Journal of Environmental Management 188 (2017) 49–57

Contents lists available at ScienceDirect

Journal of Environmental Management

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

Research article

Environmental impacts and production performances of organic agriculture in China: A monetary valuation

Fanqiao Meng [a,*], Yuhui Qiao [a], Wenliang Wu [a], Pete Smith [b], Steffanie Scott [c]

[a] Beijing Key Laboratory of Biodiversity and Organic Farming, College of Resources and Environmental Sciences, China Agricultural University, Beijing, 100193, China
[b] Institute of Biological & Environmental Sciences, University of Aberdeen, 23 St Machar Drive, Aberdeen, AB24 3UU, UK
[c] Department of Geography & Environmental Management, University of Waterloo, Waterloo, Canada

ARTICLE INFO

Article history:
Received 23 March 2016
Received in revised form
31 October 2016
Accepted 30 November 2016
Available online 5 December 2016

Keywords:
Organic agriculture
Environmental benefits
Crop yield
Nitrogen fertilizer
Economic value

ABSTRACT

Organic agriculture has developed rapidly in China since the 1990s, driven by the increasing domestic and international demand for organic products. Quantification of the environmental benefits and production performances of organic agriculture on a national scale helps to develop sustainable high yielding agricultural production systems with minimum impacts on the environment. Data of organic production for 2013 were obtained from a national survey organized by the Certification and Accreditation Administration of China. Farming performance and environmental impact indicators were screened and indicator values were defined based on an intensive literature review and were validated by national statistics. The economic (monetary) values of farming inputs, crop production and individual environmental benefits were then quantified and integrated to compare the overall performances of organic vs. conventional agriculture. In 2013, organically managed farmland accounted for approximately 0.97% of national arable land, covering 1.158 million ha. If organic crop yields were assumed to be 10%–15% lower than conventional yields, the environmental benefits of organic agriculture (i.e., a decrease in nitrate leaching, an increase in farmland biodiversity, an increase in carbon sequestration and a decrease in greenhouse gas emissions) were valued at 1921 million RMB (320.2 million USD), or 1659 RMB (276.5 USD) per ha. By reducing the farming inputs, the costs saved was 3110 million RMB (518.3 million USD), or 2686 RMB (447.7 USD) per ha. The economic loss associated with the decrease in crop yields from organic agriculture was valued at 6115 million RMB (1019.2 million USD), or 5280 RMB (880 USD) per ha. Although they were likely underestimated because of the complex relationships among farming operations, ecosystems and humans, the production costs saved and environmental benefits of organic agriculture that were quantified in our study compensated substantially for the economic losses associated with the decrease in crop production. This suggests that payment for the environmental benefits of organic agriculture should be incorporated into public policies. Most of the environmental impacts of organic farming were related to N fluxes within agroecosystems, which is a call for the better management of N fertilizer in regions or countries with low levels of N-use efficiency. Issues such as higher external inputs and lack of integration cropping with animal husbandry should be addressed during the quantification of change of conventional to organic agriculture, and the quantification of this change is challenging.

1. Introduction

Chinese farmers have achieved harmonious coordination with nature over the past several millennia using traditional farming technologies (King, 1927; Ellis and Wang, 1997). From the 1970s to the 2000s, agriculture was intensified through farming practices of high-yield crop varieties and increasing reliance on irrigation and agro-chemicals. With the introduction of relevant laws, regulations

* Corresponding author. College of Resources and Environmental Sciences, China Agricultural University, No. 2 Yuanmingyuan Xilu, Haidian District, Beijing, 100193, China.
E-mail address: mengfq@cau.edu.cn (F. Meng).

http://dx.doi.org/10.1016/j.jenvman.2016.11.080
0301-4797/

and standards in 2005, organic agriculture in China has developed rapidly, driven by an increasing domestic demand (Guo and Zheng, 2011) and exportation to developed countries (CNCA, 2014). By the end of 2013, China became one of the largest organic producers worldwide (Willer and Lernoud, 2014) and is expected to see a rapid growth in organic agriculture in the future (CNCA, 2014).

Organic agriculture is a production system that sustains the health of the ecosystem and human beings by relying on processes and cycles of ecological biodiversity adapted to local conditions. External (synthetic) inputs are dramatically reduced in organic agriculture because of the prohibition of synthetic fertilizers, pesticides, and additives (IFOAM, 2014). Organic agriculture has been promoted as an environmentally friendly alternative to conventional agriculture (Giovannucci, 2006; De Schutter, 2010; The National Academies, 2010). Within the past decades, a multitude of studies have been undertaken to compare the performances of organic agriculture with that of conventional agriculture, in various dimensions. Generally, these studies have shown that organic agriculture performs better than conventional agriculture in most environmental aspects (Gomiero et al., 2008; Schader et al., 2012; Tuomisto et al., 2012; Meier et al., 2015), social well-being (Reganold and Wachter, 2016) and economic viability (Crowder and Reganold, 2015), although the crop yields are lower (Badgley and Perfecto, 2007; Kirchmann et al., 2008; De Ponti et al., 2012; Seufert et al., 2012). As the key function of agriculture is the production of food and fiber, one critical important question to be answered is: can the environmental benefits and production performances of organic agriculture compensate for its lower crop yields?

