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Intraregional Agricultural Characteristics Critical in Explaining Farmland Abandonment: Evidence from Chugoku and Shikoku Region of Japan

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Abstract: Since the 1980s, Japan has witnessed an unprecedented decline in agriculture chiefly due to farmers' aging, depopulation, and unfavorable socio-economic conditions. This development has resulted in an increase of farmland abandonment (FLA) across the country. However, it remains unclear as to how and to what extent FLA is influenced by intraregional agricultural characteristics. As such, this article discusses the issue of FLA by taking a closer look at the Chugoku and Shikoku region, as it has experienced the highest FLA rates in Japan in recent years. For this analysis, a total of 25 indicators retrieved from the census of agriculture and forestry at the former municipalities scale were selected to describe intraregional agricultural characteristics. We employed principal component analysis (PCA) to evaluate agricultural characteristics, while multiple linear regressions (MLR) was applied to explore their correlations with FLA and spatial variations. First, there are strong intraregional differences in the agricultural characteristics across the Chugoku and Shikoku region, with eight different principle components (PCs) describing their characteristics. Second, variables measuring agricultural characteristics explain nearly 52.8% of the variation in FLA in our sample. The sales orientation and scale of agriculture have the strongest negative correlation to FLA in the region, while the status of agricultural succession displays the strongest positive correlation to FLA. Third, in areas where agriculture is more stable and easier to maintain, FLA is more strongly influenced by changes in agricultural characteristics than by geographical variations. We argue that localized approaches and policies for future management need to take intraregional differences in agricultural characteristics and FLA into account. Our findings help to explain spatial variations in agricultural characteristics and FLA in regional contexts, suggesting the need for better-informed farmland use policies to mitigate further abandonment.

Keywords: intraregional agricultural characteristics; farmland abandonment (FLA); Chugoku and Shikoku region, Japan

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1 Introduction

In recent years, Japan has been experiencing serious depopulation and aging, particularly in rural areas, which cause severe labor shortages and agricultural decline. Rural lifestyle has been characterized as peaceful and enjoyable, and the multifunctionality of rural areas and agriculture has been shown to be of great economic values in general (Aizaki et al., 2006). However, rural areas and the lifestyle of rural residents are drastically

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changing worldwide as result of the demographic shrinkage, with dramatic impacts on rural landscapes, such as settlement structure change and intensification of agriculture (Ruskule et al., 2013). For instance, a population decline in rural areas may bring about the withdrawal of essential services, a decline in job opportunities, and in rural inaccessibility, all of which lead to further depopulation (MAFF, 2018). Based on the agricultural census, the number of farmers in Japan was 2.155 million in 2015, 373 000 (14.7%) fewer compared to 2010. In addition, the working population of business farmers (who mainly engage in self-employed agriculture) was 2.097 million. This number decreased by 509 000 (19.5%) from 2010 to 2015. Moreover, the average age of the working population in agriculture was 66.4, and the proportion of people aged 65 and over was 63.5% (MAFF, 2015). Furthermore, population outflow from rural areas and a lack of successors for farm households exacerbate the situation (Yamashita and Hoshino, 2018). This trend can lead to further isolation and marginalization of vulnerable rural populations (FAO, 2006). All the above-mentioned factors make it difficult to ensure agricultural succession. In addition, many external (socioeconomic condition, public policies) and internal (agroecological features of agricultural holdings) factors (Lasanta et al., 2017) directly or indirectly aggravate the problem of farmland abandonment (FLA) (Zhang et al., 2016).

FLA, also known as agricultural abandonment (MacDonald et al., 2000; Kuemmerle et al., 2008; Ramankutty et al., 2010; Prishchepov et al., 2013; Osawa et al., 2016; Levers et al., 2018), cropland abandonment (Deininger et al., 2012; Zhang et al., 2014; Meyfroidt et al., 2016), or idle farmland (Morimoto, 1993) can generally be described as the cessation of agricultural activities on farmlands, which subsequently leads to undesirable biodiversity and the ecosystem changes (Corbelle-Rico et al., 2014; Terres et al., 2015; Levers et al., 2018). As FLA is a gradual process, scholars normally categorize FLA into two types of abandonment degrees: total or complete abandonment and semi- or partial abandonment. Total abandonment is defined as complete cessation of any agriculture activity on a farmland without other activities such as urbanization or afforestation (Pointereau et al., 2008). Semi-abandonment refers to farmland that is no longer used for agricultural production, but remains regularly managed, for example through cutting grass or shrubs that were left on the farmland (Zaragozí et al., 2012; Vinogradovs et al., 2018). Such farmland is not formally abandoned and is subjected to some utilization, which may shape future uses such as tourism (Keenleyside et al., 2010). Meanwhile, there might be transitions among farmlands, such as from abandoned farmland to forest land or other land and semi-abandonment to total abandonment over time and space driven by a different set of determinants (Munroe et al., 2013). In our study of FLA, we consider only total abandonment which implies no signs of future uses.

The process of FLA is usually dynamic and difficult to measure because its conceptual definition varies over space and time, and a different focus of study can yield very distinct results (Rudel et al., 2005; Terres et al., 2015). According to existing studies, developed countries, such as the United States (Ramankutty et al., 2010), Australia (Williams and Schirmer, 2012), Japan (Osawa et al., 2016), and some European nations (Plieninger et al., 2016; Lasanta et al., 2017; Ustaoglu and Collier, 2018), share the greatest dispersion of FLA acres across the relevant territory. In Europe, FLA was first observed in the mid-20th century (Lasanta et al., 2017) and came to be viewed as a serious problem in the 1990s (Ustaoglu and Collier, 2018). Recent scholarship puts more emphasis on this issue in developing countries, where people rely more heavily on agriculture for their livelihoods (Löw et al., 2015; Yamaguchi et al., 2016; Zhang et al., 2016; Xu et al., 2019). For the measurement of FLA, previous studies have chiefly focused on its spatial characteristics (Sluiter and De Jong, 2007), driving forces or determinants (Prishchepov et al., 2013; Levers et al., 2018), countermeasures (Ito et al., 2016), and future prospects (van der Zanden et al., 2018). In terms of causes or drivers of FLA, most studies have been conducted with a focus on environmental or ecological (Ustaoglu and Collier, 2018) and socio-economic aspects (Gellrich and Zimmermann, 2007; Yamaguchi et al., 2016), and these studies have considering linear (Sang et al., 2014) and non-linear (Levers et al., 2018) relationships. Thus, previous studies largely use regressions to estimate the effect of a group of predictor variables on FLA. However, major problems could occur if the independent variables are highly correlated (Tan et al., 2016). Hence, an approach that eliminates problems of multicollinearity within the predictor will allow more stable estimation of the causes of FLA.

Relevant studies in Japan focus on FLA and its driving factors or countermeasures mainly at the national, local, or individual farm levels. The general relationship between FLA and environmental as well as socio-economic factors has been examined at national scale. Factors such as small size and low accessibility of farmland, slope, and the aging of farmers are likely to increase FLA (Osawa et al., 2013; 2016; Su et al., 2018). Farmers have been trying to re-utilize their abandoned farmland in recent years. Ito et al. (2016) analyze how land exchange institutions facilitate farmland use and reverse abandonment. On a local scale, many case studies examine the process and drivers of FLA by conducting field surveys and in-depth interviews. Farm household structures, labor conditions (Morimoto, 1991), successors (Kuki and Takahashi, 1997), and agricultural management strategies have been shown to be strongly correlated with FLA (Morimoto, 1993; Teratoko, 2009; Shoji, 2015). Such localized results illustrate farmers' and farm households' perceptions of FLA in a developed country and how they vary across different spaces. However, few studies of FLA focus on the regional level and take into account specific intraregional agricultural characteristics. Hence, it is meaningful to clarify FLA in a regional context, to discuss intraregional agricultural characteristics, and to formulate better recommendations for future farmland use.

Different socio-economic situations of farmers or characteristics of agriculture in a region will affect abandonment differently, and the effect of and solutions regarding FLA will also be different. Indeed, agricultural management varies from region to region as a consequence of natural conditions, historic traditions, and socio-economic or demographic contexts (Smaliychuk et al., 2016). On one hand, agricultural characteristics influence FLA mainly in its scale (Cocca et al., 2012). For instance, Japanese agriculture is characterized by small farm sizes (Hisano et al., 2018) and is often located in hilly and mountainous areas (HMAs), which constitute about 70% of national territory (MAFF, 2015). Such farmland is extremely unfavorable, as it requires higher labor and economic costs for cultivation and can easily turn into abandoned farmland. Proper scale-setting for farming (Yamaguchi et al., 2016) or adjustment of fragmented farmland (Arimoto, 2010) has been shown to act as an effective countermeasure against FLA. On the other hand, FLA affects the remaining agriculture in that the abandonment of one farm renders adjacent farmland more challenging to cultivate because of the change in geographical and biological conditions (MacDonald et al., 2000). In addition, FLA and the subsequent restoration of vegetation will significantly change rural land use patterns, landscapes, and farmers' livelihoods (Li and Li, 2017). As a consequence, FLA needs to be analyzed with due consideration of the agricultural characteristics in a given region to support better agricultural management.

In our study, agricultural characteristics constitute a broad concept that can describe and measure different dimensions of agriculture. Specifically, the Ministry of Agriculture and Forestry (MAFF) conducts an agricultural census every five years to track the changes in these characteristics, including agriculture scale, management statutes, farmland share, household types, labor condition, and agriculture products. Through such characteristics, farmers can easily divide the entire region into different subregion on the basis of the type and organization of agriculture that occur there. Studies have analyzed characteristics of mountainous villages (Okahashi, 1986) and agricultural region in Japan (Nihei, 2006). The findings provided a comprehensive division of Japanese administrative areas regarding different characteristics and informing region-specific administrative decisions. Generally, agricultural intensification or expansion is linked to urbanization, which is often associated with FLA and a decline of land-use intensity in peripheral region (Plieninger et al., 2016). Typically, owners of abandoned farmland are heirs to their ancestors' farmland who have migrated to urban areas for employment and do not intend to cultivate the inherited farmland further. In addition, the structure, type, and socio-economic situation of farm households will affect agricultural strategies and can thus lead to FLA (Ito et al., 2016; Su et al., 2018), as abandonment of farmland is basically decided by individual farm households (Zhang et al., 2014). Moreover, regional agricultural policies regarding farmland can have a strong impact on FLA prevention. This is because the location and scale of the farmland predict FLA outcomes, providing information that can be used in developing targeted measures for areas that face similar management challenges (van der Zanden et al., 2017). Furthermore, planning and policy that aim at either preventing FLA or managing abandonment should consider social and environmental challenges (van der Zanden et al., 2018). Finally, setting taxes at appropriate levels can encourage farmers to sell or lease their abandoned farmland and aid in its transition (Nishihara, 2012). Abandoned farmland can also be considered for future use, such as renewable energy production (Abolina and Luzadis, 2015). Although the general weakening of agriculture is found to cause FLA, the impacts of problems in specific domains of agriculture and of regional agricultural characteristics on FLA are still largely unknown. These factors further support our focus upon the regional level rather that national or local scales.

