from ecosystem recreation, and aesthetic experiences (ecotourism, use of nature for religious acts etc.) and lastly supporting services: the basis for the services of the other three categories.

[2] As defined by UNEP (1993), biodiversity is the “variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which these are a part: this includes diversity within species, between species, and of ecosystems”.

[3] In France, the SAR is a zoning made up of various municipalities with homogeneous conditions in terms of agricultural systems, soil and climate.