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RESEARCH PAPER

How Climate Change Affects Land Use Pattern: An Iranian Provincial Experience

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Abstract
Climate change is exacerbating the challenges faced by the agriculture sector especially in arid and semi-arid regions. Climate change-induced increases in temperature, rainfall variation (both spatial and time) and the frequency and intensity of extreme weather events are adding to pressure on the global agriculture system—which is already struggling to respond to the rising demands of the growing population for food. This paper specifies a spatial econometric model to determine the major drivers of land use change, with emphasis on climate variables, in three bordering provinces of Iran during 2004–2016. Results indicate that changes in the usage of land and adaptation to climate change occur through time, but these changes have a major locative dependence on the nearby areas. In most of the regions under study, the increase in temperature exerts negative impacts on the proportion of lands devoted to grass and agriculture. Cropland value and farmer income have indirect and direct impact on the share of agricultural lands, respectively. Land slope is also indirectly related to urban and agricultural land allocation. Provision of more supports to farmers through direct payment and price support policies aiming at preserving of agricultural lands is recommended.

Article Highlights

- **A spatial multinomial logit model is used to identify drivers of land use change (with emphasis on climate variables) in Iran.**
- **Changes in usage of land and adaptation to climate change occur through time and these changes have a major locative dependency on the nearby areas.**
- **Designing supportive policies to mitigate adverse effects of climate change on agriculture is recommended.**

Keywords Climate change · Land use · Spatial econometrics · Iran

Introduction

Climate change has emerged as a global phenomenon and is expected to worsen the challenges faced by agriculture. It has been widely accepted that climate change is, on balance, a negative externality. It adds to the obstacles to achieve sustainable food security arising from population and income growth (Tol 2015). Changing climate is also contributing to resource problems beyond food security, such as water scarcity, pollution and soil degradation. As resource scarcity and environmental quality problems emerge, so does the urgency of addressing these challenges (OECD 2015).

Climate parameters, including rainfall and temperature, are among the main factors affecting plant growth, and, thus, agricultural output. So, long-term climate change-induced shift in these parameters is mostly responsible for unsteady crop supply and, consequently, unstable farmers' income and well-being. Therefore, land owners would change their land use pattern (leave agriculture) to get maximum return (Cho et al. 2015).

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According to the International Panel on Climate Change (IPCC), climate change will affect the Middle East and North Africa (MENA) region in the coming decades. Decrease in precipitation and higher temperatures will raise the occurrence of droughts, while increasing population and need for more food will enhance the demand for water. Hence, the productivity of the agricultural sector might be affected by climate change which, in turn, leads to change in the land use pattern (Tayebi and Fulginiti 2016).

Iran located in the Middle East suffers from water scarcity and is expected to experience detrimental impacts of climate change on its water resources, agricultural output and land use pattern. Based on the Ministry of Jihad-Agriculture (MOJA) official data, roughly one-third of Iran's total surface area is suited for farmland, but because of poor soil and lack of adequate water in many areas, only 12% of the country area is under cultivation of which less than one-third is irrigated. Climate change would lessen the share of irrigated farming and domestic production of agricultural commodities on one hand and leave farmers in a more risky environment on the other hand, which would cause change in land use pattern in favour of non-agricultural activities. Designing proper policy packages aiming at mitigation of undesirable follow-up consequences of climate change requires studies dealing with different aspects (including land use change) of this global phenomenon.

Many studies have been devoted to plant responses to climate change (Yang et al. 1997; Di et al. 1994; Schultz and Halpert 1993). Some other studies have also documented the regional effects of climate change on agricultural production and water resources (Alcamo et al. 2007; Asada and Matsumoto 2009; Barnett et al. 2005). Flexibility of the agricultural sector over climate change and farmers' decisions to alternate their land usage in response to lack of water have been reported in a group of studies (Reidsma et al. 2009; Finger and Schmid 2008; Ranjan and Tapsuwan 2008). Cho et al. (2015) introduced climate change as a driver of land use change in the USA. They also showed that movements to and from agricultural land and grassland are adversely affected by climate change. Li et al. (2013) showed that population growth and timber production industry were two major driving forces for land conversions from 1985 to 2005 in China. Batar et al. (2017) examined land cover changes during 1976–2014. They calculated the overall annual rate of change in the forest cover at 0.22% and 0.27% in the 1976–1998 and 1998–2014 periods, respectively. Zhang et al. (2017) found that human activities like farming were negatively correlated with the landscape diversity of wetlands. Furthermore, evidence of degraded wetlands caused by air temperature and annual precipitation was also observed.

