



Agricultural Land Abandonment in the Hill Agro-ecological Region of Nepal: Analysis of Extent, Drivers and Impact of Change

Yuba Raj Subedi¹ · Paul Kristiansen¹ · Oscar Cacho² · Roshan Babu Ojha¹

Received: 20 December 2020 / Accepted: 5 March 2021 / Published online: 17 March 2021
© The Author(s), under exclusive licence to Springer Science+Business Media, LLC, part of Springer Nature 2021

Abstract

Despite widely reported trends of agricultural land abandonment across many parts of the globe, this land use change phenomenon is relatively new in the context of Nepal. In recent years, rural farming communities in the hill region are gradually reducing the intensity of farming, leading to underutilisation and abandonment of agricultural lands. Adopting a mixed methods research approach, this study investigated the extent of agricultural land abandonment, its underlying causal drivers and perceived impacts in the hill agro-ecological region of Nepal. A structured survey of 374 households and six focus group discussions were carried out in three districts. The study revealed that around 40% of agricultural lands in the hill agro-ecological region have been abandoned and 60% of farmers have left at least one parcel of agricultural land abandoned. It was found that biophysical drivers (distance from homestead to parcel, slope of the parcel, land fragmentation, land quality and irrigation availability) and socio-demographic drivers (family size, higher education of the household members, domestic migration and out-migration) were responsible for agricultural land abandonment. Negative impacts of land abandonment were observed on the rural landscape, human-made farm structures, socio-economic systems, local food production and food security. In line with global studies, this research suggest that marginal land quality, demographic changes and rising alternative economic opportunities elsewhere contribute to farmland abandonment. This study also discusses land management approaches and policy implications to address the issue of agricultural land abandonment.

Keywords Farmland abandonment · Land use change · Driver · Farmer perception · Land management

Introduction

Agricultural land abandonment has been a common land use change in many parts of the globe since the 1950s (Gellrich and Zimmermann 2007; Li and Li 2017). The occurrence of farmland abandonment in the rural agricultural landscape has manifold effects on biodiversity, environment and human society (Ustaoglu and Collier 2018). Amid concerns of looming global land scarcity for

food production and rapidly increasing global food demand (Lambin and Meyfroidt 2011; Munroe et al. 2013), farmland abandonment is happening at an unprecedented rate in recent times (Alcantara et al. 2013; Li et al. 2018a). Thus, it has become crucial to explore the underlying factors of this land use change to adequately understand its diverse social and environmental trajectories.

Agricultural land abandonment has generally been defined as (a) a gradual process where farming intensity is decreased leading to underutilisation and reaching a stage where farming is completely terminated (Pazur et al. 2014; Sroka et al. 2019); and (b) a state of land which is left idle or unmanaged for a certain period with no indication that farming will occur in the future under existing circumstances (Shi et al. 2016; Rai et al. 2019). Different terminologies such as “farmland abandonment”, “cropland abandonment”, “abandoned agricultural land”, and “under-utilised agricultural land” are used interchangeably with “agricultural land abandonment” in the literature. Despite different terminologies, these terms embrace the same concept of agricultural land abandonment as defined above.

Supplementary information The online version contains supplementary material available at <https://doi.org/10.1007/s00267-021-01461-2>.

✉ Yuba Raj Subedi
yubarajsubedi@gmail.com

¹ School of Environmental and Rural Science, University of New England, Armidale, NSW 2351, Australia

² UNE Business School, University of New England, Armidale, NSW 2351, Australia

Studies have attempted to estimate the extent of abandonment and understand the underlying causal factors of agricultural land abandonment in different regions of the world. Land abandonment has been widely reported and studied across European and former Soviet Union states as compared to other parts of the world (Rey Benayas 2007; Li and Li 2017; Ustaoglu and Collier 2018). Across Europe, a study recorded 128.7 million hectares of abandoned farmland which comprised 24.4% of the total farmland within the period between 2001 and 2012 (Estel et al. 2015). In post-soviet Russia, more than 40 million hectares of agricultural land was found to be abandoned in the 20 years after the collapse of the Soviet Union in 1990 (Prishchepov et al. 2012; Munroe et al. 2013). However, in the United States, only 65 million hectares of abandoned lands were recorded across the entire U.S. from 1850 to 2016 (Yu and Lu 2018). Studies on farmland abandonment in Asian countries are relatively few (Li and Li 2017), with some studies conducted in the hilly and mountainous areas of China (Li et al. 2018a; Guo and Song 2019), Japan (Su et al. 2018) and Nepal (Ojha et al. 2017) reporting increasing farmland abandonment. In mountainous counties of China, Li et al. (2018a) estimated around 28% of abandoned croplands during the period of 2000–2010. Likewise, Su et al. (2018) estimated that the rate of farmland abandonment at a national level in Japan increased from 9.7 to 12.2% over the period of 2005–2015. Although the studies on land abandonment in Asian countries are limited, the existing state of knowledge on the extent of abandonment across different regions suggests that land abandonment is a prominent global land use change process which requires adequate studies.

The occurrence of farmland abandonment has been influenced by different factors, therefore investigation of underlying causal factors and their interaction is an important first step to understand future trajectories of farmland abandonment and options to minimise negative impacts. Global studies have suggested broadly seven categories of factors: demographic, household characteristics, farm characteristics, biophysical, economic, social-political and regulatory, as responsible for agricultural land abandonment. Factors such as migration and rural depopulation (Cvitanovic et al. 2017; Han and Song 2019; Sroka et al. 2019), availability of rural labor force (Zhang et al. 2018; Wang et al. 2020), household demography (Meyfroidt et al. 2016; Yan et al. 2016), farmers characteristics (Rai et al. 2019; Castillo et al. 2020), household economy (Terres et al. 2015; Yu et al. 2017), the interest of youth in farming (Blair et al. 2018; KC and Race 2020) are some commonly reported socio-economic drivers. Similarly, attributes such as accessibility to the farm or the remoteness of the farmland (Shi et al. 2018; Vidal-Macua et al. 2018), the slope of farmland (Zhang et al. 2014; Koleccka et al. 2017), soil

quality (Pazur et al. 2014), land fragmentation (Muller et al. 2009; Sikor et al. 2009), irrigation availability (Blair et al. 2018; Guo and Song 2019), wildlife encroachment and crop damage (KC and Race 2020) are a few prominent biophysical factors. As biophysical and socio-economic factors have been reported frequently in global studies, these categories of drivers of land abandonment tend to be considered more important compared to other categories of drivers such as socio-political and regulatory factors. However, the fact that some drivers have been less studied or reported does not mean they are less important. In practice, the importance of drivers may vary depending on when and where the land abandonment occurs. For instance, political factors such as changes in the political system of a region is not a common driver of farmland abandonment globally. Yet, this particular driver was a prominent reason for farmland abandonment in eastern European and former Soviet Union states (Kuemmerle et al. 2009; Prishchepov et al. 2012). Therefore, an understanding of drivers of land abandonment in the local context is crucial to develop effective and targeted land management approach.