As illustrated above, understanding intraregional agricultural characteristics and their relationships with FLA is of great significance to managing both farmlands use and future FLA. Empirical studies have revealed that FLA and agricultural structures are strongly correlated worldwide (Gellrich et al., 2007; Uematsu et al., 2010; Lasanta et al., 2015). However, few studies have shed light on differences in agricultural characteristics and their relationship with FLA, that is, how explicit spatial and variations of agricultural characteristics cause FLA. In Japan, few studies have investigated how agricultural characteristics shape FLA, especially in the western Japan. Agriculture has had a long history in Japan; the sector, however, has experienced stagnation since the rapid economic growth period of the late 1980s and is weakening every year (Ito et al., 2016; Hisano et al., 2018). From 1990 to 2015, seven region in Japan (Hokkaido, Tohoku, Kanto, Chubu, Kinki, Chugoku and Shikoku, and Kyushu region) experienced a rapid increase in FLA rates. Among these region, the FLA rate in Chugoku and Shikoku region exhibited the highest levels. Local government and residents have also attempted to deal with FLA by providing more financial and labor support. The effect is difficult to seen without a clear understanding of agricultural characteristics. Therefore, this paper aims to fill this gap and to discuss FLA in connection with particular intraregional agricultural circumstances. We have three main objectives: 1) to unveil and understand the spatial variation and uneven patterns of agricultural characteristics in the Chugoku and Shikoku region, 2) to explain the causes of FLA by taking intraregional agricultural characteristics as independent variables instead of individual factors; 3) to discuss the relationship between agricultural characteristics and FLA. Our results can support administrative governments in making better informed farmland use decisions and can mitigate further FLA through more localized farmland use suggestions, eventually preserving regional agriculture.

2 Materials and Methods

2.1 Study area

The Chugoku and Shikoku region consists of the Chugoku subregion (Chugoku-Chiho), located in the westernmost part of Honshu Island, and the Shikoku subregion (Shikoku-Chiho), which is an isolated island just next to Chugoku subregion (Fig. 1). The Seto Inland Sea separates the Chugoku and Shikoku subregion. In terms of administrative units, the Chugoku subregion consists of the prefectures of Hiroshima, Yamaguchi, Shimane, Tottori and Okayama covering an area of about 31 900 km^2. The Shikoku subregion covers about 18 800 km^2 and consists of four prefectures: Ehime, Kagawa, Kochi, and Tokushima. The Chugoku and Shikoku region are basically regarded as one administrative unit; however, the Chugoku and Shikoku subregion differ in their geographical composition. As regards elevation, the Chugoku and Shikoku subregion show remarkable differences. The mountain ranges in Chugoku subregion run from east to west and stretch across the interior territory with gentle slopes. In contrast, mountains in the Shikoku subregion is characterized by their bumpiness and steepness (Kanzaka, 2009).

Though many efforts have been made to improve farmland conditions in the region, the scale of agriculture is still small compared with the rest of Japan. The aging of farmers and depopulation are widespread, leading to an increase in deforestation and wild animal damage to farmland (MAFF, 2016). Hilly and mountainous areas occupy a large part of the region, and they mostly specialize in rice production, especially in the Chugoku Mountains. The Okayama, Shimane, and Tottori prefectures have large alluvial plains created by rivers, and their well-conditioned agricultural lands are suitable for rice production. However, in an attempt to adapt to unfavorable geography, other farmers have developed regional agriculture suited to local agricultural conditions. Crops such as rice, wheat, and soybeans have been widely cultivated on sloping farmland and hills in addition to fruit and livestock production.

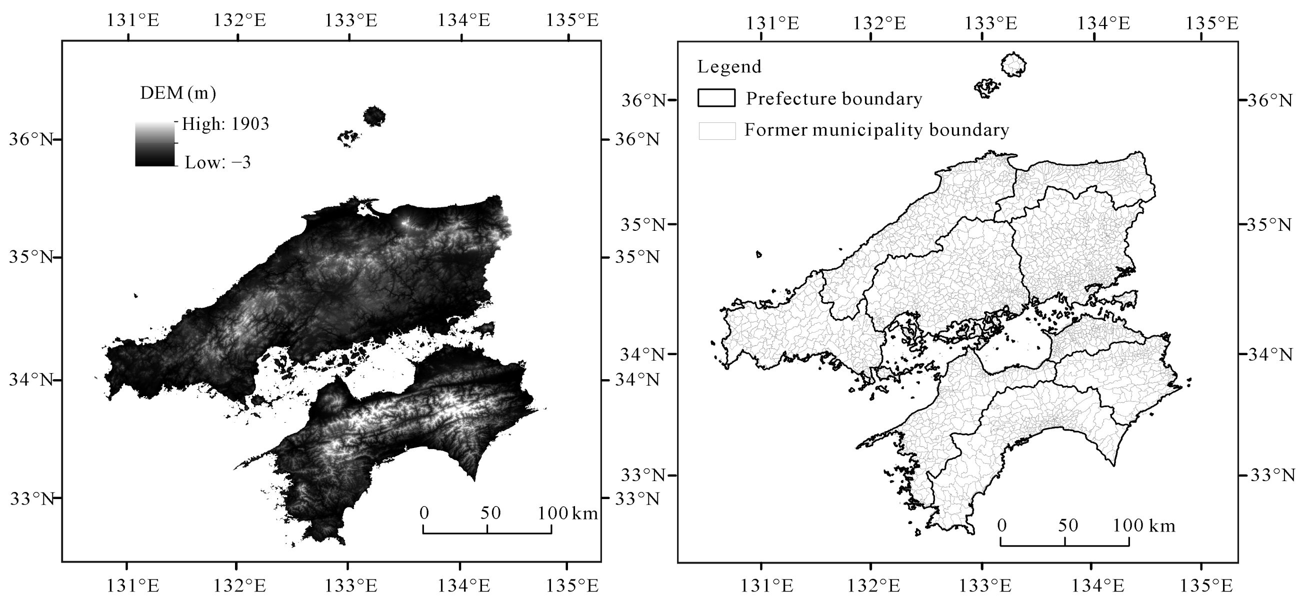

Fig. 1 Geographical characteristics of study region. Source: National Land Numerical Information, http://nlftp.mlit.go.jp/ksj-e/index.html

With the afore-mentioned geographical and socio-economic characteristics of the Chugoku and Shikoku region, agriculture exhibits unique features and the FLA rate remains the highest in Japan. As such, the effects of agricultural characteristics on FLA in this region merit more in-depth discussion.

2.2 Data

Our study utilizes the MAFF definition of FLA; abandoned farmland refers to farmland that has not been cultivated for one year and where there is no indication that it will be cultivated in the subsequent years (MAFF, 2015). To evaluate their impacts on FLA, we collected factors regarding agricultural characteristics in the Chugoku and Shikoku region. Based on previous studies and understanding the agriculture context in the region, 25 variables or attributes were extracted from the region via the 2015 census of agriculture and forestry (Table 1). We considered three types of farm units: total farm households, business farm households, and total agriculture management bodies. For many years, MAFF conducted surveys of 'individual farm households' that mainly engaged in agriculture to represent the average situation across the municipality. However, in recent years, the number of organizations, companies, and agricultural cooperatives engaged in farming has increased, and it has become difficult to understand the entire agricultural structure by focusing solely on farm households. Therefore, in 2005, the concept of 'agricultural management body', which refers to both agricultural management (family management body) by households and organizational management (organization management body) such as companies and agricultural corporations, was introduced (MAFF, 2015). Table 1 provides the definitions of our variables along with descriptive statistics. For the data analysis, we employed the former municipalities (in Japanese: *Kyushichoson*) in 1950 as sample units, similar to agricultural census data, after balancing data availability and data loss. Compared to former municipalities, contemporary municipalities are too large to describe regional variations in detail; in contrast, agricultural settlements are too small to have sufficient data support.

As our variables differ in range of variance, we use a normalization technique that implies the transforming each variable in the dataset to a specific range (0–1); it is thus essential that the data be normalized prior to the implementation of PCA (Uddin et al., 2019). In this study, before statistical analysis, normalization has been conducted using the following equation:

$$X_i = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}} \tag{1}$$

where, X_i is an observed value in an array of observed values for a variable; $X_{\max}$ is the highest value in the same array; $X_{\min}$ is the lowest value.