Iranian literature on climate change and land use is not so rich. Although few studies focusing on a small area could be found (Abdollahi et al. 2008; Azimi et al. 2012; Rahimi 2016), unfortunately, there has not been a relatively comprehensive study covering a reasonably large area assessing the effects of climate change on land use and especially on agricultural lands. So, the present work, for the first time, tries to bridge this gap. Furthermore, we aim at evaluation of land use change between three time horizons (2004, 2010 and 2016) in three important Iranian provinces and, by applying proper econometric methods, the main drivers of land use change were identified.

Materials and methods

Since the present study aims at exploring an economically sound relationship between climate change and land use, econometric models should be selected as the best method for reaching the above goal. A common challenge facing these empirical studies is spatial dependence, which may arise when land uses in nearby areas directly affect each other or are affected by the same unobserved factors. The former case is referred to as spatial lag dependence (or spatial interaction), and the latter case is called spatial error dependence. Ignoring spatial dependence will lead to biased (or inconsistent) estimates if the dependence structure induces heteroscedasticity in a discrete dependent variable model (Yatchew and Griliches 1985).

Also, Anselin (1988) argued that those econometric methods (regular time series or panel models) based on Gauss–Markov assumptions are not appropriate for regional studies due to spatial autocorrelation and heterogeneity in such data. Spatial autocorrelation refers to the fact that the observed data in two or more bordering areas affect each other. Spatial heterogeneity implies that on changing the geographical location, data distribution features (mean and variance) may alter. To solve the problem, spatial lag models (which can be supported by statistical tests such as Moran's I test) are typically proposed. In the spatial econometric models, an adjacency (spatial weights) matrix is used so that the influence of nearby observations can be used as a new explanatory variable. A general spatial model is represented in Eq. (1).

$$Y = \alpha + \rho WY + X\beta + U, \tag{1}$$

$$U = \delta WU + \mu,$$

$$U \sim N(0, \sigma^2 \mathrm{I}),$$

$$\mu \sim N(0, \Omega),$$

where W is spatial weights (adjacency) matrix, β is a $k \times 1$ vector of parameters associated with exogenous (not lagged dependent) variables X, which is an $n \times k$ matrix, and ρ is the coefficient of the spatially lagged dependent variable. Spatial weights matrix (W) has entries depending on the distance between the spatial units and a distance-decay parameter.

By this model and following Cho et al. (2015) and Li et al. (2013), we assume that land use changes and adaptation to climate change in an area depend on neighbouring areas. These changes can be attributed to factors such as: weather condition, technology adoption, land quality, economic variables, and labour transfer. Also, Eq. (1) is specified as an aggregated logit-linearized share model which provides important information on the probability of change between different land uses.

Study area

Three northern nearby provinces including Tehran (Iran's capital), Alborz and Mazandaran providing significant share of national agricultural production and six land uses (forest, urban, agriculture, grass, water, and other) are considered. Figure 1 provides a map of the study area.

Moreover, the composition of different land uses in the period under study is represented in Fig. 2a–c.

By exact examination of the above figures, one may conclude that urban areas in Tehran are expanded during the period which could be attributed to the movement of people from mostly agriculture-based province (Mazandaran). In other words, unprofitable agriculture (due to water shortage and other climate change-related limitations) forced farmers to leave their farms and migrate to the capital, hoping to find a job. As a result, land use has changed not only in Mazandaran, but also in its nearby province of Tehran. This clearly justifies our spatial lag model as a proper specification for data analysis. Similar explanations could be stated for land use conversion from "other" to "agriculture". Decrease in available water resources has resulted in expansion of greenhouse agriculture which can be regarded as a conversion from "other" to "agriculture".