Global studies have shown contrasting consequences of farmland abandonment on biodiversity, environment and society. In some situations abandoned farmlands provide habitat for multiple species and promote biodiversity (Beilin et al. 2014; Queiroz et al. 2014), experience improved soil properties, enable carbon sequestration (Novara et al. 2017; Werthebach et al. 2017) and reduce the risk of soil erosion and landslides by increasing surface cover (Cerdeja et al. 2019). However, negative consequences of abandonment are reported in a majority of studies. Some of significant negative impacts of agricultural land abandonment include degradation of farmland and farm structures (Chaudhary et al. 2020a), invasive plant and wildlife encroachment (Ojha et al. 2017; KC and Race 2020), risk of wildfire with the increased combustible fuel load (Sil et al. 2019), homogenisation of rural agricultural landscape and loss of locally valued traditional farming culture (Alix-Garcia et al. 2012; Cocca et al. 2012; Chaudhary et al. 2018), decline in local food production and risk of food insecurity (Ojha et al. 2017; Li and Li 2019), reduction in farm income and increased dependency on imported food (Khanal and Watanabe 2006; KC and Race 2020).

In the context of Nepal, farmland is one of the most important natural resources for the livelihoods of rural communities (Paudel et al. 2014). The possession of arable land is not only for food production but also to portray status in society and as an asset for future financial security (Gartaula et al. 2012). In recent years, rural farming communities are gradually reducing farming activities and farmlands are being left idle and unmanaged, particularly in the hill agro-ecological region (Ojha et al. 2017; Chaudhary et al. 2018; KC and Race 2020). A study conducted in the

Madi Municipality of Kaski district of Nepal with 240 farming households showed around 40% of studied households had at least one of their farm plots abandoned for more than two consecutive years (Khanal 2018). Similarly, a case study conducted in four districts (Kavre, Lamjung, Parvat and Pyuthan) of hill ecological region argue that 18–37% of agricultural land are abandoned in this region (Paudel et al. 2014). Another study conducted in a hill village of the Koshi River Basin recorded around 22% of the total farmland abandoned (Paudel et al. 2020). This trend of farmland abandonment has been viewed as a major threat to food security and agricultural development in Nepal.

Most of the farmlands on hill ecological region of Nepal are small and narrow terraces, which are spatially scattered across the undulated topography. A government report suggests that an average size of a farmland parcel in hill ecological region is 0.21 hectare and an average farmer owns four parcels of farmlands (CBS 2013). Due to the inheritance law for dividing land equally among sons, the rate of land fragmentation has increased and the average size of farm holdings have been decreasing gradually (Paudel et al. 2013; Dhakal and Khanal 2018). Shrinking farm size, scattered farmlands, fragmented landholding and physical constraints associated with harsh topography limit the possibilities for farm mechanisation, thus farmers rely predominantly on manual labour. In recent years, growing off-farm opportunities in urban areas of Nepal and abroad, have triggered a rural exodus and depopulation from the hills (Sunam and McCarthy 2016; Maharjan et al. 2020). This has created agricultural labour shortages leading to inadequate land management and underutilisation of arable lands (Jaquet et al. 2015; Ojha et al. 2017). Agricultural lands located far from the homestead, closer to forested land, or in places that are difficult to access are comparatively less likely to be cultivated in a situation of labour scarcity (Pazur et al. 2014; Vinogradovs et al. 2018).

The extent of land abandonment and its causal factors are likely to vary temporally and spatially across the regions. Physiographic diversity, variation in the socio-economic background of farmers, patterns of land use and agricultural practices uniquely differentiate the hill agro-ecological region from the rest of the country. An understanding of the drivers of abandonment will help to address the challenges and constraints associated with agricultural land management. Recent case studies in Nepal (Khanal and Watanabe 2006; Ojha et al. 2017; Schwilch et al. 2017; Khanal 2018; Chaudhary et al. 2019; Jaquet et al. 2019; KC and Race 2020), do not provide sufficient evidence to identify the main drivers of abandonment in the hill region, the reasons for abandonment, and its impacts on environment and society. This study addresses these knowledge gaps by adopting quantitative and qualitative research

approach. The ultimate objective is to contribute to evidence-based policies to address the issue of land abandonment and its consequences in hill agro-ecological region of Nepal.

Methods

Study Area

Nepal is divided into three agro-ecological regions running from east to west: the mountain to the north, the hill in the middle and the *Terai* to the south (Malla 2008; Khanal et al. 2018; MoAD 2020). This study was conducted in the hill agro-ecological region, as preceding studies have indicated a higher rate of farmland abandonment in that region and predict it to continue increasing into the future (Ojha et al. 2017; Khanal 2018; Paudel et al. 2020). The hill agro-ecological region lies from 610 to 4877 meters above sea level and comprises 42% of the country's total land (Manandhar et al. 2011). The climate in this region varies from sub-tropical to sub-temperate (Devkota et al. 1999). The region has steeply slope land with a number of small valleys and around 15% of this region is cultivated (Khanal et al. 2018). The distribution of human settlements in the hill agro-ecological region is largely uneven; the majority of people live in the relatively fertile valleys. The farmers of this region adopt diverse farming systems due to the topographical variability that provides ecological niches for diverse crop species. Agricultural crops, livestock and tree crops are the main components of a typical Nepalese hill farming system. Farming is done generally on two types of agricultural lands: lowland (known locally as *Khet*) is generally flat, relatively fertile with decent irrigation facilities, and upland (known locally as *Bari*) is generally terraced, rainfed and comparably less fertile than lowland. Due to their better quality in terms of clay content, nutrient and water retention ability, lowlands are generally used for growing at least 3–4 seasonal crops including cereal crops, leguminous crops, and cash crops such as vegetables, oil-seeds, potatoes etc. In contrast, usually two types of seasonal rainfed crops are grown on uplands annually.

Three districts: Kavrepalanchok (Kavre), Lamjung and Kaski were selected as representative districts of the hill agro-ecological region for the study (Fig. 1). These districts were selected as they depict the diversity of demographic and socio-economic status of farmers, land use and farming practices, economic opportunities and livelihood systems of the hill ecological region of Nepal (Cedamon et al. 2017; Ojha et al. 2017; Pandey 2019).