Table 1 Description of variables for assessing agricultural characteristics and FLA (N = 2354)

Type of variables	Description	Min	Max	Mean	SD
Dependent variable Y. Farmland abandonment rate (TH)	Abandoned land area/(abandoned land area + total arable land area)×100%	0	100	27.12	18.25
Independent variables					
X_1 Forest rate	Forest land area/total land area ×100%	0	99	60.67	25.71
X_2 Arable land ratio of self-sufficient farm households (TH)	Self-sufficient household arable land area/total arable land area×100%	0	100	19.56	18.75
X_3 Arable land ratio of land holding non-farm households (TH)	Non-farm household arable land area/total arable land area×100%	0	100	20.83	14.63
X_4 Arable land area per household (TH)	Total arable land area/total farm households (Ha)	0	3	0.64	0.33
X_5 Ratio of business farm household (TH)	Business farm households/total farm households×100%	2	100	54.85	20.26
X_6 Share of land holding non-farm household (TH)	Land holding non-farm households/total farm households×100%	5	940	76.45	81.16
X_7 Ratio of the first type part-time farm households (BH)	The first type part-time farm households/total farm households×100%	1	67	8.93	5.82
X_8 Ratio of the second type part-time farm households (BH)	The second type part-time farm households/total farm households×100%	2	100	54.37	16.06
X_9 Farmer's average age (BH)	Total farmers average age (years old)	48	81	69.60	3.28
X_{10} Labors per farm household (BH)	Total agricultural laborers /total farm households (People)	0	3	1.45	0.29
X_{11} Ratio of workers below 65 years (BH)	Younger than 65-year-old worker /total agriculture workers	0	100	33.08	10.91
X_{12} Ratio of non-successor farm households (BH)	Total farm households without successors/total farm households×100%	17	100	74.89	11.36
X_{13} Solely rice production farm household rate (BH)	Rice production farm households/total farm households×100%	0	100	60.92	26.63
X_{14} Solely vegetable production farm household rate (BH)	Vegetable production farm households/total farm households×100%	0	94	9.63	14.64
X_{15} Solely fruits production farm household rate (BH)	Fruits production farm households/total farm households×100%	0	100	18.65	26.95
X_{16} Solely husbandry production farm household rate (BH)	(Dairy single + beef cattle single + pig single + chicken single + sericulture single + other livestock single)/total farm households×100%	0	95	1.34	4.15
X_{17} Combined management farmers rate (BH)	Number of combined management farm households/total farm households×100%	0	40	4.98	4.26
X_{18} Ratio of leased-in land (MB)	Leased-in land area/total arable land area×100%	0	100	30.34	17.02
X_{19} Ratio of leased-out land (MB)	Leased-out land area/total arable land area×100%	0	85	5.34	5.83
X_{20} Paddy field rate (MB)	Paddy field area /total arable land area×100%	0	100	74.30	26.11
X_{21} Crop land rate (MB)	Dry land area /total arable land area×100%	0	100	14.16	16.34
X_{22} Fruit land rate (MB)	Fruit land area/total arable land area×100%	0	100	13.72	23.64
X_{23} Rice commissioned work management body rate (MB)	Rice commissioned work management entity/total management bodies×100%	0	45	7.44	4.70
X_{24} Rate of farm households with more than 10 million yen in sales (MB)	More than 10-million-yen sales value farm household/total farm households×100%	0	100	4.03	7.23
X_{25} Share of agriculture management bodies with less than 0.5 ha farmland (MB)	Agriculture management bodies with less than 1 ha farmland/ total agriculture management bodies×100%	0	100	33.03	18.01

Notes: Source, Ministry of Agriculture, Forestry and Fishery (MAFF), http://www.maff.go.jp/e/index.html. TH, data is derived from total farm households; BH, data is derived from business farm households; MB, data is derived from total agriculture management bodies

2.3 Methods

In our study, principal component analysis (PCA) and multiple linear regressions (MLR) were combined to obtain a comprehensive understanding of FLA associated with intraregional agricultural characteristics. First, PCA was performed to identify regional divisions defined by agricultural characteristics; this method also eliminates problems arising from multicollinearity in our data set (Tan et al., 2016). Secondly, an MLR analysis was employed to predict the causes of FLA. In particular, predictors for MLR were selected by obtaining the factor scores associated with the PCA results, which describe the intraregional agricultural characteristics. Based on the results of these tests, we discuss how and to what extent intraregional agricultural characteristics affect FLA and make suggestions for policy implications considering their variations. All of the statistical analyses and mapping were implemented using SPSS 15.0 and ArcGIS 10.3 software.

2.3.1 Principal component analysis (PCA)

PCA is a popular method used in many disciplines to describe patterns of variation within a multi-dimensional dataset and is one of the simplest and most robust ways of accomplishing dimensionality reduction (Abdi and Williams, 2010). PCA uses an orthogonal transformation to convert a number of potentially correlated variables into a set of uncorrelated variables called principal components (PCs); these components capture the variability in the original data (Abson et al., 2012; Uddin et al., 2019). The data capturing processes continue with additional PCs until all original data are fully captured (Teffera et al., 2018); the final number of PCs is determined based on eigenvalues (Zeinalzadeh and Rezaei, 2017). In our study, we use PCA to reduce the number of variables while providing the useful information of the original dataset. The PCs in our case describe the agricultural characteristics.

2.3.2 Multiple Linear Regression (MLR)

In our study, we applied a stepwise MLR (Caravaggi et al., 2016; Chagas et al., 2016) to determine the correlations between intraregional agricultural characteristics (PCs) and FLA. In MLR, we entered the PC factor scores, which represent agricultural characteristics, as independent variables and the FLA rate as the dependent variable. Through this analysis, the impact of intraregional agricultural characteristics on the process of FLA in the Chugoku and Shikoku region of Japan will be examined.

3 Results

3.1 Identifying the intraregional agricultural characteristics in the Chugoku and Shikoku region

As discussed above, the PCA method was ideal for reducing the dimensionality of the initial data set, which involved a large number of interrelated variables. Eight PCs with eigenvalues of 5.569, 4.345, 2.543, 1.818, 1.633, 1.342, 1.072 and 1.006 were identified for the description of intraregional agricultural characteristics. We conducted a Kaiser-Meyer-Olkin (KMO) test and a Bartlett's test of sphericity (Patil and Kokate, 2017). Results show that the KMO statistics are greater than 0.60 (0.716) and Bartlett's test of sphericity provides values of $P < 0.001$, both of which indicate the suitability of the dataset for running PCA. For accumulated dispersion, those eight PCs can explain about 77.31% of the variance for the 25 variables we selected; the heaviest loadings have been marked as bold faced in Table 2.

From Table 2, we can clearly see that the PC 1 explained 22.3% of the total variance in the dataset. This component is characterized by strong positive associations with the rate of farm households with more than 10 million Japanese yen in sales, the rate of farm households producing only vegetables, the average number of laborers per farm household, and the rate of first type part-time farm households. PC 1 is also negatively affected by the farmers average ages and the ratio of second type part-time farm households. Here, the first type means households where at least one member is engaged in non-farm employment and whose farm income exceeds their non-farm income, while the second type denotes households where at least one member engages in non-farm employment and whose non-farm income exceeds their farm income (MAFF, 2010). Therefore, this PC 1 seems to capture *the activeness of agriculture*. PC 2 accounted for 17.4% of the total variation in the data set, and it is positively associated with ratio of business farm households among all farms and arable land area per household. PC 2 was negatively associated with the percentage of arable land occupied by self-sufficient farm households and the share of agriculture management bodies with less than 0.5 ha of farmland. In combination,

Table 2 List of rotated principal component matrix for all agricultural characteristics

Factors	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	PC 7	PC 8
X_{24} Rate of farm households with more than 10 million yen in sales	**0.869**	0.145	0.029	0.037	0.123	–0.024	0.118	0.056
X_{14} Solely vegetable production farm household rate	**0.841**	–0.127	–0.114	–0.102	0.072	0.118	–0.026	0.039
X_9 Farmers average ages	**–0.828**	–0.168	–0.069	–0.021	0.136	0.127	0.036	0.054
X_{10} Average number of laborers per farm household	**0.826**	–0.012	0.280	–0.111	–0.063	–0.027	–0.182	–0.061
X_8 Ratio of second type part-time farm households	**–0.686**	–0.022	–0.305	0.051	–0.002	–0.560	0.017	–0.005
X_7 Ratio of first type part-time farm households	**0.601**	0.269	0.240	0.264	0.061	0.016	0.011	0.276
X_2 Arable land ratio of self-sufficient farm households	–0.062	**–0.929**	0.060	0.051	0.037	0.028	–0.072	–0.040
X_5 Ratio of business farm household	0.025	**0.905**	–0.055	–0.228	–0.030	–0.049	0.137	0.001
X_{25} Share of agriculture management bodies with less than 0.5 ha farmland	–0.052	**–0.876**	0.117	–0.108	–0.026	0.003	0.107	–0.031
X_4 Arable land area per household	0.099	**0.867**	**–0.084**	0.148	0.127	–0.005	–0.008	0.058
X_{15} Rate of farm households producing only vegetables	0.052	–0.084	**0.938**	–0.067	–0.139	0.067	0.043	0.006
X_{22} Fruit land rate	0.052	–0.086	**0.934**	–0.136	–0.095	0.134	–0.020	–0.058
X_{20} Paddy field rate	–0.213	0.156	**–0.806**	0.168	–0.354	–0.052	0.179	0.105
X_{13} Solely rice production farm household rate	–0.563	0.106	**–0.655**	0.144	–0.120	–0.107	0.282	–0.029
X_3 Arable land ratio of land holding non-farm households	–0.018	–0.054	–0.220	**0.779**	–0.215	–0.096	–0.011	–0.017
X_{18} Ratio of leased-in land	–0.034	0.229	–0.054	**0.748**	0.212	0.004	0.017	0.003
X_6 Share of land holding non-farm household	0.048	–0.276	–0.085	**0.733**	–0.228	0.223	–0.081	–0.010
X_{21} Cropland rate	0.280	–0.150	0.146	–0.109	**0.712**	–0.075	–0.267	–0.100
X_{16} Solely husbandry production farm household rate	–0.038	0.135	–0.093	–0.006	**0.632**	–0.009	–0.034	–0.002
X_1 Forest rate	–0.309	–0.017	0.073	–0.113	**0.506**	0.261	0.452	0.125
X_{12} Ratio of non-successor farm households	0.056	0.002	0.150	0.096	0.039	**0.884**	0.108	0.050
X_{11} Ratio of workers below 65 years	0.400	0.328	–0.056	0.138	0.231	**–0.495**	0.308	0.207
X_{17} Combined management farm household rate	0.002	–0.033	0.138	0.028	0.196	–0.023	**–0.797**	0.149
X_{19} Ratio of leased-out land	0.140	0.045	–0.050	–0.077	–0.099	0.051	–0.162	**0.863**
X_{23} Rice commissioned work management body rate	–0.276	0.143	–0.167	0.392	0.222	–0.134	0.197	**0.455**
Eigenvalues	5.569	4.345	2.543	1.818	1.633	1.342	1.072	1.006
% of variance	22.276	17.380	10.174	7.270	6.532	5.367	4.289	4.026
Cumulative (%)	22.276	39.656	49.829	57.100	63.631	68.998	73.287	77.313