Data

Following Li et al. (2013), we collected a geographic information system (GIS) database on land use, economic variables, topographic features and weather conditions. Due to the huge number of cells and difficulty of calculation, we aggregated the small cells and used the same cells of 10 km × 10 km as proposed by Cho et al. (2015) and Li et al. (2013) totalling 431 as sample size. For the gridded cells of 10 km × 10 km, we utilized a fishnet function within ArcGIS software. Census data at county level for economic and social factors were obtained for 2004, 2010, and 2016 from the Statistical Center of Iran (SCI), MOJA, Central Bank of the Islamic Republic of Iran (CBI), and Ministry of Roads and Urban Development (MRUB). Data on climate variables (temperature and precipitation) were obtained from Iran Meteorological Organization (IMO). Slope data were taken from DEM images, while remotely sensed data were obtained from MODIS images. After image pre-processing, maximum likelihood classification were performed to classify the images in different land cover categories. The maximum likelihood classifier is generally preferred because of its accuracy and considering variability. Since the rate of land use change has significantly altered after 2010, model estimation has been done in two periods (before and after 2010).

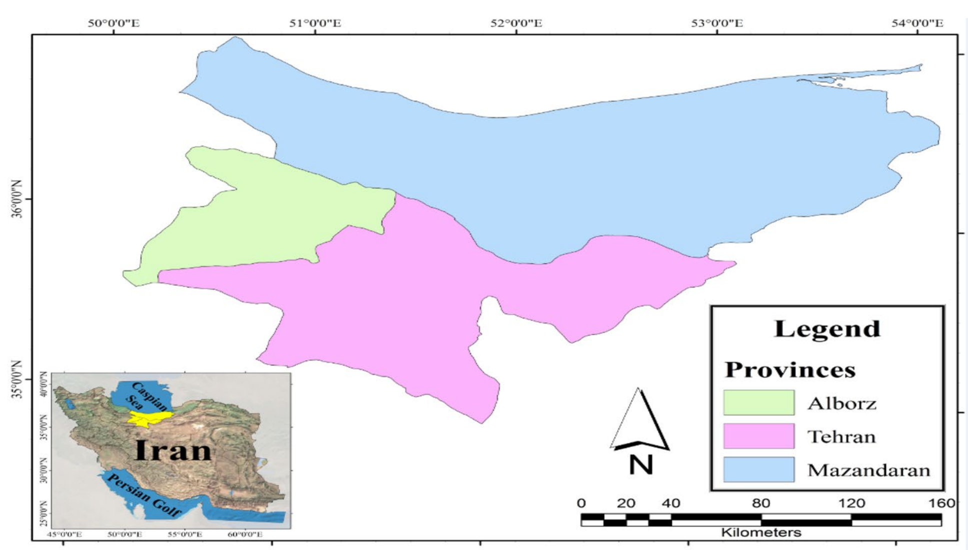

Fig. 1 Map of the study area

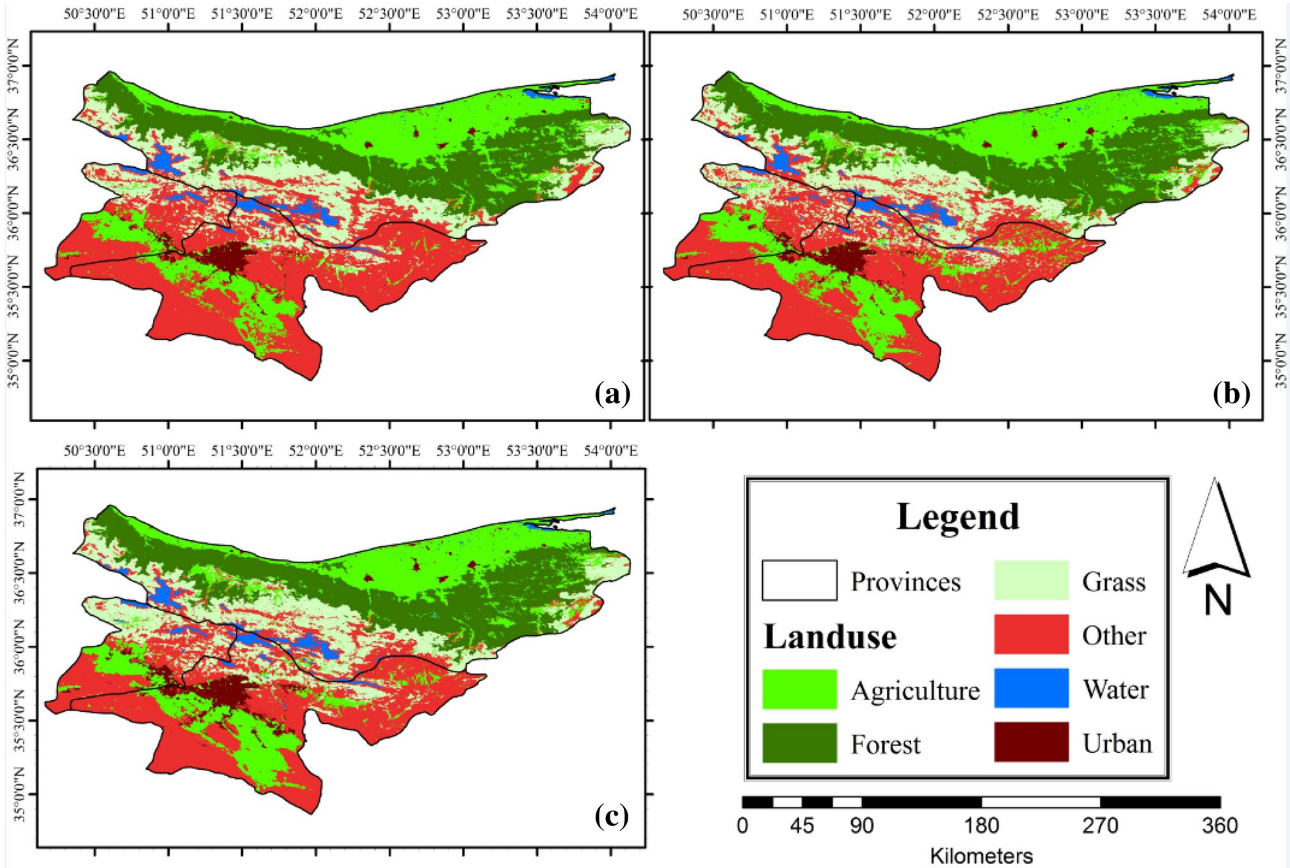

Fig. 2 Land use pattern (**a** 2004, **b** 2010, **c** 2016)

Results and discussion