Instead of focusing on individual aspects, many comparative studies emphasized the importance of a comprehensive assessment, i.e., integrating the research from various related categories (Gomiero et al., 2008; Schader et al., 2012; Tuomisto et al., 2012; Reganold and Wachter, 2016). In 2005, the International Fund for Agriculture Development (IFAD) conducted a survey in China and India and concluded that organic agriculture could ensure long-term soil fertility, reduce external resource consumption and promote regional food security and poverty alleviation (Giovannucci, 2006). In UK, organic production mostly utilizes less energy than conventional production (except poultry and eggs), but organic production often results in increased burdens in greenhouse warming potential (GWP), acidification and eutrophication (Williams et al., 2006). In the studies mainly for European countries, Schader et al. (2012) concluded that organic agriculture has positive impacts on biodiversity, nutrients and energy efficiency, greenhouse gas (GHG) emissions, eutrophication, ammonia volatilization and soil biological activity. Reganold and Wachter (2016) found that the performances of organic agriculture were better than that of conventional agriculture in many ecological, social and economic dimensions, though not in crop yields. However, few of these studies were undertaken at a relatively larger spatial-temporal scale, such as by targeting a region or nation as the study context, and this has lowered the efficacy of transferring the research conclusions to policy making. In addition, the assessment impacts can be expressed either in physical (e.g., carbon (C) sequestrated) or monetary terms. In the communication of the assessment results to farmers, consumers and policy makers, the monetary approach is particularly useful because the environmental impacts can then be easily understood, aggregated and compared (Schader et al., 2012). Hence, as proposed and used in farming systems research (Pretty et al., 2000; Pizzol et al., 2015), a simple language, such as monetary value, can better quantify and compare the performances of organic and conventional agriculture.

Given China's rapidly growing economy and the need to protect the environment and enhance ecosystem services, development of sustainable agriculture, including organic agriculture, has become one of the nation's priority strategies (Ministry of Finance, 2015). According to the Organic Agriculture Development Report (CNCA, 2014), the area of organically managed farmland in China was 1.158 million ha in 2013. An integrated comparative study for organic production at this scale could provide support for sound decision making on agriculture development in China. The aims of this study are to 1) analyze the individual environmental impacts and production of organic agriculture across China as a whole in 2013 and 2) to quantify the environmental impacts and saved production costs in monetary terms and compare them with the economic losses due to crop yield decreases. In the discussion section, we analyze the methodological difficulties and uncertainties of the current study, while examining those implications from this assessment that should be incorporated into future agricultural research and development.

2. Materials and methods

2.1. Theoretical framework and assessment indicator, boundary and unit

This study targeted the total certified organic farmland (arable land), including that in conversion, in China in 2013. As the relationship between an agricultural system and the environment is complex, we chose the Driver-State-Response (DSR) framework (van Huylenbroek et al., 2009), in which a social activity, agriculture in our study, is the "driving force" disturbing the environment. Agricultural functions can be categorized into four key metrics: productivity, environmental impact, social well-being and economic viability (Reganold and Wachter, 2016). Although evidence indicates that a greater social well-being is also delivered by organic agriculture than by conventional agriculture, this was not covered in our study because of lack of appropriate quantification methodologies considering the complexities between farming activities and social well-being, e.g., the social benefits of soil C sequestration (Pretty et al., 2000; Forman et al., 2012; Schader et al., 2012). For the economic viability category, as Crowder and Reganold (2015) highlighted in a global meta-analysis, the total and variable costs are not significantly different, except the higher costs of labor in organic agriculture, and higher use of synthetic fertilizers and pesticides in conventional agriculture. Based on a state-of-the-art literature screening, we selected the following assessment indicators for use in our comparison (Table 1): 1) inputs of synthetic fertilizers, pesticides, labor and energy; 2) agricultural production; and 3) environmental impacts of soil C sequestration, GHG emissions, biodiversity and nitrate leaching.

The use of various methodologies to assess farming systems make comparison among systems difficult. This is particularly true for determining farming system boundaries (Gomiero et al., 2011; Schader et al., 2012). For the system boundary, we analyzed only the production of organic crops because the organic livestock production is in the very early stages of development and total production quantity is low in China (CNCA, 2014). Although organic food/product processing is important throughout the entire food chain, particularly in life cycle assessment (LCA) studies (Ziesemer, 2007), the processing does not differ significantly from conventional processing in causing environmental impacts, except for the use of fewer additives and processing aids. Therefore, processing is not analyzed in most studies and nor was it in our study (Schader et al., 2012; IFOAM, 2014; Reganold and Wachter, 2016). Transportation stage was not included in the assessment because both organically and conventionally produced foods need to be transported from the farm gate to consumers, although transportation may account for a substantial proportion of the environmental