A multistage sampling procedure was adopted to select the study locations and participants. A consultation meeting was conducted with representatives of local government,

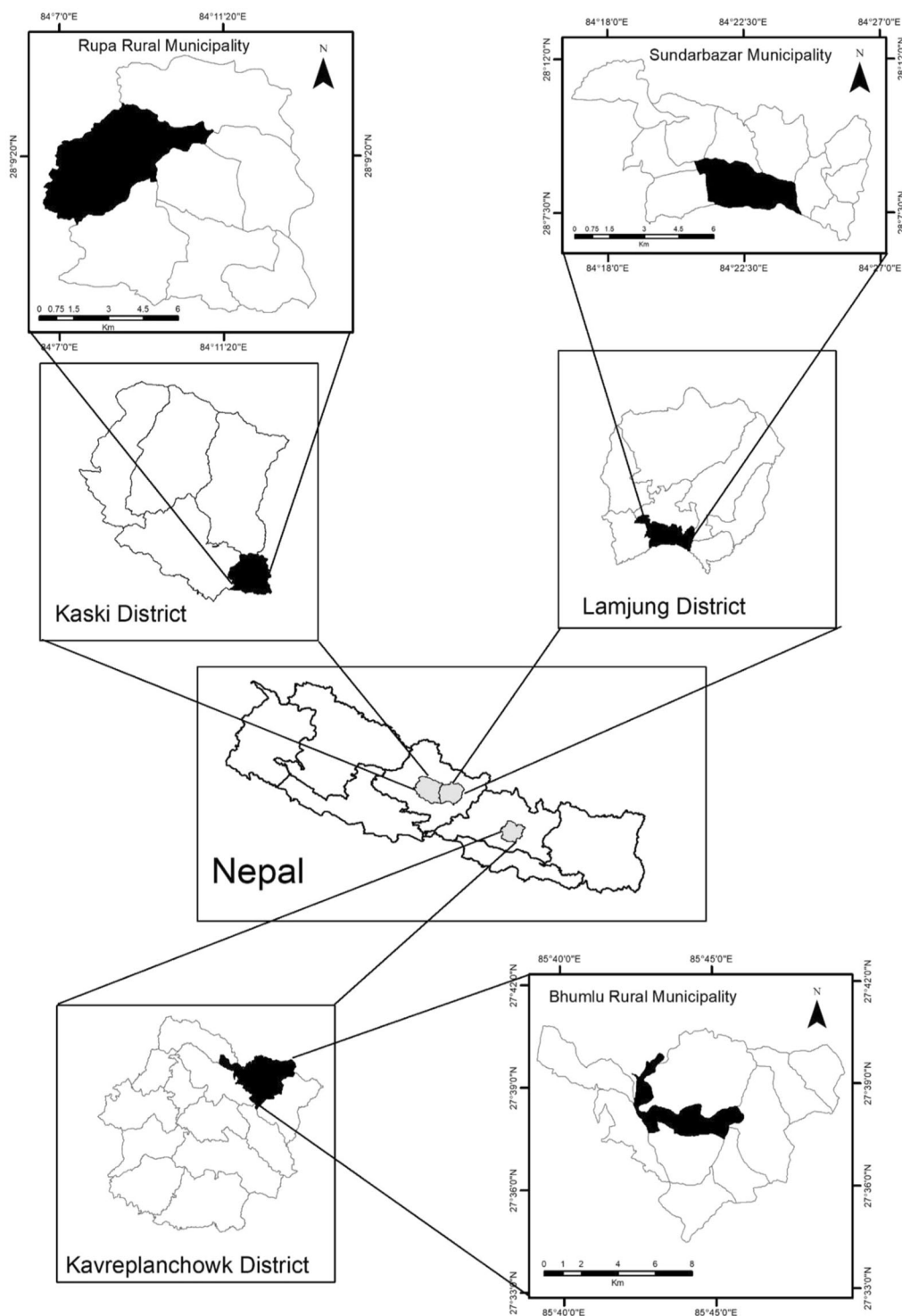


Fig. 1 Map of the study area in the hill agro-ecological region of Nepal

social groups, farmer groups and other key stakeholders of the district to delineate the study area in each district. The main purpose of the meeting was to identify the villages that have experienced farmland abandonment and to inform local communities about the objective of the study. After this

consultation, ward number 8 of Bhumlu Rural Municipality in Kavre district; ward number 6 of Rupa Rural Municipality in Kaski district and ward number 11 of Sundarbazar Municipality were selected for the study. Key characteristics of the study locations are presented in Table 1.

Table 1 Key characteristics of the study area

Characteristics	Description		
Name of the study area	Rupa	Bhumlu	Sundarbazar
Ward Number	6	8	2
District	Kaski	Kavrepalanchowk	Lamjung
Province	Gandaki	Bagmati	Gandaki
Elevation range (m) ^c	700–1280	1250–1750	700–980
Total area (km ²) ^a	95	91	72
Total households ^a	728	529	706
Total population ^a	2958	1885	2646
Male ^a	728	864	1127
Female ^a	1277	1021	1519
Accessibility			
Distance to country capital (km) ^b	193	65	168
Distance to district headquarters (km) ^b	21	37.5	23
Major five socio-demographic groups (%) ^a	Gurung (28.7), Chhetri (21.3), Musalman (15.6), Brahman (12.0), Magar (5.0)	Newar (23), Tamang (19.9), Majhi (17.3), Brahman (16.0), Chhetri (6.9)	Brahman (24.8), Chhetri (17.5), Newar (14.6), Sarki (12.2), Kami (9.4)

^aSource: (CBS 2017a, 2017b, 2017c)^bDistance estimated from 2020 Google map^cAuthors' field note

Data Collection

A mixed methods research approach was adopted to collect quantitative and qualitative data (Timans et al. 2019). Quantitative data was collected through a household survey and qualitative data was collected from focus group discussions (FGDs). Mixed methods are beneficial to provide a complete understanding of the research problem, which may not be detected from the data obtained merely from quantitative or qualitative research methods in isolation (Bhattacharjee 2012; Wisdom and Creswell 2013). A household survey questionnaire and a checklist of semi-structured questionnaires for FGDs were developed from an intensive review of the literature. The fieldwork and data collection were undertaken from September to November 2019. This study was approved by the Human Research Ethics Committee of the University of New England, Australia (Approval No HE19-162).

Household survey

A standardised set of questionnaires was prepared to capture responses through face-to-face interviews. Lists of households and contact details were obtained from the municipality office. Simple random sampling was carried out to obtain the sample households from the full list in each study

site. In total 374 sample households were selected, comprising 125 households from Bhumlu, 125 from Rupa and 124 from Sundarbazar. The head of each selected household was contacted by telephone to request voluntary participation in the study. If the household head was not available for the interview, another available adult member of the household was requested. A convenient time and venue in the nearest public place were arranged for the meeting for those who agreed to participate. Interviews were conducted on a paper-based questionnaire, which was developed in the local (Nepali) language and around 40–45 min was required to complete one questionnaire. The questionnaire was pre-tested with ten households of Bhumlu village to examine the clarity of the questions and some minor revisions were carried out before starting the survey.

Broadly, the household survey covered five sections: A. basic household demographics and characteristics, B. household economy and social capital, C. land ownership and land use, D. reasons for and consequences of agricultural land abandonment, and E. present conditions and future of abandoned agricultural land.

Focus group discussion

Six FGDs, two in each study area, were conducted with a homogenous group of 6–8 respondents. Respondents were

farmers with or without abandoned land and members of social groups such as farmer groups, forest user groups and cooperatives. The list of social groups/organisations present in the research site was obtained from the municipality office. Only social groups related to the field of agriculture were selected. An invitation letter was sent to the contact person of the social group requesting to convey the message to the members of the group to take part in the group discussion. The participants were randomly selected from the list of interested members and they were provided with the information sheet and consent sheet for participation. The group discussions were conducted in the local (Nepali) language, facilitated by the lead author and were ~1 h in duration. The small group size meant that all participants were able to have some input at all stage of the discussion. All group discussions were audio-recorded.