All variables are described in Table 1. The dependent variable is a vector of proportions $S=(S_1, S_2 \ldots S_J)'$ of land use shares among the J (1, 2,…, 6) mutually exclusive usages. For the base reference in the estimated spatial multinomial logit model, the "other" land use category that was indexed by $J=6$ is used.

Figure 3 briefly presents the total land use transitions for the period 2004–2016. Agricultural activities have taken 50.778 km^2, 188.637 km^2, 402.381 km^2, 1000.228 km^2 and 122.462 km^2 lands from urban, forest, grass, other and water, respectively. On the other hand, agriculture has released 246.657 km^2, 476.778 km^2, 126.234 km^2, 146.927 km^2 and 34.927 km^2 lands to urban, forest, grass, other and water, respectively. As a result the total agricultural area rose from 9223.794 km^2 to 9956.767 km^2. The same explanation could be provided for the remaining five uses. In summary, agriculture, forest, urban and grassland have expanded, while water and others have narrowed.

Before estimation of Eq. (1) and as a support to our model, Moran's I test was used. Unfortunately, this test only utilizes the cross-sectional dimension of the data. Therefore, we applied it for each time horizon.

Moran's I test is greater than 1.96 in both periods. Results confirmed the existence of spatial autocorrelation of six dependent variables (Table 2).

Table 3 represents the goodness of fit tests. The likelihood ratio test results which are significant at the 1% level indicate the significance of the final regression. In other words, the assumption of the relationship between dependent and independent variables is accepted. The pseudo R^2 also shows that the independent variables used in multinomial logit model explain the high degree of dependent variables and are wisely chosen.