Note: The heaviest loadings have been marked as bold faced

these characteristics capture *the sales orientation and scale of agriculture*. PC 3 explained 10.2% of variance and is positively associated the percentage of households engaged solely in fruit production and the percentage of arable land engaged in fruit production; it is negatively associated with the percentage of arable land consisting of paddy fields and the percentage of farms engaged solely in rice production. In combination, this component seems to capture *the fruit production agriculture*. PC 4 explained 7.3% of variance and is positively associated with the percentage of arable land held by non-farm households, the percentage of arable land that is leased-in, and the percentage of all households that hold land but are non-farming households. Therefore, this component seems to capture *the impact of non-farm households on agriculture*. PC 5 explained 1.6% of variance and is associated with the percentage of arable land devoted to vegetable or dry season crop production, the percentage of farm households devoted solely to livestock production, and the percentage of total land area covered by forests. Therefore, this component seems to capture *the dependence on rice production*. PC 6 explained 1.3% of variance and is positively associated with the percentage of farm households with no designated successor and the percentage of workers who are under 65 years of age. Therefore, this component seems to capture *the status of agricultural succession*. PC 7 explained 1.1% of variance and is negatively associated with the percentage of farms operated under combined management. Therefore, this component seems to capture *the diversification of agriculture*. PC 8 explained 1.0% of variance and is positively associated with the percentage of arable land that is leased-out land and the rice commissioned work management body rate. Here, commissioned work refers to the outsourcing of agricultural work or leasing of farmland by elder farmers due to lack of laborers. Therefore, this component seems to present *the transition of farmland*.

3.2 Spatial variations of agricultural characteristics in the Chugoku and Shikoku region

All of the PCs indicate that there are obvious intraregional differences in the agricultural characteristics across the Chugoku and Shikoku region. Variation in the PC (1–8) scores on the regional map is shown in Fig. 2 to Fig. 9; the positive values correspond to red triangles, while the negative values are blue dots. Fig. 2 shows that PC 1, *the activeness of agriculture*, dominates in the southern Shikoku subregion (Kochi and Tokushima prefectures), the Seto Inland Sea area, and the northern part of Chugoku subregion (Tottori prefecture). Fig. 3 indicates that PC 2, *the sales orientation and scale of agriculture*, is the highest in west Yamaguchi, central Hiroshima, Tottori, and to the west of Ehime and Kagawa prefectures. Fig. 4 demonstrates that PC 3, *the fruit production agriculture*, is the highest in coastal areas and Tottori, Ehime, Kagawa and Tokushima prefectures. All of these areas are famous for fruit production with Tottori prefecture being famous for Japanese pear production. Tokushima and Kagawa prefectures are famous for yuzu production and Ehime prefecture and the Seto Inland sea areas are the biggest producers for citrus fruits. Fig. 5 shows that PC 4, *the impact of non-farm households on agriculture*, is the highest in the southern part of Okayama, Hiroshima, Tottori and the southern part of Ehime. Fig. 6 suggests that PC 5, *the dependence on rice production*, is the highest in the northern part of Okayama, Hiroshima, Shimane and the southern part of Ehime. Fig. 7 shows that PC 6, *the status of agricultural succession*, is the most serious in Hiroshima, Yamaguchi, Ehime, and Kagawa prefectures. Fig. 8 indicates that PC 7, *the diversification of agriculture*, is the highest in the southern part of Okayama, Hiroshima, Shimane, Yamaguchi and Kagawa prefectures. Finally, Fig. 9 shows that PC 8, *the transition of farmland*, is the highest in the Shimane and Yamaguchi prefectures.