Data Analysis

Survey data were coded in Excel sheets and descriptive analysis was conducted to estimate the status and condition of agricultural lands. Further statistical analyses were carried out in R-Studio (R-Studio Team 2020). Principal component analysis (PCA) was employed to identify the relationship between independent and explanatory variables and binary logistic regression analysis (BLR) was conducted to analyze the drivers of agricultural land abandonment in the study area. Ordinary linear regression was not appropriate because the dependent variable is binary. Before building the BLR model, the multicollinearity of independent variables was tested using the Spearman rank correlation. The correlation between the predictors was found to range from low ($R = \pm 0.01$) to moderate ($R = -0.47$ to 0.65). The variance inflation factor of the predictors was below 4. Since significant multicollinearity was not detected, all the 24 independent variables were included in the model to estimate the drivers of land abandonment. The BLR model is defined as:

$$\ln \left[\frac{p}{1-p} \right] = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \dots + \beta_n x_n \quad (1)$$

where, $\left[\frac{p}{1-p} \right]$ is the odds ratio and p is the probability of a household displaying agricultural land abandonment, β_0 is the model constant and the coefficients β_1, \dots, β_n indicate the effect of each independent variable on the log of the odds ratio. The value of $\ln \left[\frac{p}{1-p} \right]$ is negative when $0 < p < 0.5$ and positive when $p > 0.5$. The accuracy of the model was determined by computing the ratio of the mean of the predicted values to the observed values and the pseudo R^2 of

the model was calculated using McFadden's and Nagelkerke's R^2 values.

The dependent variable in the model, agricultural land abandonment, was assigned a value of 1 if the household had at least one parcel of abandoned agricultural land and 0 if it did not. For ease of interpretation explanatory variables were grouped into socio-demographic, economic, biophysical, and farm resource variables (Table 2). A detailed explanation behind the expected signs of coefficients for each variable is presented in the Supplementary Materials (Table S1).

Results

Socio-demographic Characteristics of Households

Among the 374 surveyed households, 74% of the respondents were male and the average age of the respondents was 53, with average 31 years of experience in subsistence farming. Over 70% of the sampled households have lived in the village for more than three generations. In the full sample 38% of respondents were just literate with no formal education, with some variation between the three study areas (33–46%). whereas only 6% had completed a higher education degree.

The primary occupation of 61% of the respondents was agriculture and although the average household size was 6.6, only around 35% of household members were actively engaged in agricultural work. The average landholding was 0.70 hectare, which is similar to the national average for Nepalese farmers of 0.79 hectares (CBS 2014a; Chaudhary et al. 2020b).

In the case of migration, more than 75% of the households have at least one family member living out of the village. Among migrant households ($n = 287$), 56% had at least one family member living within the country but away from the village whereas 44% households had at least one family member living outside the country. In contrast, an insignificant number of immigrant households were recorded in the study area.

Though draft animals still have an important role in hill farming, only 8.5% of households own draft animals. The average livestock holding per household was 2.28 livestock standard units, with goats being the most common species. On average cattle holding was only 1.4 head, whereas goat holding was 6.0 head per household. More than 85% of the farmers were involved in subsistence farming whereas only 4% were involved in poultry and goat-based commercial farming. The detailed household information is presented in the Supplementary Materials (Table S2).

Table 2 Description of variables used in the logistic regression model and anticipated positive (+) or negative (–) relationship to agricultural land abandonment

Variable	Variable description	Variable type	Anticipated relationship
Age	Age of the decision-making household member (respondent) of the household in years	Continuous	+
Family size	The number of economically active members (above 18 years old) in the household	Continuous	–
Higher education	Highest level of male and female education in the household in years	Continuous	+
Migrant household	A household with at least one migrant member (1 if yes, 0 otherwise)	Dummy	+
Domestic migration	Number of family members living outside the village but within the country	Continuous	+
Out-migration	Number of family members living outside the country	Continuous	+
Farming interest	The interest of the younger generation to continue agriculture as their primary occupation (1 if interested, 0 otherwise)	Dummy	–
Farm income	Change in agricultural income in the household economy in last 10 years (1 if it increased, 0 otherwise)	Dummy	–
Off-farm income	Change in non-agricultural income in the household economy in last 10 years (1 if it increased, 0 otherwise)	Dummy	+
Income diversity	Number of off-farm income sources for the household	Continuous	+
Livestock holding	Total number of livestock, in livestock standard units	Continuous	–
Total landholding	Total land holdings of the household in ha	Continuous	+
Subsistence farming	Involvement household in subsistence or commercial farming (1 if subsistence, 0 if commercial)	Dummy	+
Distance to parcel	Distance between home and parcel in minutes	Continuous	+
Distance to road	Distance between parcel and nearest road in minutes	Continuous	+
Land fragmentation	The total number of scattered parcel holdings of a household	Continuous	+
Irrigation	Availability of irrigation (1 if present, 0 if absent)	Dummy	–
Parcel slope	The slope of the parcel (1 if steep land, 0 otherwise)	Dummy	+
Land quality	Land quality (1 if <i>Chahar</i> (poorest land quality), 0 otherwise)	Dummy	–
Draught animal power	Possession of draught animal for ploughing (1 if yes, 0 otherwise)	Dummy	+
Finance	Access of a household to finance (1 if yes, 0 otherwise)	Dummy	–
Market distance	Distance from households to market in km	Continuous	+
Service office distance	Distance from the household to service offices in km	Continuous	+
Training and extension	Any training, capacity building, exposure visit related to agriculture received by any family member of a household (1 if yes, 0 otherwise)	Dummy	–

Table 3 Farmers' response to the possession of at least one abandoned agricultural parcel by the household in the hill ecological region of Nepal

Statement	Response	Hill region	Study area		
			Rupa	Bhumlu	Sundarbazar
Own at least one parcel of abandoned farmland	Yes, %	60.8	60.5	59.7	62.1
	No, %	39.2	39.5	40.3	37.9
	Total (<i>n</i>)	372	124	124	124
Change in total farmland in the last 5 years	Increased, %	5.3	4.1	3.4	8.5
	Decreased, %	24.3	19.0	32.8	21.2
	No Change, %	70.4	76.9	63.9	70.3
	Total (<i>n</i>)	358	121	119	118

Status of Agriculture Land Use and Abandonment

Around 60% of households, with a narrow range of 59.7–62.1% for the three study locations, have at least one abandoned agricultural land parcel (Table 3). On average,

each household abandoned 0.31 of their total agricultural landholdings. The size of agricultural landholdings did not change significantly for the majority of households involved in the study over the last 5 years (Table 3), with 70% of farmers reporting no change, only 5% reporting that they

have increased their land area, and 24% reporting that their aggregate land holding area has decreased.

In total, around 40% of agricultural lands (263 hectares) were abandoned, ranging from 31.5 to 48.9% depending on the location in the hill agro-ecological region (Table 4). Among these abandoned lands, more upland areas (42.5%) were abandoned than lowland areas (38.8%). These findings are in line with previous case studies (Khanal and Watanabe 2006; Rai et al. 2019) that were conducted in some districts (Kaski, Nuwakot, Lamjung, Baglung, Rasuwa) of the hill agro-ecological region of Nepal.