Results of the estimated spatial multinomial logit model are reported in Tables 4 and 5 for two sub-periods 2004–2010 and 2010–2016. In fact, each table consists of the results for five estimated models ("other use" is considered as reference category). It is obvious that the sign

Table 1 Description of variables

Variables	Description	Aggregation
% Agriculture	Share of agricultural land (%)	10 km × 10 km
% Grass	Share of grasslands (%)	10 km × 10 km
% Forest	Share of forest (%)	10 km × 10 km
% Urban	Share of urban land (%)	10 km × 10 km
% Water	Share of water/ice (%)	10 km × 10 km
% Other	Share of other lands (%)	10 km × 10 km
Temperature	5-year average of annual mean temperature (degrees Celsius)	10 km × 10 km
Precipitation	5-year average of annual total precipitation (100 mm)	10 km × 10 km
Temperature SD	Standard deviation of temperature	10 km × 10 km
Precipitation SD	Standard deviation of precipitation	10 km × 10 km
Altitude	Altitude from the sea level (100 m)	10 km × 10 km
Slope	Slope of land (°)	10 km × 10 km
Irrigation rate	Irrigation rate of cropland (%)	County
Cropland asset value	Logarithm of cropland asset value (rial*/ha)	County
Farm income	Farm income (1000 rial/ha)	County
Housing value	Logarithm of median value of owner housing (rial)	County
Log (population density)	Logarithm of population density (persons/ha)	County