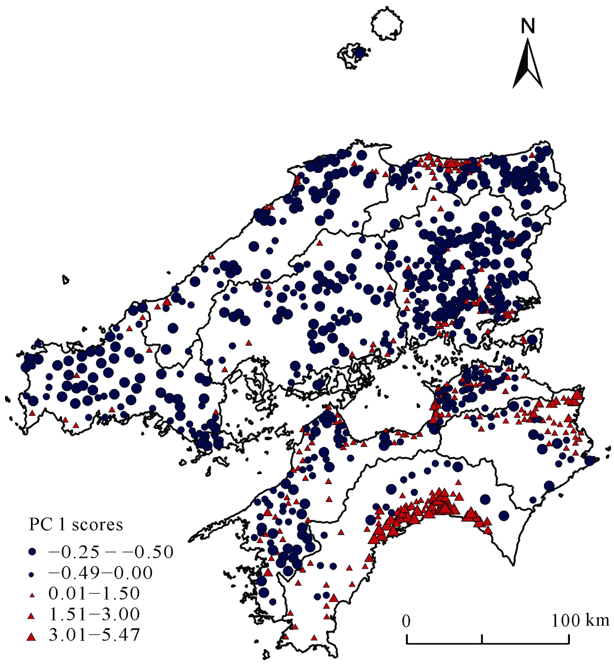

Fig. 2 Distribution of PC 1 scores in the Chugoku and Shikoku region

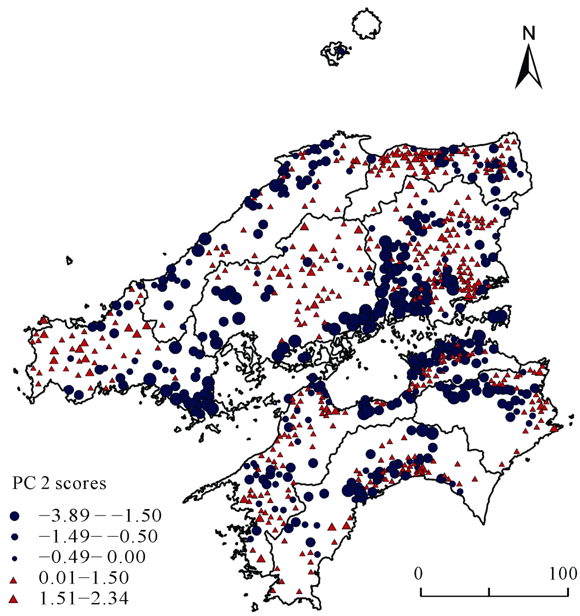

Fig. 3 Distribution of PC 2 scores in the Chugoku and Shikoku region

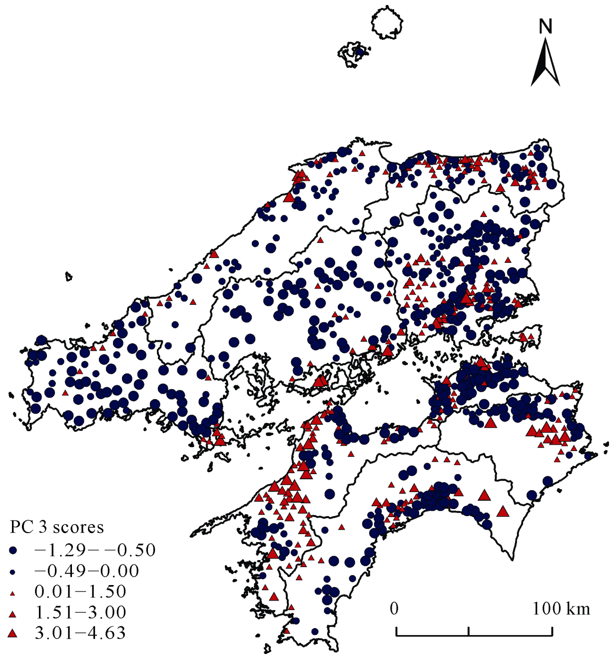

Fig. 4 Distribution of PC 3 scores in the Chugoku and Shikoku region

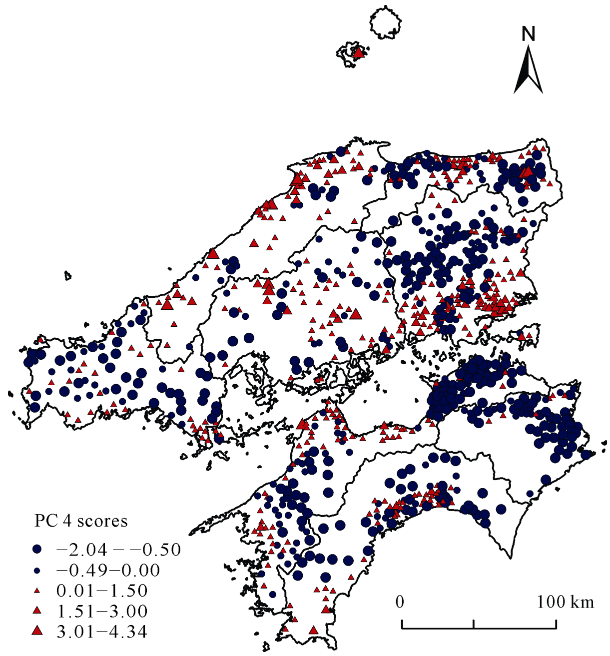

Fig. 5 Distribution of PC 4 scores in the Chugoku and Shikoku region

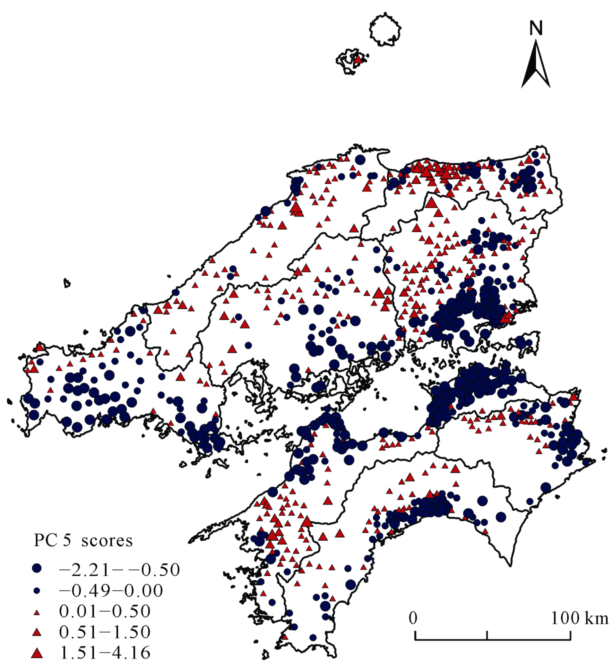

Fig. 6 Distribution of PC 5 scores in the Chugoku and Shikoku region

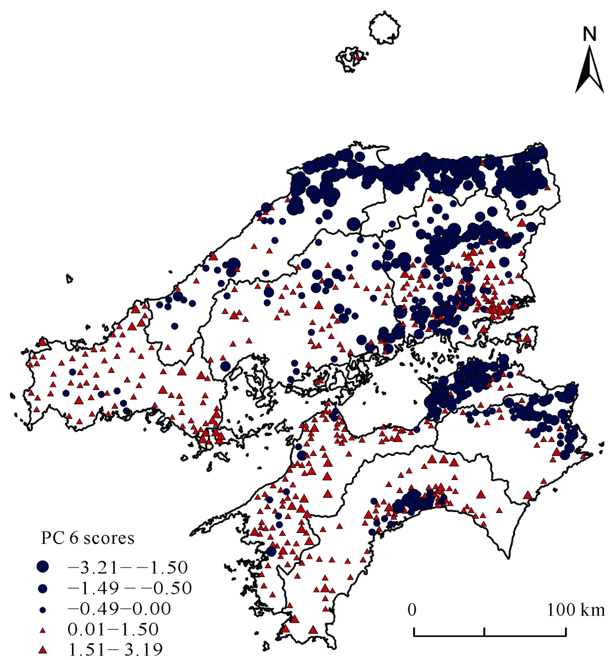

Fig. 7 Distribution of PC 6 scores in the Chugoku and Shikoku region

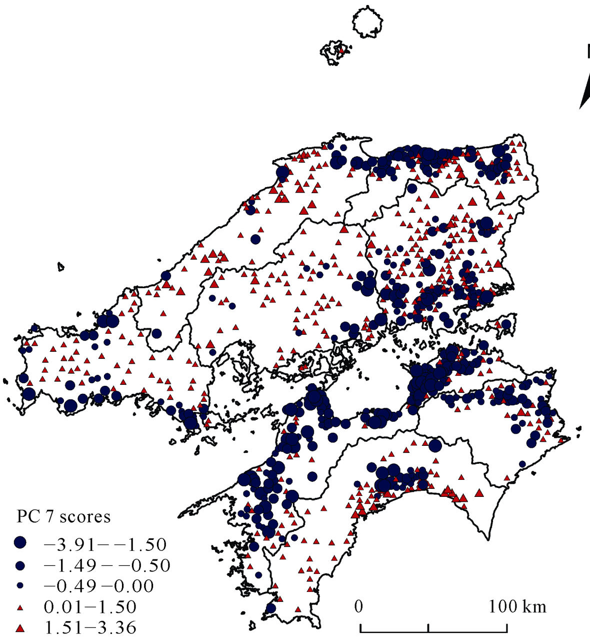

Fig. 8 Distribution of PC 7 scores in the Chugoku and Shikoku region

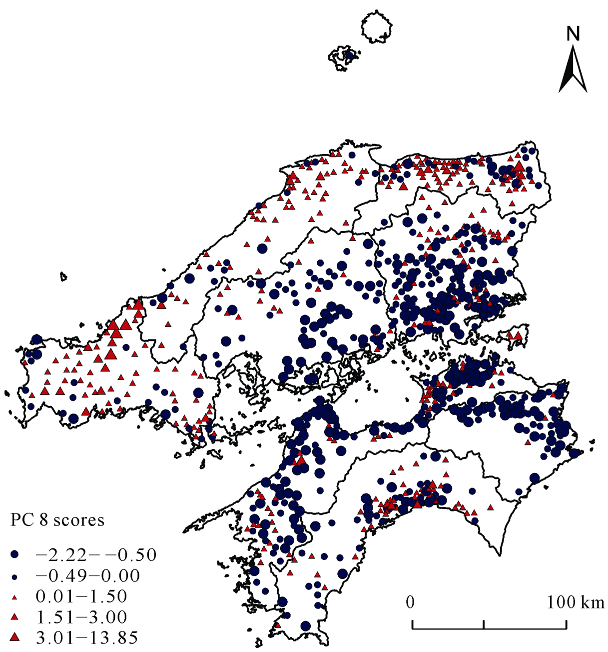

Fig. 9 Distribution of PC 8 scores in the Chugoku and Shikoku region

3.3 Relationships between intraregional agricultural characteristics and FLA

In Japan, agricultural region are classified by MAFF as either urban areas, flatland farming areas, intermediate farming areas, or mountainous farming areas according to their geographical conditions (Fig.10) (MAFF, 2015). Table 3 depicts the standard indicators and characteristics for those four farming areas and their definitions. Fig. 11 illustrates the spatial patterns of FLA in our study region, which include significant variations. The areas with the highest rate of FLA were the small islands and the coastal areas of the Seto Inland Sea, especially on the Chugoku subregion side. In the Chugoku subregion, Hiroshima and Okayama prefectures also exhibit a high rate of FLA in the mountainous farming areas along their borders. In the Shikoku subregion, high rates of FLA are chiefly concentrated in the mountainous farming areas of Tokushima prefecture.

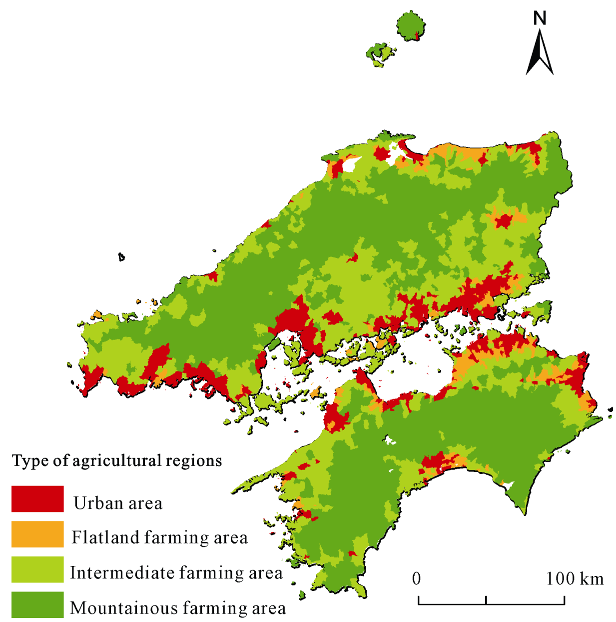

Fig. 10 Spatial distribution of agricultural area types in the Chugoku and Shikoku region. Source: Ministry of Agriculture, Forestry and Fishery (MAFF), http://www.maff.go.jp/e/index.html

Table 3 Types of farming areas in the Chugoku and Shikoku region

Agricultural area type	Explanation
Urban area	Areas where the population density is 500 people/km^2 or more and the (Densely Inhabited District) DID area occupies 5% or more of the habitable area
Flatland farming area	Areas that either have 20% arable rate and less than 50% forest OR have 50% or more arable rate
Intermediate farming area	Areas between flat and mountainous farming areas with forest rates between 50% and 80% and arable land with many slopes
Mountainous farming area	Areas with a forest rate of more than 80% and an arable land rate of less than 10%

Note: Ministry of Agriculture, Forestry and Fishery (MAFF)

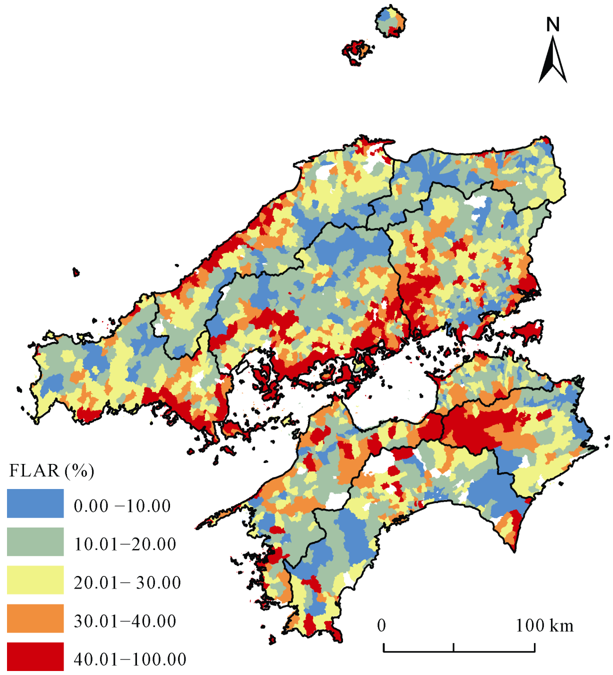

Fig. 11 Spatial distribution of farmland abandonment rates (FLAR) in the Chugoku and Shikoku region in 2015 Source: Ministry of Agriculture, Forestry and Fishery (MAFF)

In this study, we explore correlations between agricultural characteristics and FLA and how they vary in different farming areas. We divided our study region into the four farming area types discussed in Table 3 in order to minimize the influence of different geographical conditions in MLR. Factor scores for PCs 1–8 were retained as independent variables and a stepwise MLR was performed for four different agriculture areas. The obtained results demonstrate that the 8 PCs have different explanatory power for FLA in the Chugoku and Shikoku region (Table 4). All of the coefficients in the regressions are statistically significant as their *P*-values are each smaller than 0.05.

The MLR results indicate that, first, PC 2 has the strongest negative correlation for each of the four agriculture region. As PC 2 stands for the sales orientation and scale of agriculture, we conclude that as the size of farm operations increases, FLA declines in our study region. As previously discussed, the data in our study consist of not only individual farm households but also agriculture management bodies. Therefore, the agriculture scale and sales status of both will affect FLA. Second, PC 6, which represents the status of agricultural succession, exhibits the strongest positive correlation for each of the four types of agriculture region. In other words, the lack of agriculture successors in our study region increases FLA. Third, MLR has the highest explanatory ability for FLA in flatland farming areas (adjusted R^2 = 62.2%), followed by intermediate farming areas (adjusted R^2 = 61.3%), urban farming areas (adjusted R^2 = 45.6%), and mountainous farming areas (adjusted R^2 = 40.9%).