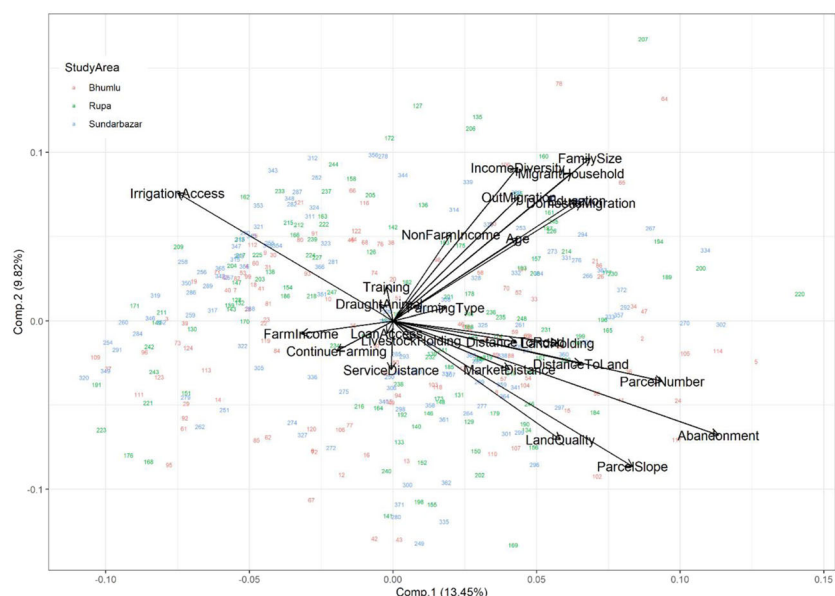
Drivers of Agricultural Land Abandonment

Principal component analysis (PCA) suggested that biophysical factors are strongly correlated to agricultural land abandonment whereas socio-demographic and economic

Table 4 Status of lowland and upland agricultural lands in the hill ecological region of Nepal

Land category	Hill region	Study area		
		Rupa	Bhumlu	Sundarbazar
Lowland (ha)	142	51.2	38.4	53.1
Cultivated land, %	61.2	52.0	52.7	76.4
Abandoned land, %	38.8	48.0	47.3	23.6
Upland (ha)	121	40.4	44.2	36.2
Cultivated land, %	57.5	66.7	49.7	56.9
Abandoned land %	42.5	33.3	50.3	43.1
Total Land (ha)	263	91.6	82.5	89.3
Total cultivated land, %	59.5	58.4	51.1	68.5
Total abandoned land, %	40.5	41.6	48.9	31.5

Fig. 2 Principal component analysis of the factors of agricultural land abandonment in the hill ecological region of Nepal



factors are moderately correlated (Fig. 2). Biophysical factors like parcel slope, land fragmentation, land quality and distance to land showed a strong positive correlation to farmland abandonment. In contrast, availability of irrigation has a strong negative correlation to farmland abandonment. Socio-demographic variables including age of respondent, family size, household with migrant, higher education, domestic migration and out-migration, as well as economic variables, particularly off-farm income and diversity, showed moderate correlation to farmland abandonment. Finally, the majority of farm resource factors did not show any correlation to farmland abandonment. It is noteworthy that there were no apparent differences between the three study areas, with data points being evenly spread across the biplot (Fig. 2).

Regression analysis with the BLR model suggested that farmland abandonment in the hill region of Nepal is greatly influenced by biophysical and socio-demographic factors compared to economic and farm resource factors (Table 5). Some of the economic variables that were moderately correlated to farmland abandonment in PCA analysis, were not found significant in BLR analysis. Land fragmentation ($p = 0.000$), distance between home and parcel ($p = 0.002$), availability of irrigation ($p = 0.001$), slope of the parcel ($p < 0.000$), and poor land quality of the parcel ($p = 0.006$) were highly significant biophysical factors responsible for land abandonment. Similarly, size of the family ($p = 0.048$), education level of the household members ($p = 0.028$), domestic migration ($p = 0.036$), and out-migration ($p = 0.020$) were significant socio-demographic factors that are responsible for farmland abandonment in the hill region. Economic factors and farm resource variables were not found to be significant for determining farmland

Table 5 List of variables used in the binary logistic model and the results of the regression analysis for the hill ecological region of Nepal

Independent variables	BLR model results for the hill region				
	β	SE	Wald (χ^2)	Exp (β)	Sig. (p)
<i>A. Socio-demographic variables</i>					
Age of the respondent	−0.020	0.022	0.839	0.980	0.360
Family size of the household	−0.265	0.134	3.93	0.767	0.048*
Higher education of household members	0.201	0.092	4.83	1.22	0.028*
Household with at least one migrant member	−0.898	0.696	1.66	0.407	0.197
Domestic migration	0.332	0.158	4.41	1.39	0.036*
Out-migration	0.687	0.296	5.37	1.99	0.020*
Interest of younger members in farming	0.011	0.535	0.000	1.01	0.983
<i>B. Economic variables</i>					
Increase in farm income	−0.115	0.879	0.017	0.891	0.896
Increase in off-farm income	0.115	0.552	0.043	1.12	0.835
Income diversity	−0.377	0.388	0.946	0.686	0.331
Livestock holding	−0.175	0.141	1.53	0.840	0.216
Total landholding	0.000	0.000	0.169	1.00	0.681
Subsistence type of farming	−0.053	0.765	0.005	0.948	0.945
<i>C. Biophysical Variables</i>					
Distance between home and parcel (minutes)	0.062	0.020	9.69	1.06	0.002**
Distance between parcel and motorable road (minutes)	0.043	0.030	2.07	1.04	0.150
Land fragmentation	2.199	0.448	24.13	9.01	0.000***
Availability of irrigation	−1.986	0.579	11.76	0.137	0.001***
Slope of the parcel	4.363	0.918	22.60	78.47	0.000***
Poor land quality of the parcel	3.026	1.098	7.60	20.6	0.006**
<i>D. Farm resource variables</i>					
Draught animal possession for ploughing	0.210	0.701	0.090	1.23	0.765
Access to agricultural loan	−0.984	0.762	1.67	0.374	0.197
Distance from home to market (km)	−0.050	0.064	0.614	0.951	0.433
Distance from home to nearest service office (km)	−0.029	0.029	1.05	0.971	0.307
Agricultural training received by any family member	−0.070	0.561	0.016	0.932	0.900
Number of observation (n)	372				
Model constant	−4.164	1.882			
Model Accuracy	92.740				
McFadden R^2	0.752				
Nagelkerke R^2	0.860				

β is the estimated coefficient of the model; SE is the standard error; Wald (chisq) is the Wald test (chi-squared) values; Exp (β) is the odds ratio; Sig. (p) is significance level (indicated by P value), R is the coefficient of determination, and with an asterisk (* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$) the value is significant and without asterisks, the value is not significant

abandonment. Similarly, the effect of research location on farmland abandonment was also found insignificant ($p = 0.924$).

