



Multiple factors drive regional agricultural abandonment

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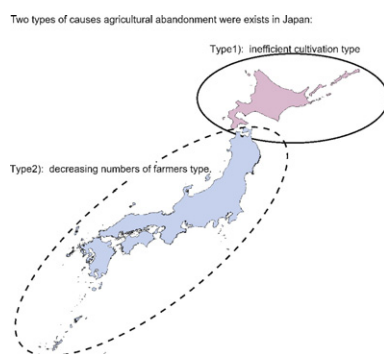
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HIGHLIGHTS

- Agricultural abandonment occurs worldwide.
- We analyzed the factors influencing agricultural abandonment, both social and environmental conditions at the macro scale.
- The main factors leading to agricultural abandonment differed among the regions.
- We identified two main causes: inefficient cultivation and fewer farmers.
- Agricultural abandonment cannot be prevented by adopting a single method or policy.

GRAPHICAL ABSTRACT



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ABSTRACT

An understanding of land-use change and its drivers in agroecosystems is important when developing adaptations to future environmental and socioeconomic pressures. Agricultural abandonment occurs worldwide with multiple potentially positive and negative consequences; however, the main factors causing agricultural abandonment in a country i.e., at the macro scale, have not been identified. We hypothesized that socio-environmental factors driving agricultural abandonment could be summarized comprehensively into two, namely “natural” and “social”, and the relative importance of these differs among regions. To test this postulate, we analyzed the factors currently leading to agricultural abandonment considering ten natural environment variables (e.g., temperature) and five social variables (e.g., number of farmers) using the random forest machine learning method after dividing Japan into eight regions. Our results showed that agricultural abandonment was driven by various socio-environmental factors, and the main factors leading to agricultural abandonment differed among regions, especially in Hokkaido in northern Japan. Hokkaido has a relatively large area of concentrated farmland, and abandonment might have resulted from the effectiveness of cultivation under specific climate factors, whereas the other regions have relatively small areas of farmland with many elderly part-time farmers. In such regions, abandonment might have been caused by the decreasing numbers of potential farmers. Thus, two different drivers of agricultural abandonment were found: inefficient cultivation and decreasing numbers of farmers. Therefore, agricultural abandonment cannot be prevented by adopting a single method or policy. Agricultural abandonment is a significant problem not only for food production but also for several ecosystem services. Governments and decision-makers should develop effective strategies to prevent further abandonment to ensure sustainable future management of agro-ecosystems.

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1. Introduction

Humans have transformed more than 75% of the Earth's ice-free land surface (Ellis and Ramankutty, 2008). Land-use change resulting from the destruction of natural habitats for human use is a leading driver of global environmental change (Sala et al., 2000; Goldewijk, 2001; Foley et al., 2005, 2011). Agriculture occupies about 38% of the Earth's terrestrial surface and is the largest form of land use on the planet (Foley et al., 2005, 2011). In agricultural ecosystems, land-use changes influence various components and processes such as biodiversity, soil and water resources, landscape fragmentation, and land degradation, with significant implications for many ecosystem functions and services, as well as for human society (De Groot et al., 2002; Kamusoko and Aniya, 2007; Ries, 2010; Zimmermann et al., 2010).

Land-use changes occur on local to global scales, and are a result of both short- and long-term interactions of multifaceted drivers (Verburg and Overmars, 2009; Sirami et al., 2010). In agricultural ecosystems, land-use changes are influenced by both climate factors such as temperature and precipitation (e.g., Yoshida et al., 2012) and social factors such as population movement and economic activity (e.g., Lambin and Meyfroidt, 2011) because agriculture is influenced by both the natural environment in terms of providing suitable conditions for cultivation and human activities such as specific crop requirements. Nainggolan et al. (2012a,b) suggested that in semi-arid Mediterranean agro-ecosystems these types of land-use changes were caused by various biophysical and socioeconomic drivers within a catchment.

Changes in agricultural land use have followed two main trajectories, either abandonment or the development of intensive modern farming practices (Meeus, 1995; Uematsu et al., 2010) and both of these fates are thought to be driven mainly by economic pressures (Bouma et al., 1998; Fukamachi et al., 2001, 2005; Uematsu et al., 2010). Agricultural abandonment can have multiple consequences, including negative effects such as loss of food production and loss of biodiversity, which is strongly related to several ecosystem services (Millennium Ecosystem Assessment, 2005; Tscharrntke et al., 2005; Osawa et al., 2013), and positive effects such as improved soil condition (Robledano-Aymerich et al., 2014), forest regeneration (Ramankutty et al., 2010) and regeneration of natural ecosystems (Hölzel et al., 2002; Osawa et al., 2013). Agricultural abandonment is widespread in many regions (Cramer et al., 2008), including North America (Parody et al., 2001), northern Europe (Robinson and Sutherland, 2002), southern Europe (Ostermann, 1998), Spain (Nainggolan et al., 2012a,b; Robledano-Aymerich et al., 2014) and monsoon Asia (Fujihara et al., 2005; Tokuoka et al., 2011; Osawa et al., 2013). Given this global issue, we focused on studying the main factors that influence agricultural abandonment in a country i.e., at the macro spatial scale.