4 Discussion

4.1 General findings

First, in recent years, the Chugoku and Shikoku region experienced the highest FLA rate in Japan, and the driving forces behind this trend are complicated. Agricultural characteristics are very diverse in the Chugoku and Shikoku region. Since 1979, the One Village One Product (OVOP) scheme, initially adopted in Oita

Table 4 MLR models for FLA prediction using PCs

Agriculture region	Urban area	Flatland farming area	Intermediate farming area	Mountainous farming area	Total
PC 1		–0.119**	–0.086**		–0.050**
PC 2	–0.565**	–0.734**	–0.721**	–0.605**	–0.638**
PC 3	0.255**	0.431**	0.278**		0.247**
PC 4				0.129**	0.077**
PC 5		0.202**	0.114**		0.094**
PC 6	0.324**	0.240**	0.230**	0.123**	0.194**
PC 7		–0.117**		–0.141**	–0.071**
PC 8			–0.099**		–0.068**
N	140	151	389	190	860
Adjusted R^2	0.456	0.622	0.613	0.409	0.528

Note: **, Correlation is significant at the 0.01 level (2-tailed); *, Correlation is significant at the 0.05 level (2-tailed) prefecture, has been in place in Japan as an idea for regional agriculture revitalization. Also influenced by OVOP scheme, agricultural characteristics in the Chugoku and Shikoku region display great diversity. The OVOP movement advocated for the sales of products that best represent the locale, thereby generating income and improving the local economy (Schumann, 2016). Agricultural characteristics, such as products, scale, labor, and physical conditions, were improved to fit local conditions. From PCA, 8 PCs were identified to describe the intraregional characteristics of agriculture and each PC displays significant spatial variations. This diversity is reflected in an explicit intraregional division among farming areas. PC 1, *the activeness of agriculture*, earns the highest scores (22.3%) of the total variance in the dataset and dominates in southern Shikoku subregion. This suggests some positive signals about agriculture management. Special agriculture products and flowers suitable for warm climates are being produced in greenhouses. For example, in the mountain region of southern Shikoku subregion, farmers have benefited economically from the warm climate, producing many early crops and vegetables in greenhouses for the rest of Japan (Kanzaka, 2009). Therefore, climate condition is one of the essential factors for maintaining agriculture production. The MLR models display higher explanatory power for flatland farming areas and intermediate farming areas than for the other two areas. In flatland farming areas and intermediate farming areas where agriculture is more stable and easier to maintain, the causes of FLA are more influenced by changes in agricultural characteristics than geographical condition. For the urban areas and mountainous farming areas, the MLR exhibits lower explanatory power than for the other two areas. The land use situations are more complex in urban areas, where factors such as urbanization could have a stronger influence on FLA (Ruskule et al., 2013). Because the effect of altitude on agricultural tends to be non-linear, small changes in altitude and slope matter more in mountainous areas than low-lying areas (Yamaguchi et al., 2016). The remarkably high rate of FLA in western parts of Tokushima prefecture in Shikoku subregion is also largely due to the complex geographical conditions and the bumpiness and steepness of the Shikoku Mountains.

Second, our study finds that PC 2 (*the sales orientation and scale of agriculture*) has the strongest influence on FLA. Previous work finds that agricultural scale, in terms of farmland size, reduces FLA mainly because it takes more labor and economic costs to maintain small-size and dispersed farmlands (Grədinaru et al., 2015; Kolecka et al., 2017). In our study, big scale and sales orientation also affect labor costs and farm income. Indeed, high cultivation costs and low yields are more likely to cause FLA (Gellrich and Zimmermann, 2007). As such, second type part-time farm households whose non-farm income exceeds their farm income are believed to focus less on agriculture, ultimately leading to abandonment. From Fig. 3, high values of PC 2 are clustered in the central Chugoku subregion and southern Shikoku subregion. As a result, FLA was relatively low in these areas. In contrast, the increase in abandoned farmland in our study region especially along the coastal areas of the Seto Inland Sea can be ascribed to the small scale and abandonment of citrus fruit fields due to the low profit and price. As Fig. 4 shows, high levels of PC 3 (*the fruit production agriculture*) are concentrated in the coastal areas of the Seto Inland Sea, which are dominated by urban areas, flat farming areas, and intermediate farming areas. Table 5 also displays significant effects of PC 3 on FLA in these three farming areas. Although the farmland's geographical condition in these areas is better than in mountainous farming areas, abandonment occurred, nonetheless. Fig. 12 displays the change of abandoned farmland and orange (in Japanese: *Mikan*) production areas in our study region from 1975 to 2015. We observe that orange production areas started to decline beginning in 1975 and abandoned farmland areas increased each year, particularly after 1985. In postwar Japan, the commercialization of agriculture progressed nationwide and even in the Chugoku and Shikoku region. In most coastal areas, including islands in the Seto Inland Sea, oranges became one of the most profitable products. However, after 1970, overproduction of oranges led to lower prices. As a result, only a few traditional production areas remained in parts of Ehime and Hiroshima prefectures (Kanzaka, 2009). In contrast, most of the more recently established production areas gave up fruit production due to the market conditions and an insufficient labor force. This trend resulted in the abandonment of fruit fields in the coastal areas and contributed chiefly to the increase in FLA.

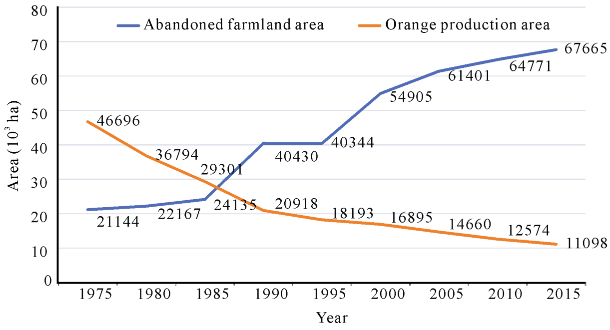

Fig. 12 Change of abandoned farmland and orange production areas in the Chugoku and Shikoku region. Source: Ministry of Agriculture, Forestry and Fishery (MAFF), http://www.maff.go.jp/e/index.html

Third, high FLA rates in the southern Chugoku subregion, particularly in Hiroshima and Okayama prefectures, are largely due to the serious aging and depopulation. As Table 4 indicates, PC 6 (*the status of agricultural succession*) seems to influence FLA over the study region. The aging of farmers (Ruskule et al., 2013; Pazúr et al., 2014; Terres et al., 2015) and the lack of successors (Keenleyside et al., 2010; Yamashita and Hoshino, 2018) for farms have been found to affect FLA by many previous studies. In Japan, rural depopulation is said to have begun in the Chugoku subregion, and many settlements there face a lack of laborers and successors (Kanzaka, 2009). In addition, there was a rapid growth of the industrial labor market on the Seto Inland Sea coast, with a corresponding and intensive outflow of population in this direction from the mountain villages. For this reason, the agriculture that remained was small scale and mainly for subsistence farming. This is contrary to the situation in northern Japan, especially in the Tohoku region, where depopulation was not so serious, and the local labor shortage did not spread to neighboring areas. Instead of entire families, only individuals there left their homes to take employment in large cities (Okahashi, 1996). Therefore, the region enjoys better labor conditions in the agriculture sector than southern Japan. In the future, improving labor accessibility and strengthening family kinship ties in the Chugoku and Shikoku region will be essential for solving the labor shortage.

4.2 Policy implications

In order to encourage better management of regional agriculture and FLA, we argue that policies should take intraregional variations and uneven patterns of agricultural characteristics into account. First, as the agricultural characteristics are diverse and varied within the region, agricultural policies should adapt to the actual local conditions. For instance, the direct payment scheme (DPS), which began in 2000 to promote agricultural on areas where farm management has been ineffective in some areas, thereby fueling FLA expansion (Ito et al., 2019). DPS needs to develop a spatially explicit, regionally specific system that targets agriculture, such as different scales, crops, or farming structures. Communities with differentially unfavorable conditions (e.g., low activeness of agriculture, small scale and sales orientation of agriculture, lack of agricultural successors, low farmland transition) supposed to be supported by proportionately higher compensation. Second, in the future, proper zoning and scale-setting to manage agricultural resources intensively will be vital to stabilizing the farming workforce and alleviating FLA, especially in rural areas. In the center of Chugoku Subregion (which features to mountainous farming areas and is facing serious aging and a lack of laborers), FLA rate displays relatively low level compared to other areas. The reason behind this trend is that there has been some community-based farm cooperatives (CBFCs) (in Japanese: *Syuraku Einou Hōjin*) that are playing an increasingly active role in maintaining local agriculture and mitigating FLA (Ichikawa, 1993). These CBFCs collect farmland from individual households in the municipality using contractual arrangements and help elderly farmers manage their farmland effectively. So, we suggest that on the one hand, for small farms and farm households who need laborers, the consolidation and leasing of their farmlands to larger CBFCs (Shimizu, 2017), farmland banks (Jentzsch, 2017) or enhancing the firm's entry into agriculture (Goto, 2015) could be promising approaches to maintain their farmlands and revitalize regional agriculture. On the other hand, for those who wish to return to work in rural areas in agriculture, local governments should simplify the laws to allow them to get farmland easier and policies should provide more financial support. Finally, promoting the development of smart agriculture or value-added agriculture while considering the ecological value of farmland will be necessary to addressing FLA. Two of the high abandonment areas in our study region are coastal areas and the northern shimane prefecture area. For abandoned fruit farmlands along the Seto Inland Sea coast, which have a long history, local administrative governments should make clear initiatives to re-cultivate fruit farms or to add more value to the products, such as combination of agriculture, processing, and retail to agricultural products and increase consumption. Some of the remote and disadvantaged farmlands in northern Shimane prefecture with low activeness of agriculture and low farmland transition activities, can be converted into natural forestland in the future. When trying to make clear the implications of policies, all the intraregional agricultural characteristics should be considered and evaluated comprehensively.