The regression results in Table 5 indicate the direction and magnitude of the effects of independent variables on land abandonment. Figure 3 shows the average marginal effects of explanatory variables on agricultural land abandonment. These marginal effects indicate the percent change in probability of land abandonment associated with a change in the explanatory variable. Results suggest that the probability of steep agricultural land being abandoned is

around 20% higher than for flat agricultural land. Similarly, farmland with poor land quality has around 15% more chance of being abandoned than other land. The probability of agricultural land being abandoned rises by around 10% with the increase in land fragmentation (i.e. the number of scattered parcel holdings owned by a household). Moreover, the probability of farmland abandonment increases by a small margin (<5%), if the number of domestic or abroad migrants in a household is increased.

In contrast, the probability of farmland being abandoned decreases by around 10% if the farmland has access to

Fig. 3 Average marginal effects of variables on the farmland abandonment in the hill ecological region of Nepal. Error bars represent 95% confidence interval of marginal effects. Red error bars represent the contributing variables that positively influence the agricultural land abandonment, yellow bars for neutral influence and green bars for negative influence to agricultural land abandonment

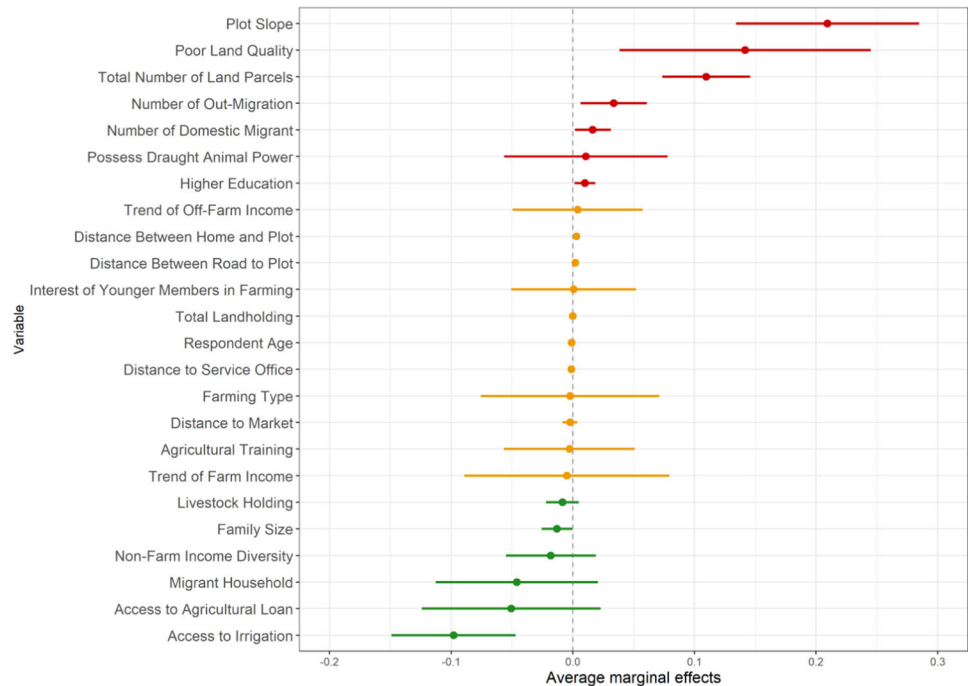
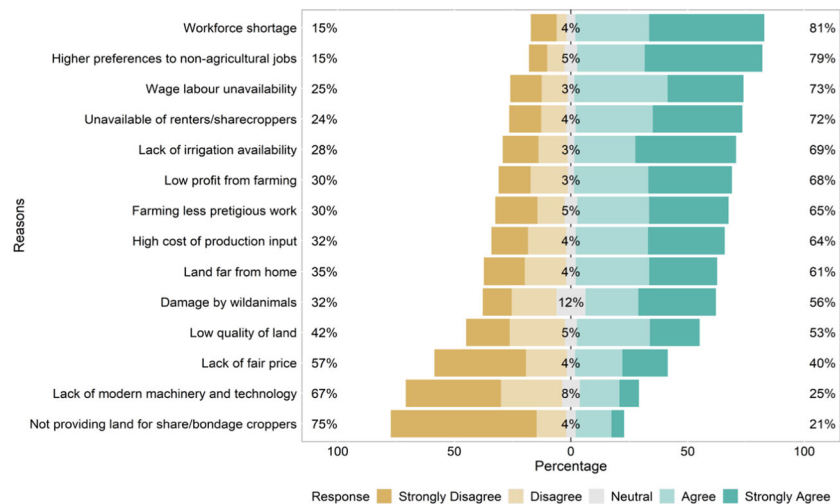


Fig. 4 Farmers' perceived reasons for agricultural land abandonment in the hill ecological region of Nepal ($n = 369$). The numbers on the left, centre and right indicate the proportion of responses for Disagree/Strongly Disagree, Neutral and Agree/Strongly Agree respectively for each reason



irrigation throughout the cropping seasons. Similarly, the probability that agricultural land is abandoned decreases by around 5% if the household has access to agricultural loans or has at least one household migrant that supports the household through remittances. However, the effects of these last two variables are not significant ($p > 0.1$).

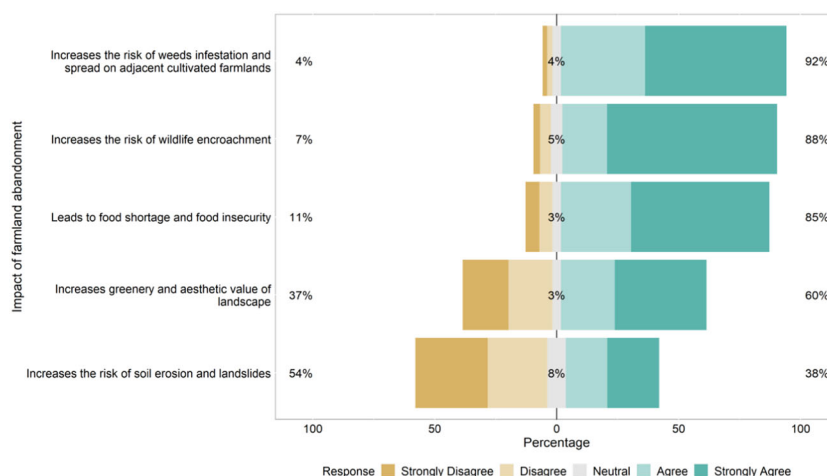
Perceived Reasons For and Impacts of Agricultural Land Abandonment

The group discussions provided comprehensive lists of reasons that farmers felt were responsible for causing agricultural land abandonment, as well as the perceived

impacts. In the household survey, farmers were asked to specify their level of agreement with these reasons and impacts using a 5-point Likert scale. Based on “agree” and “strongly agree” responses, the key perceived reasons for agricultural land abandonment (Fig. 4) were shortage of household agricultural workforce due to the migration (81%), higher preferences of family members, particularly younger household members, for non-agricultural jobs as compared to farming (79%), unavailability of wage labor during the farming seasons (72%), and unavailability of renters or sharecroppers in the village (72%).