Studies have suggested that the factors that influence agricultural abandonment and its consequences differ regionally, depending on both environmental and social conditions (Munroe et al., 2013). Therefore, to understand the main factors that influence agricultural abandonment, the effects of environmental and social factors should be analyzed under a variety of conditions (Nainggolan et al., 2012a).

The Japanese archipelago is subject to a range of temperatures from north to south and contains landscapes ranging from flatland to mountainous zones. Since changes in Japanese farming practices have drastically increased the rate of agricultural land abandonment during the last two decades (Osawa et al., 2013), Japan constitutes a good case study of agricultural abandonment. In addition, the Government of Japan has a strategic plan to improve food production (Ministry of Agriculture Forestry, and Fisheries: MAFF, 2012). Japan has also been designated as a biodiversity hot spot (Hanson et al., 2009), where exceptional concentrations of endemic species are undergoing exceptional habitat loss (Myers et al., 2000). Osawa et al. (2013) showed that the distribution of the abandoned areas overlaps the ranges of threatened plant species throughout Japan, suggesting that the rate of species extinctions is

related to agricultural land abandonment. The rate of agricultural land abandonment is currently increasing and an understanding of the main factors behind the increase and the ability to predict future changes are needed to improve agrarian policies and planning (MAFF, 2012).

This study examined the main factors causing agricultural abandonment in the Japanese agro-ecosystem to improve future land-use and management planning. We hypothesized that various socio-environmental factors driving agricultural abandonment could be summarized comprehensively as two, namely “natural” and “social”, and the relative importance of these differs among the regions of the Japanese archipelago. First, we established a machine learning model to explain the distribution of currently abandoned areas based on several environmental and social factors. Then, we conducted a factor analysis of the results obtained from the machine learning analysis to divide the factors into “natural” and “social” comprehensively. We subsequently evaluated the regional differences. Based on our study, we consider the implications of our results for the future management of agricultural fields.

2. Study area

The study was examined mainland Japan (Fig. 1). A grid size of approximately 10 km was used for the analysis. This grid is the Japanese Standard Second-Order Mesh (hereafter, 2nd mesh), which corresponds to a 1:25,000 map grid (Fig. 1). The location of the 2nd mesh grid was determined arbitrarily by the Japanese government for comparing several statistics, including population, infrastructure, and the prevention of disasters at this scale of geographical resolution (The Ministry of Internal Affairs and Communications, Tokyo, Japan).

The islands of Japan extend from subarctic to subtropical regions, and have a variety of geographical features and weather conditions that vary among the regions. Although Japan contains several types of geographic landscape, including floodplains, flatlands, and mountain regions, each region of the country contains agricultural areas. This climatic and geographic variation might provide information on the factors that have caused increased agricultural land abandonment. Since both environmental and social factors can vary regionally, we divided Japan, excluding the small islands, into eight regions, Hokkaido, Tohoku, Hokuriku, Tokai, Kinki, Chugoku-Shikoku, Kanto, and Kyushu (Fig. 1), classified according to the Regional Agricultural Administration Office of Japan.

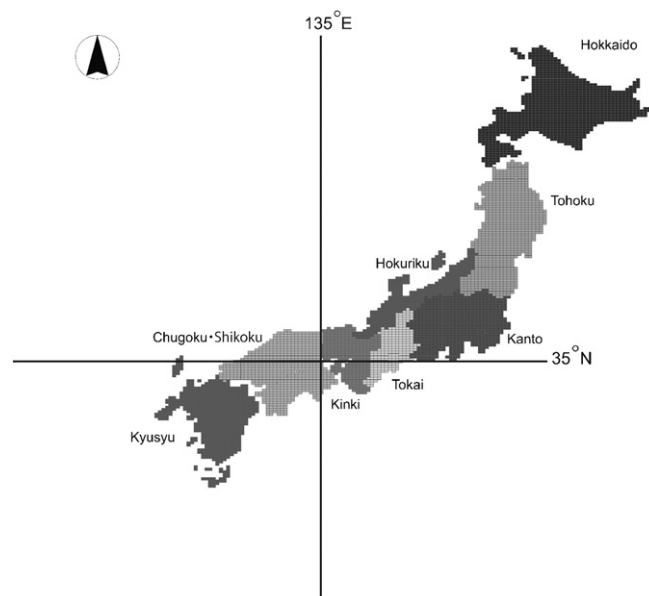


Fig. 1. The location of Japan, the units used for analysis, and the regions. Grid size was approximately 10 km.

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