5 Conclusions

FLA is generally a complex process, which cannot be described by a single variable or determinant. Our study analyzed agricultural characteristics and FLA in the Chugoku and Shikoku region in Japan, which had the highest FLA rate until 2015. We applied a combination of PCA and MLR methods to explain the driving forces or processes of FLA by different domains of agricultural characteristics extracted from variables. The main conclusions are as follows. First, there are strong intraregional differences in the agricultural characteristics across the Chugoku and Shikoku region with eight significant PCs being extracted. They are grouped as PC 1 (*the activeness of agriculture*), PC 2 (*the sales orientation and scale of agriculture*), PC 3 (*the fruit production agriculture*), PC 4 (*the impact of non-farm households on agriculture*), PC 5 (*the dependence on rice production*), PC 6 (*the status of agricultural succession*), PC 7 (*the diversification of agriculture*), and PC 8 (*the transition of farmland*). Second, we found that variables measuring agricultural characteristics explain nearly 52.8% of the variation in FLA in our study region. The PC 2, presenting the sales orientation and scale of agriculture has the strongest negative correlation to FLA in the region, while PC 6, presenting the status of agricultural succession displayed the strongest positive correlation to FLA. The highest abandonment in Seto Inland Sea areas is chiefly due to the low profit of fruit production. Third, in flatland farming areas and intermediate farming areas, where agriculture is more stable and easier to maintain, FLA is more strongly influenced by changes in agricultural characteristics than by geographical variations, such as slope or altitude. We suggest that administrative governments should be careful when making agricultural policies and should take intraregional differences of agricultural characteristics into account. Finally, our study is not free of limitations, and there are some aspects requiring future study. We hope future research can extend and further test our findings as a number of gaps remain in our knowledge around regional agricultural characteristics and FLA:

(1) Since FLA is a long and complex process, to clearly distinguish total abandonment or semi abandonment, further longitudinal research is needed with time spans ranging from 30-50 years. Understanding FLA in different stages will help to manage future abandonment more effectively.

(2) Qualitative analyses, using in-depth interviews with farm households, should be conducted to confirm the findings about agricultural characteristics and FLA. This might illustrate how local traditions and cultural background interact with agricultural characteristics to shape FLA (Ruskule et al., 2013).

(3) Many articles on farmlands and the rural landscape seek to address issues of sustainability (Czyżewski and Matuszczak, 2016), regionality (Sang et al., 2014) and environmental ecology (Parcerisas et al., 2012). As such, new localized approaches for the management of FLA and agriculture still need to be explored.

References

Abdi H, Williams L J, 2010. Principal component analysis. *Wiley Interdisciplinary Reviews: Computational Statistics*, 2(4): 433–459. doi: 10.1002/wics.101

Abolina E, Luzadis V A, 2015. Abandoned agricultural land and its potential for short rotation woody crops in Latvia. *Land Use Policy*, 49: 435–445. doi: 10.1016/j.landusepol.2015.08.022

Abson D J, Dougill A J, Stringer L C, 2012. Using Principal Component Analysis for information-rich socio-ecological vulnerability mapping in Southern Africa. *Applied Geography*, 35(1–2): 515–524. doi: 10.1016/j.apgeog.2012.08.004

Aizaki H, Sato K, Osari H, 2006. Contingent valuation approach in measuring the multifunctionality of agriculture and rural areas in Japan. *Paddy and Water Environment*, 4(4): 217–222. doi: 10.1007/s10333-006-0052-8

Arimoto Y, 2010. Impact of land readjustment project on farmland use and structural adjustment: the case of Niigata, Japan. In: *Agricultural & Applied Economics Association 2010 AAEA, CAES, & WAEA Joint Annual Meeting*. Denver, Colorado.

Caravaggi P, Leardini A, Giacomozzi C, 2016. Multiple linear regression approach for the analysis of the relationships between joints mobility and regional pressure-based parameters in the normal-arched foot. *Journal of Biomechanics*, 49(14): 3485-3491. doi: 10.1016/j.jbiomech.2016.09.019

Chagas C S, Junior W C, Bhering S B et al, 2016. Spatial prediction of soil surface texture in a semiarid region using random forest and multiple linear regressions. *Catena*, 139: 232–240. doi: 10.1016/j.catena.2016.01.001

Cocca G, Sturaro E, Gallo L et al., 2012. Is the abandonment of traditional livestock farming systems the main driver of mountain landscape change in Alpine areas? *Land Use Policy*, 29(4): 878–886. doi: 10.1016/j.landusepol.2012.01.005

Corbelle-Rico E, Crecente-Maseda R, 2014. Evaluating IRENA indicator 'Risk of Farmland Abandonment' on a low spatial scale level: the case of Galicia (Spain). *Land Use Policy*, 38: 9–15. doi: 10.1016/j.landusepol.2013.10.013

Czyżewski B, Matuszczak A, 2016. A new land rent theory for sustainable agriculture. *Land Use Policy*, 55: 222–229. doi: 10.1016/j.landusepol.2016.04.002

Deininger K, Savastano S, Carletto C, 2012. Land fragmentation, cropland abandonment, and land market operation in Albania. *World Development*, 40(10): 2108–2122. doi: 10.1016/j.worlddev.2012.05.010

Food and Agriculture Organization of the United Nations, 2006. The role of agriculture and rural development in revitalizing abandoned/depopulated areas. In: *The 34th Session of the European Commission on Agriculture*. Riga, Latvia.

Gellrich M, Baur P, Koch B et al., 2007. Agricultural land abandonment and natural forest re-growth in the Swiss mountains: a spatially explicit economic analysis. *Agriculture, Ecosystems and Environment*, 118(1–4): 93–108. doi: 10.1016/j.agee.2006.05.001

Gellrich, M, Zimmermann N E, 2007. Investigating the regional-scale pattern of agricultural land abandonment in the Swiss mountains: a spatial statistical modelling approach. *Landscape and Urban Planning*, 79(1): 65–76. doi: 10.1016/j.landurbplan.2006.03.004

Goto T, 2015. Increase in firms' entries into agriculture and their impact on the producing areas in Japan: the case of Oita Prefecture. *Annals of the Association of Economic Geographers*, 61(1): 51–70. doi: 10.20592/jaeg.61.1_51 (in Japanese)

Grədinaru S R, Iojə C I, Onose D A et al., 2015. Land abandonment as a precursor of built-up development at the sprawling periphery of former socialist cities. *Ecological Indicators*, 57: 305–313. doi: 10.1016/j.ecolind.2015.05.009

Hisano S, Akitsu M, McGreevy S R, 2018. Revitalising rurality under the neoliberal transformation of agriculture: experiences of *re-agrarianisation* in Japan. *Journal of Rural Studies*, 61: 290–301. doi: 10.1016/j.jrurstud.2018.01.013

Ito J, Nishikori M, Toyoshi M et al., 2016. The contribution of land exchange institutions and markets in countering farmland abandonment in Japan. *Land Use Policy*, 57: 582–593. doi: 10.1016/j.landusepol.2016.06.020

Ito J, Feuer H N, Kitano S et al., 2019. Assessing the effectiveness of Japan's community-based direct payment scheme for hilly and mountainous areas. *Ecological Economics*, 160: 62–75. doi: 10.1016/j.ecolecon.2019.01.036

Jentzsch H, 2017. Abandoned land, corporate farming, and farmland banks: a local perspective on the process of deregulating and redistributing farmland in Japan. *Contemporary Japan*, 29(1): 31–46. doi: 10.1080/18692729.2017.1256977

Kanzaka S, 2009. Discovering Japan: a new regional geography. Tokyo: Teikoku-Shoin.

Keenleyside C, Tucker G, Key T et al., 2010. *Farmland Abandonment in the EU: An Assessment of Trends and Prospects*. London: Institute for European Environmental Policy.

Kolecka N, Kozak J, Kaim D et al., 2017. Understanding farmland abandonment in the Polish Carpathians. *Applied Geography*, 88: 62–72. doi: 10.1016/j.apgeog.2017.09.002

Kuemmerle T, Hostert P, Radeloff V C et al., 2008. Cross-border comparison of post-socialist farmland abandonment in the Carpathians. *Ecosystems*, 11(4): 614–628. doi: 10.1007/s10021-008-9146-z

Kuki Y, Takahashi T, 1997. Analysis of influential factors in abandonment of cultivation using quantification theory type I: studies on prevention of abandonment of cultivation in suburban area (I). *Transactions of the Japanese Society of Irrigation, Drainage and Reclamation Engineering*, 1997(191): 603–613. doi: 10.11408/jsidre1965.1997.603 (in Japanese)

Lasanta T, Arnáez J, Pascual N et al., 2017. Space-time process and drivers of land abandonment in Europe. *Catena*, 149: 810–823. doi: 10.1016/j.catena.2016.02.024

Levers C, Schneider M, Prishchepov A V et al., 2018. Spatial variation in determinants of agricultural land abandonment in Europe. *Science of the Total Environment*, 644: 95–111. doi: 10.1016/j.scitotenv.2018.06.326

Li S F, Li X B, 2017. Global understanding of farmland abandonment: a review and prospects. *Journal of Geographical Sciences*, 27(9): 1123–1150. doi: 10.1007/s11442-017-1426-0

Löw F, Fliemann E, Abdullaev I et al., 2015. Mapping abandoned agricultural land in Kyzyl-Orda, Kazakhstan using satellite remote sensing. *Applied Geography*, 62: 377–390. doi: 10.1016/j.apgeog.2015.05.009

MacDonald D, Crabtree J R, Wiesinger G et al., 2000. Agricultural abandonment in mountain areas of Europe: environmental consequences and policy response. *Journal of Environmental Management*, 59(1): 47–69. doi: 10.1006/jema.1999.0335

Meyfroidt, P., Schierhorn, F., Prishchepov et al, 2016. Drivers, constraints and trade-offs associated with recultivating abandoned cropland in Russia, Ukraine and Kazakhstan. *Global Environmental Change*, 37: 1–15. doi: 10.1016/j.gloenvcha.2016.01.003

Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF), 2015. FY2014 Annual Report on Food, Agriculture and Rural Areas in Japan. Available at: https://www.maff.go.jp/e/data/publish/attach/pdf/index-38.pdf

Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF),

2016. FY2015 Summary of the Annual Report on Food, Agriculture and Rural Areas in Japan. Retrieved from https://www.maff.go.jp/e/data/publish/attach/pdf/index-57.pdf

Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF), 2018. FY2017 Summary of the Annual Report on Food, Agriculture and Rural Areas in Japan. Retrieved from http://www.maff.go.jp/e/data/publish/attach/pdf/index-93.pdf

Morimoto T, 1991. The increase of fallow and abandoned cultivated land with the development of intensive agriculture in Hasaki-Machi, Ibaraki Prefecture. *Geographical Review of Japan*, 64: 613–636. doi: 10.4157/grj1984a.64.9_613 (in Japanese)