*Iranian national currency which roughly equals 0.00003 USD by August 2017

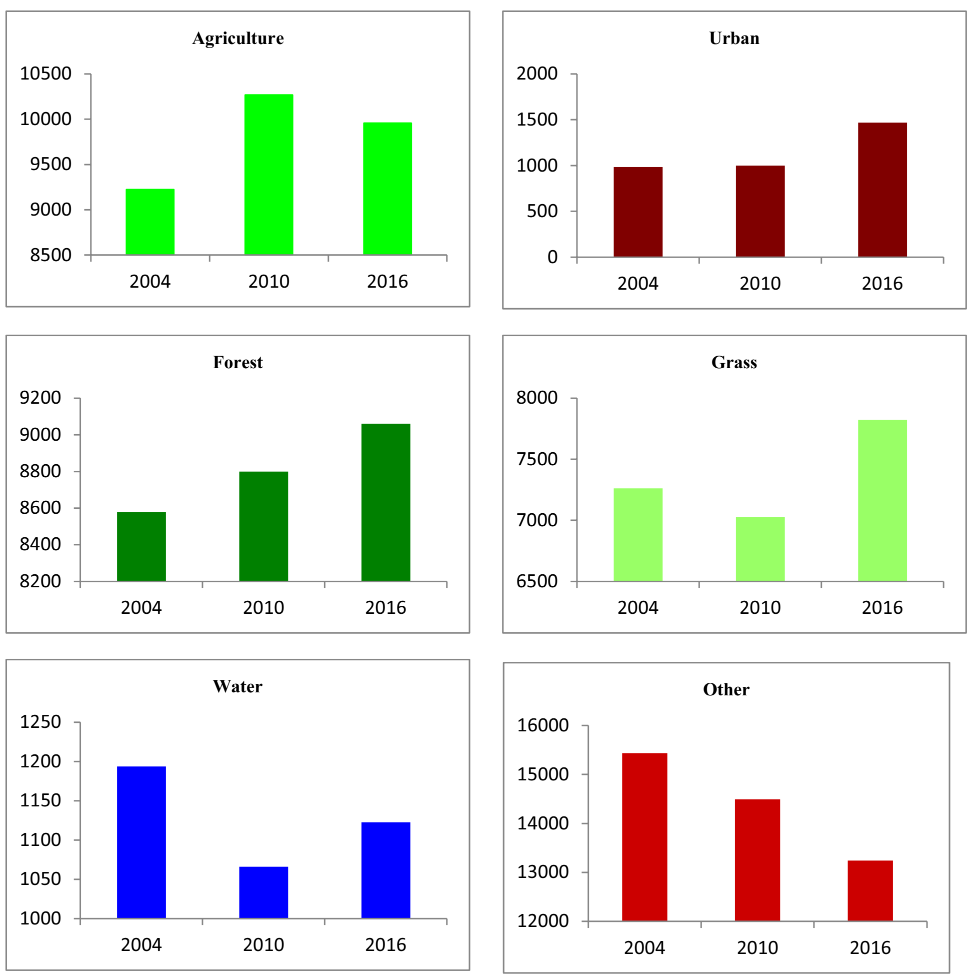

Fig. 3 Land use transitions in 2004, 2010 and 2016 (km^2)

Table 2 Moran's *I* test

	2004–2010	2010–2014
Moran *I* statistic	3.009	5.887
P value	(0.001)	(0.000)

Table 3 Model fitting information

	− 2 Log likelihood	Chi square
Final	206.694	189.162***
	Pseudo R-square	
	2004–2010	2010–2016
Cox and Snell	0.63	0.71
Nagelkerke	0.66	0.76
McFadden	0.34	0.39

of the parameters is unchanged in two tables, though in terms of size they are a little different.

To provide more economically meaningful information, the marginal effects of variables are calculated and reported in Table 6. The marginal effect states the extent of responsiveness of dependent variable to 1% change in explanatory variables. For example, 1% rise in temperature causes 0.0043% decline in agricultural land share. The same figure in the second sub-period is estimated at − 0.0056, which clearly reveals stronger association between the two above-mentioned variables.

Climate variables of interest (temperature and precipitation) show expected signs as they are indirectly and directly related to the probability of agricultural area share, respectively. In other words, any increase in temperature results in reduction in probability of agricultural area share. Each plant needs an optimum temperature (in growth terms) to grow. If the temperature rises or falls to more or less than the optimum temperature, the plant will get a temperature tension. These tensions lead to a decrease in output and may even lead to plant death. The adverse impact of temperature on grassland share is greatest, while precipitation shows highest influence on grassland as 1% increase in precipitation causes 0.0036% and 0.0044% rise in grassland share in two sub-periods, respectively. The increase in temperature and evaporation, transpiration of water and the reduction in humidity will also decrease the grassland share. Precipitation is the most important water supplier in grassland and agriculture. Developing rain-fed farming systems and cultivation are possible with enhanced precipitation. Hence, higher precipitation has a positive effect on agricultural and grasslands. Also, numerous variations in the amount of precipitation and temperature reduce the agricultural land share. Population density positively affects the probability of agricultural and urban area shares, since more people demand more food and accommodation. These findings agree with Cho et al. (2015). Since housing in Iran is a

Table 4 Parameters estimates of spatial multinomial logit model (2004–2010)

Variables	Agriculture	Grass	Forest	Urban	Water
Temperature	− 0.0114***	− 0.0269***	0.0156***	0.0218**	− 0.0081*
Precipitation	0.0327***	0.0912***	0.0257***	0.0027**	0.0043*
Temperature SD	− 0.8322***	− 0.9003***	− 0.3123***	− 0.3317***	− 0.3900***
Precipitation SD	− 0.0329***	0.1012***	− 0.0709***	− 0.0217**	− 0.0363***
Altitude	− 0.0311***	0.0142***	0.0098**	− 0.0165***	− 0.0215***
Slope	− 0.0018***	0.0025***	0.0067***	− 0.0026***	0.0044***
Irrigation rate	0.2601***	0.0111*	− 0.2048*	− 0.3897*	0.0951*
Cropland value	− 0.1730***	− 0.0789***	0.0125*	0.0979***	− 0.0095**
Farm income	0.0148***	− 0.0023*	0.0011*	0.0019*	0.0001
Housing value	0.0911***	− 0.0151*	0.0501***	0.0190***	− 0.0222**
Population density	0.0996***	− 0.0161***	− 0.0731***	0.0980***	− 0.0032**
Share of agriculture (t − 1)	7.5112***	2.0171***	2.2201***	6.6013***	1.9875***
Share of grass (t − 1)	3.2210***	7.0039***	2.9667***	4.0112***	2.0007***
Share of forest (t − 1)	4.0112***	3.9509***	8.0323***	5.0024***	2.0431***
Share of urban (t − 1)	7.0247***	5.8670***	4.9658***	9.8739***	4.0479***
Share of water (t − 1)	5.2570***	3.5571***	4.8581***	6.8798***	8.9116***
Constant	− 1.0079*	− 0.9987***	− 3.5678*	− 5.1574***	− 1.1780*
Spatial lag	0.0346***	0.0471***	0.0289***	0.0192***	0.0320***