Agricultural factors were also perceived to influence land abandonment. Particularly lack of irrigation (69%), low

Fig. 5 Farmers' perceptions of the impacts of agricultural land abandonment in the hill ecological region of Nepal ($n = 369$). The numbers on the left, centre and right indicate the proportion of responses for Disagree/Strongly Disagree, Neutral and Agree/Strongly Agree respectively



farm profit (68%), farming becoming a less prestigious job (65%), high cost of agricultural inputs (64%), farmland located far from the home (60%), farmland being prone to damage by wild animals (56 %) and low land quality (52%).

Based on “disagree” and “strongly disagree” responses, weak reasons for agricultural land abandonment were lack of willingness of landowners to lend their uncultivated parcels to share/bondage croppers (76%); lack of modern farm tools, machinery and technology (67%); and lack of fair price for agricultural products (57%).

Based on “agree” and “strongly agree” responses, the key perceived impacts of agricultural land abandonment (Fig. 5) were weed infestation (92%), wildlife encroachment (88%) and reducing food security (85%). Farmers' views about the impacts of agricultural land abandonment on increasing ‘greenery’ and risks of soil erosion and landslides were somewhat ambivalent. Most farmers noted increased greenery (60%) but were not concerned about erosion/landslides (54%), while many disagreed with those views.

Present Condition and Future of Abandoned Farmland

On average, farmlands that are being abandoned in the sample are 6.7 years old; ranging from 6.3 to 7.4 years (Table 6). Once farming stops, the abundance and type of natural vegetation observed is influenced by the quality of the land. The majority of abandoned agricultural lands in the hill region are covered with bushes (40%) followed by grass (30%) and trees (11%). Likewise, around 6% of the abandoned farmlands were reported to be completely bare, with no vegetative cover at all. Although these lands were not being farmed, many landowners used them for collecting fodder (51%), along with different combinations of fodder, firewood and timber, but almost 33% were left completely unused (Table 6). Grass species such as

Table 6 Present condition and use of abandoned agricultural lands in the study area and hill ecological region of Nepal

Statement	Hill region	Study area		
		Rupa	Bhumlu	Sundarbazar
Average abandoned period (years)	6.7	7.4	6.5	6.3
Present condition of abandoned agricultural land, %				
Bare	6.2	2.8	3.8	11.8
Bush	39.6	35.8	28.8	53.6
Grass	30.3	22.0	46.2	23.6
Tree	11.1	18.3	12.5	2.7
Bush and Tree	6.2	9.2	4.8	4.5
Grass and Bush	5.0	11.0	1.9	1.8
Other	1.5	0.9	1.9	1.8
Total response (n)	323	109	104	110
Current use of abandoned agricultural land, %				
Fodder	51.1	48.1	60.0	45.5
Firewood	2.6	6.3	1.3	0.0
Timber	0.9	0.0	0.0	2.6
Firewood and Timber	1.3	1.3	0.0	2.6
Fodder and Firewood	8.7	12.7	2.7	10.4
Fodder and Firewood and Timber	3.0	1.3	2.7	5.2
No use	32.5	30.4	33.3	33.8
Total response (n)	79	75	77	231

Imperata cylindrical (Siru), *Cynodon dactylon* (Dubo), *Bidens biternata* (Kuro), *Arundinella nepalensis* (Musekhari), *Artemesia vulgaris* (Titepati), *Eupatorium adenophorum* (Banmara) and tree species such as *Schima wallichii* (Chilaune), *Alnus nepalensis* (Uttis), *Castanopsis tribuloides* (Katus) etc. were most commonly found in the abandoned farmlands.

More than 85% of landowners of abandoned farmlands reported they do not want to sell them, and a vast majority

Table 7 Response of farmers on abandoned farmlands in the different study area of the hill ecological region of Nepal

Statement	Response	Hill region	Study area		
			Rupa	Bhumlu	Sundarbazar
Planning to sell abandoned farmland soon	Yes, %	13.6	8.1	15.6	17.3
	No, %	86.4	91.9	84.4	82.7
	Total (n)	213	74	64	75
Should abandoned agricultural lands be brought back into productive use	Yes, %	92.3	88.4	97.4	91.2
	No, %	7.7	11.6	2.6	8.8
	Total (n)	339	112	114	113
Faced any legal problems or social trouble for keeping arable agricultural lands abandoned	Yes, %	2.8	1.4	2.7	4.3
	No, %	97.2	98.6	97.3	95.7
	Total	212	69	74	69
Received any services from government or non-government institutions for reutilisation of abandoned farmlands	Yes, %	3.0	6.5	0.0	2.6
	No, %	97.0	93.5	100	97.4
	Total (n)	231	77	77	77

(92%) believe that they should be brought back into productive use. Since the occurrence of farmland abandonment is a relatively new phenomenon in the area, around 97% of landowners stated that they have not faced any social or legal problems for keeping their arable farmlands uncultivated. The same number of respondents indicated that they have not received any support or services from government or non-government institutions for reutilisation of abandoned farmlands (Table 7). These responses show that this land use change has not only raised concerns about the future of agriculture but also suggests possibilities of new opportunities.

Discussion

Extent, Drivers and Dynamics of Agricultural Land Abandonment

Despite agriculture still being an integral part of rural communities and one of the major sources of livelihood, it was found that more than 50% of hill farmers interviewed have abandoned land, on average, one-third of their total agricultural land has been abandoned. The extent of abandonment was higher in the uplands than in the lowlands. Given the labour force shortage, most farmers have begun to prioritise certain land parcels rather than attempting to cultivate all their arable parcels. They tend to cultivate parcels that are closer to the homestead, relatively fertile and productive. This means uplands that are mostly rainfed and least productive are left uncultivated early whereas lowlands with good irrigation and relatively more productive land are kept under cultivation. In some cases, even lowlands were abandoned, if they were far from home and adjacent to the forest edge (i.e. near community forest) despite their productivity.

There were no statistically significant differences in the drivers of agricultural land abandonment among the three study areas, suggesting that the drivers and responses are very consistent throughout the hill ecological region. Results indicated that biophysical and socio-demographic drivers are significantly responsible for agricultural land abandonment in the hill ecological region.

Among biophysical factors, accessibility and slope of the parcel, land fragmentation, land quality, and availability of irrigation were the most significant drivers of abandonment. The hill region has geographical limitations due to harsh and undulating topography, hence biophysical features play important roles directly or indirectly in influencing farmers' decision to continue or cease farming. In line with global studies like Zhang et al. (2016), Koleccka et al. (2017) and Vinogradovs et al. (2018), this study also found that agricultural parcels that are located away from farmers' homestead were more likely to be abandoned. Previously, when there used to be sufficient workforce within most households, farmers used to manually transport agricultural inputs such as farmyard manure, seeds, and fertilisers. However, with the shortage of labour, the more distant parcels do not get the same priority as parcels located near the homestead.