Morimoto T, 1993. Idle and abandoned farmland in Kashiwai-cho 4-chome, Ichikawa City, Chiba prefecture. *Geographical Review of Japan*, 66(9): 515–539. doi: 10.4157/grj1984a.66.9_515 (in Japanese)

Munroe D K, van Berkel D B, Verburg P H et al., 2013. Alternative trajectories of land abandonment: causes, consequences and research challenges. *Current Opinion in Environmental Sustainability*, 5(5): 471-476. doi: 10.1016/j.cosust.2013.06.010

Nihei T, 2006. Regional division of Japanese agriculture in terms of comprehensive indices of farm management: development of a method by means of multivariate analyses and GIS. *Studies in Human Geography*, 30: 69–98. (in Japanese)

Nishihara M, 2012. Real option valuation of abandoned farmland. *Review of Financial Economics*, 21(4): 188–192. doi: 10.1016/j.rfe.2012.07.002

Okahashi H, 1986. Rural deprivation in mountainous areas of Japan: a preliminary assessment. *Japanese Journal of Human Geography*, 38(5): 461–479. doi: 10.4200/jjhg1948.38.461 (in Japanese)

Okahashi H, 1996. Development of mountain village studies in postwar Japan: depopulation, peripheralization and village renaissance. *Geographical Review of Japan*, 69(1): 60–69. doi: 10.4157/grj1984b.69.60 (in Japanese)

Osawa T, Kohyama K, Mitsuhashi H, 2013. Areas of increasing agricultural abandonment overlap the distribution of previously common, currently threatened plant species. *PLoS One*, 8(11): e79978. doi: 10.1371/journal.pone.0079978

Osawa T, Kohyama K, Mitsuhashi H, 2016. Multiple factors drive regional agricultural abandonment. *Science of the Total Environment*, 542: 478–483. doi: 10.1016/j.scitotenv.2015.10.067

Parcerisas L, Marull J, Pino J et al., 2012. Land use changes, landscape ecology and their socioeconomic driving forces in the Spanish Mediterranean coast (El Maresme County, 1850–2005). *Environmental Science and Policy*, 23: 120–132. doi: 10.1016/j.envsci.2012.08.002

Patil S, Kokate K, 2017. Identifying factors governing attitude of rural women towards Self-Help Groups using principal component analysis. *Journal of Rural Studies*, 55: 157–167. doi: 10.1016/j.jrurstud.2017.08.003

Pazúr R, Lieskovský J, Feranec J et al., 2014. Spatial determinants of abandonment of large-scale arable lands and managed grasslands in Slovakia during the periods of post-socialist transition and European Union accession. *Applied Geography*, 54: 118–128. doi: 10.1016/j.apgeog.2014.07.014

Plieninger T, Draux H, Fagerholm N et al., 2016. The driving forces of landscape change in Europe: a systematic review of the evidence. *Land Use Policy*, 57: 204–214. doi: 10.1016/j.landusepol.2016.04.040

Pointereau P, Coulon F, Girard P et al., 2008. Analysis of the driving forces behind farmland abandonment and the extent and location of agricultural areas that are actually abandoned or are in risk to be abandoned. In: *European Communities*. Italy: ISPRA.

Prishchepov A A, Müller D, Dubinin M et al., 2013. Determinants of agricultural land abandonment in post-Soviet European Russia. *Land Use Policy*, 30(1): 873–884. doi: 10.1016/j.landusepol.2012.06.011

Ramankutty N, Heller E, Rhemtulla J, 2010. Prevailing myths about agricultural abandonment and forest regrowth in the United States. *Annals of the Association of American Geographers*, 100(3): 502–512. doi: 10.1080/00045601003788876

Rudel T K, Coomes O T, Moran E et al., 2005. Forest transitions: towards a global understanding of land use change. *Global Environmental Change*, 15(1): 23–31. doi: 10.1016/j.gloenvcha.2004.11.001

Ruskule A, Nikodemus O, Kasparinskis R et al., 2013. The perception of abandoned farmland by local people and experts: landscape value and perspectives on future land use. *Landscape and Urban Planning*, 115: 49–61. doi: 10.1016/j.landurbplan.2013.03.012

Sang N, Dramstad W E, Bryn A, 2014. Regionality in Norwegian farmland abandonment: inferences from production data. *Applied Geography*, 55: 238–247. doi: 10.1016/j.apgeog.2014.09.015

Schumann F R, 2016. A study of one village one product (OVOP) and workforce development: lessons for engaging rural communities around the world. *Japan Institute for Labor Policy and Training*.

Shimizu T, 2017. Present state of Japanese agriculture and future prospect for agricultural structure: detailed picture seen in 2015 Agricultural Census. *The Norin Kinyu*, 70(9):32–47.

Shoji G, 2015. Prevention mechanism of farmland abandonment in a mountain village in Nishi-Aizu Town. *Quarterly Journal of Geography*, 66(4): 284–297. doi: 10.5190/tga.66.284 (in Japanese)

Sluiter R, De Jong S M, 2007. Spatial patterns of Mediterranean land abandonment and related land cover transitions. *Landscape Ecology*, 22(4): 559–576. doi: 10.1007/s10980-006-9049-3

Smaliychuk A, Müller D, Prishchepov A V et al., 2016. Recultivation of abandoned agricultural lands in Ukraine: patterns and drivers. *Global Environmental Change*, 38: 70–81. doi: 10.1016/j.gloenvcha.2016.02.009

Su G D, Okahashi H, Chen L, 2018. Spatial pattern of farmland abandonment in Japan: identification and determinants. *Sustainability*, 10(10): 3676. doi: 10.3390/su10103676

Tan K C, Lim H S, Jafri M Z M, 2016. Prediction of column ozone concentrations using multiple regression analysis and principal component analysis techniques: a case study in peninsular Malaysia. *Atmospheric Pollution Research*, 7(3): 533–546. doi: 10.1016/j.apr.2016.01.002

Teffera Z L, Li J H, Debsu T M et al., 2018. Assessing land use and land cover dynamics using composites of spectral indices and principal component analysis: a case study in middle Awash subbasin, Ethiopia. *Applied Geography*, 96: 109–129. doi: 10.1016/j.apgeog.2018.05.015

Teratoko Y, 2009. Expansion of abandoned cultivated land and related factors in a marginal hamlet in Minamata, Kumamoto Prefecture. *Geographical Review of Japan Series A*, 82(6): 588–603. doi: 10.4157/grj.82.58(in Japanese)

Terres, J M, Scacchiafichi L N, Wania A et al., 2015. Farmland abandonment in Europe: identification of drivers and indicators, and development of a composite indicator of risk. *Land Use Policy*, 49: 20–34. doi: 10.1016/j.landusepol.2015.06.009

Uddin M N, Saiful Islam A K M, Bala S K et al., 2019. Mapping of climate vulnerability of the coastal region of Bangladesh using principal component analysis. *Applied Geography*, 102: 47–57. doi: 10.1016/j.apgeog.2018.12.011

Uematsu Y, Koga T, Mitsuhashi H et al., 2010. Abandonment and intensified use of agricultural land decrease habitats of rare herbs in semi-natural grasslands. *Agriculture, Ecosystems and Environment*, 135(4): 304–309. doi: 10.1016/j.agee.2009.10.010

Ustaoglu E, Collier M J, 2018. Farmland abandonment in Europe: an overview of drivers, consequences, and assessment of the sustainability implications. *Environmental Reviews*, 26(4): 396-416. doi: 10.1139/er-2018-0001

van der Zanden E H, Verburg P H, Schulp C J E et al., 2017. Trade-offs of European agricultural abandonment. *Land Use Policy*, 62: 290–301. doi: 10.1016/j.landusepol.2017.01.003

van der Zanden E H, Carvalho-Ribeiro S M, Verburg P H, 2018. Abandonment landscapes: user attitudes, alternative futures and land management in Castro Laboreiro, Portugal. *Regional Environmental Change*, 18(5): 1509–1520. doi: 10.1007/s10113-018-1294-x

Vinogradovs I, Nikodemus O, Elferts D et al., 2018. Assessment of site-specific drivers of farmland abandonment in mosaic-type landscapes: a case study in Vidzeme, Latvia. *Agriculture, Ecosystems and Environment*, 253: 113–121. doi: 10.1016/j.agee.2017.10.016

Williams, K J H, Schirmer J, 2012. Understanding the relationship between social change and its impacts: the experience of rural land use change in south-eastern Australia. *Journal of Rural Studies*, 28(4): 538–548. doi: 10.1016/j.jrurstud.2012.05.002

Xu D D, Deng X, Guo S L et al., 2019. Labor migration and farmland abandonment in rural China: empirical results and policy implications. *Journal of Environmental Management*, 232: 738–750. doi: 10.1016/j.jenvman.2018.11.136

Yamaguchi T, Ngodup S, Nose M et al., 2016. Community-scale analysis of the farmland abandonment occurrence process in the mountain region of Ladakh, India. *Journal of Land Use Science*, 11(4): 401–416. doi: 10.1080/1747423X.2016.1174317

Yamashita R, Hoshino S, 2018. Development of an agent-based model for estimation of agricultural land preservation in rural Japan. *Agricultural Systems*, 164: 264–276. doi: 10.1016/j.agsy.2018.05.004

Zaragozí B, Rabasa A, Rodríguez-Sala J J et al., 2012. Modelling farmland abandonment: a study combining GIS and data mining techniques. *Agriculture, Ecosystems & Environment*, 155: 124–132. doi: 10.1016/j.agee.2012.03.019

Zeinalzadeh, K., Rezaei, E, 2017. Determining spatial and temporal changes of surface water quality using principal component analysis. *Journal of Hydrology: Regional Studies*, 13(8): 1–10. doi: 10.1016/j.ejrh.2017.07.002

Zhang Y, Li X B, Song W, 2014. Determinants of cropland abandonment at the parcel, household and village levels in mountain areas of China: a multi-level analysis. *Land Use Policy*, 41: 186–192. doi: 10.1016/j.landusepol.2014.05.011

Zhang Y, Li X B, Song W et al., 2016. Land abandonment under rural restructuring in China explained from a cost-benefit perspective. *Journal of Rural Studies*, 47: 524–532. doi: 10.1016/j.jrurstud.2016.06.019