*, **, and *** indicate statistical significance at 0.1, 0.05, and 0.01 levels, respectively. (t − 1) and t indicate 2004 and 2010

Table 5 Parameters estimates of spatial multinomial logit model (2010–2016)

Variables	Agriculture	Grass	Forest	Urban	Water
Temperature	− 0.0109***	− 0.0271***	0.0149***	0.0226***	− 0.0063*
Precipitation	0.0215***	0.0941***	0.0223***	0.0017**	0.0112**
Temperature SD	− 0.4321***	− 0.6781***	− 0.2217***	− 0.0043***	− 0.1101***
Precipitation SD	− 0.0224***	0.926***	0.0160***	− 0.0032***	0.1203***
Altitude	− 0.0354***	0.0153***	0.0117***	− 0.0124***	− 0.0139***
Slope	− 0.0011***	0.0028***	0.0068***	− 0.0019***	0.0048***
Irrigation rate	0.2179***	0.0157**	− 0.1974*	− 0.3793*	0.2219**
Cropland value	− 0.1435***	− 0.0720***	0.0215**	0.1091***	0.0015***
Farm income	0.0895***	− 0.0308**	0.0024*	0.0255**	0.0019
Housing value	0.1043***	− 0.0113**	0.0489***	0.0234***	− 0.0031***
Population density	0.0757***	− 0.0169**	− 0.0748***	0.0958***	− 0.0015**
Share of agriculture ($t-1$)	7.5036***	2.0042***	2.20028***	0.6128***	1.9858***
Share of grass ($t-1$)	3.26812***	7.0196***	2.9840***	4.0014***	2.0003***
Share of forest ($t-1$)	4.0354***	3.9366***	8.0679***	5.0046***	2.0257***
Share of urban ($t-1$)	7.0270***	5.9004***	4.9653***	9.8834***	4.0219***
Share of water ($t-1$)	5.7778***	3.9279***	4.8396***	6.8598***	8.9390***
Constant	− 1.3329*	− 1.2690***	− 3.9012**	− 7.0006***	− 1.1201**
Spatial lag	0.0415***	0.0526***	0.0247***	0.0212***	0.0273***

*, **, and *** indicate statistical significance at 0.1, 0.05, and 0.01 levels, respectively. ($t-1$) and t indicate 2010 and 2016

kind of capital commodity, rise in housing value causes increase in probability of urban area share. Also, all estimated lag parameters at the bottom of the tables are highly significant indicating that the model without spatial lag terms can lead to a misspecification error and biased estimates as Pace and LeSage (2010) pointed out.

The coefficient of cropland value is negative in agriculture share equation implying that any increase in farmland value leads to fall in agricultural land share, since farmers would be eager to sell their lands and invest in a more profitable activity like housing. This has been previously found in Cho et al. (2015) and Nickerson et al. (2012). Moreover, historical data from the area under study (especially, Mazandaran province) strongly supports this finding.

Farm income and irrigation rate both have positive impact on agricultural land use share, which is in line with theoretical expectations. Other results confirm the inappropriateness of lands with more slope and higher altitudes for agricultural activities. The increase in slope will decrease the utilization and natural grazing ability of stock on steep hillsides. Therefore, these grasslands are secure against overgrazing.

Conclusions

This study used a spatial multinomial logit model to identify drivers of land use change (with emphasis on climate variables) in three nearby provinces (Tehran, Alborz and Mazandaran) in Iran during 2004–2016. The main results show that climate change has a significant effect on land use. By experiencing warmer and drier climate in the future, our findings show that agriculture will face challenging condition and meeting the food demand of the people would be a tough task for the government. Other findings confirm the role of spatial dependence in climate change adaptation on the nearby areas. In most of the regions under study, increase in temperature exerts a negative impact on grassland and agricultural land shares. Due to the rising demand for housing, the price of residential houses will increase and urban land use will gradually develop. One government strategy to reduce the number of immigrating farmers is public agricultural investment that would also help in ecological preservation. The unprecedented increase in cropland value, especially in Mazandaran, has led to change and destruction of agricultural land use. Revision of the local policies and prevention of unauthorized constructions are essential.

Table 6 Marginal effects of variables

	Agriculture	Grass	Forest	Urban	Water
2004–2010					
Temperature	− 0.0043	− 0.0368	0.0009	0.0005	− 0.0001
Precipitation	0.0017	0.0036	0.0004	0.0022	0.0009
Temperature SD	− 0.0447	− 0.0032	0.0014	− 0.0009	0.0025
Precipitation SD	− 0.0089	0.0022	− 0.0027	− 0.0003	− 0.0011
Altitude	− 0.0032	0.0010	0.0017	0.0011	0.0003
Slope	− 0.0005	0.0004	0.0002	− 0.0011	0.0003
Irrigation rate	0.0114	0.0167	− 0.0091	− 0.0053	0.0045
Cropland value	− 0.0341	− 0.0027	0.0099	0.0111	0.0009
Farm income	0.0170	− 0.0041	0.0009	0.0033	0.0002
Housing value	0.0051	− 0.0027	0.0063	0.0083	− 0.0009
Population density	0.0043	− 0.0081	− 0.0022	0.0059	− 0.0006
Share of agriculture ($t-1$)	0.6103	− 0.0540	− 0.0489	0.0477	− 0.0183
Share of grass ($t-1$)	− 0.0141	0.4809	0.2012	0.0091	− 0.0278
Share of forest ($t-1$)	− 0.0441	0.0603	0.5322	0.0038	− 0.0265
Share of urban ($t-1$)	0.0914	− 0.2300	0.0127	0.5673	− 0.0004
Share of water ($t-1$)	0.0349	− 0.0558	0.0243	0.0778	0.1033
2010–2016					
Temperature	− 0.0056	− 0.0278	0.0007	0.0001	− 0.0003
Precipitation	0.0021	0.0044	0.0003	0.0018	0.0006
Temperature SD	− 0.0425	− 0.0033	0.0011	0.0027	0.0038
Precipitation SD	− 0.0074	0.0017	− 0.0008	− 0.0001	0.0009
Altitude	− 0.0029	0.0008	0.0015	− 0.0011	0.0003
Slope	− 0.0003	0.0004	0.0003	− 0.0009	0.0001
Irrigation rate	0.0021	0.0203	− 0.0131	− 0.0034	0.0016
Cropland value	− 0.0259	− 0.0018	0.0071	0.0123	0.0020
Farm income	0.0211	− 0.0026	0.0031	0.0013	0.0010
Housing value	0.0069	− 0.0036	0.0051	0.0099	− 0.0011
Population density	0.0041	− 0.0093	− 0.0003	0.0061	− 0.0008
Share of agriculture ($t-1$)	0.7004	− 0.0503	− 0.0512	0.0492	− 0.0196
Share of grass ($t-1$)	− 0.0171	0.5037	0.2113	0.0105	− 0.0311
Share of forest ($t-1$)	− 0.0425	0.0524	0.5502	0.0025	− 0.0336
Share of urban ($t-1$)	0.0930	− 0.1900	0.0131	0.5628	− 0.0013
Share of water ($t-1$)	0.0421	− 0.0576	0.0250	0.0804	0.1301

The increase in land slope will also decrease the urban and agricultural share and increase the grassland, water and forest share. Precipitation directly affects agricultural and grassland share, and this effect is increased over time. Based on the positive and strong influence of farm income on farmland shares, designing supportive policies to increase farmers' revenue and mitigate the adverse effects of climate change on agriculture is recommended.

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