Results also indicated steep agricultural lands have a higher risk of abandonment. Steeper lands are relatively more difficult to farm and are deprived of the possibility of farm mechanisation in the future (Vidal-Macua et al. 2018). Moreover, terraces on steep farmland need regular maintenance to reduce the risk of losing topsoil during rainy seasons. Global studies have shown steep farmlands have a higher risk of soil erosion and landslides (Lasanta et al. 2001; Pepe et al. 2019). Therefore, steeper farmlands, which are ecologically fragile, are more likely to be abandoned first and may become unsuitable for farming quickly, compared to relatively flat farmlands.

Similarly, land fragmentation was another important biophysical factor responsible for farmland abandonment. This is consistent with previous studies that have reported land fragmentation and scattering of farm parcels are more likely to be abandoned (Sikor et al. 2009; Yan et al. 2016). Fragmentation not only decreases the size of the land parcels but also reduces production efficiency by limiting the possibilities of farm mechanisation (Niroula and Thapa 2007; Dhakal and Khanal 2018).

In group discussions, farmers stated that farmlands that were abandoned earliest are mostly poor quality land. Low quality lands require considerable human and capital investments to make them suitable for farming (Suziedelyte Visockiene et al. 2019). In many cases, despite considerable investments, there might not be satisfactory returns. In hill farming, farmyard manure plays a very important role in maintaining soil nutrients and fertility. However declining livestock holdings reduce the production of farmyard manure (Thapa and Paudel 2002). The available manure is primarily applied to the parcels closer to the homestead. This situation has created the enabling environment for the degradation of farmlands that are located far from the homestead. A case study conducted in Latvia also showed the occurrence of farmland abandonment was strongly associated with low land quality, proximity to forest edge and distance between farmland and homestead (Vino-gradovs et al. 2018).

In contrast, farmlands that have good irrigation are less likely to be abandoned compared to parcels that did not have access to irrigation. It was found that the probability of abandonment would decrease by around 10% if the farmland has access to irrigation. This indicates that investment in irrigation infrastructure and improving farmers' access to irrigation could help curtail the extent of abandonment.

Apart from biophysical features, family size, higher education, and household migration were found as the main socio-demographic drivers of farmland abandonment in the hill region. In line with previous studies (Yan et al. 2016; Su et al. 2018), this study found that households with larger family sizes are less likely to abandon their farmlands, as they tend to have more labour available for farming.

Similarly, households that have members with higher education were more likely to abandon their farmland. Discussion with the farmers revealed that younger members of the household, who have higher education, usually prefer to pursue off-farm employment in the field of their education. There are two main reasons rural people with higher education generally prefer not to be involved in farming. First, existing farming practices have been proven insufficient for sustaining livelihoods and farming does not ensure households' financial security; and second, the social mindset that farming is only done by uneducated people who are unable to find lucrative off-farm and professional

employment (Jaquet et al. 2019). This implicit social reality has discouraged the younger generation from adopting farming as their profession. CBS (2014b) has recorded that, among 2.4 million lifetimes migrant population in the national census of 2011, 32.3% of the rural population migrated to urban regions. Recent studies have also indicated higher trends of youth migration from rural regions to Terai and urban regions for employment with partner and children (Brøgger and Agergaard 2019; IOM 2019). Therefore, often elderly people, with less ability to undertake laborious agricultural work, are the only ones remaining in the village nowadays (KC and Race 2020).

Migration has been found to have a strong positive relation to farmland abandonment (Xu et al. 2019a; Maharjan et al. 2020). Studies have suggested that increasing off-farm opportunities in urban areas and overseas for educated and skilled labour have propelled rural migration in Nepal as well as other mountainous countries (Jaquet et al. 2019; Maharjan et al. 2020). Rural migration not only creates labour force shortage for farming but also reduces the necessity for other household members to carry-on farming to fulfil their basic livelihood needs. The remittances received from migrant members provide economic security to the household, thus they are less compelled to work on the farm (Ojha et al. 2017).

In contrast to previous studies that identified economic attributes as important drivers for agricultural land abandonment in other countries (Sroka et al. 2019; Xu et al. 2019b), this study found that economic attributes were not significant drivers of land abandonment in the hill region of Nepal. This could be due to the nature of the farming systems that prevail in the region. The majority of households are involved in subsistence farming and most of their farm products are consumed within the household. Therefore, a farmer's decision to continue or completely terminate farming is greatly influenced by subsistence reasons rather than only economic reasons.

It is obvious that several drivers and their outcomes are interlinked, suggesting land abandonment is the outcome of the interaction of multiple factors. It is important to note that factors which are not significant at a particular time and place could emerge strongly at other times and places. Thus, it is equally important to keep track of the potential drivers that may not have a significant role currently. Ojha et al. (2017) argue that farmland abandonment is a dynamic process that cannot be understood by investigating isolated causal drivers or ignoring the context of their influence. It follows that we need to investigate not only 'what' factors are causing farmland abandonment but also 'how' the causal factors are changing over time. As the drivers of abandonment and the magnitude of the drivers may vary considerably across different regions and periods investigating them in different geographical and socio-economic

context is crucial to understand the issue holistically (Levers et al. 2018). The findings of this study contribute to the global knowledge related to drivers of land abandonment and support to develop focused land management program and policy particularly for the mountainous countries with the regions that have similar agroecology of Nepalese hill region.

Agricultural Land Abandonment: Consequences and Management Opportunities

In the early years of abandonment, the collapse of human-made farm structures such as terrace walls, irrigation canals, drainage canals and earthen roads (prominently used for agricultural input and product transportation) was noticed in the study regions. It appears that these labour-intensive farm structures were hardly managed after the abandonment of the land, as a result, most of the terraces were found damaged by debris carried by rainwater and accumulated in terrace walls. This has triggered sinkholes and gully formation in some of the abandoned terraces. This degradation process due to farmland abandonment was also recorded by Chaudhary et al. (2019) in the mountainous region of western Nepal. Although the perceptions of farmers suggest they were ambivalent about the impact of land abandonment on soil erosion and landslides, in the long run, these threats are likely to increase on land with steep slopes and high rainfall intensity (Lasanta et al. 2001; Pepe et al. 2019).

Abandoned farmlands in this study were predominantly covered by unmanaged grasses and bushes. On one hand, this natural regeneration and colonisation of abandoned farmlands have positive impacts on biodiversity, by expanding habitat and food availability for different plant and animal species (Beilin et al. 2014). On the other hand, unmanaged regeneration also creates a favourable environment for farm pests and wild animals (Ruskule et al. 2013). Farmers argue that populations of monkeys, bears and rodents (such as porcupine and mice), have increased considerably after land abandonment in the village vicinity. It has become challenging to inspect plots regularly and prevent farmlands distant from the homestead from becoming invaded by wildlife. Moreover, farmers who cultivate parcels adjacent to unattended farmlands reported that they have experienced loss in farm production due to the damage caused by wildlife and pest encroachment. Discussions with members of the local communities indicated that the number of weed species has considerably increased due to farmland abandonment and expect that the encroachment of weeds will spread over the adjacent cultivated farmlands in the study area, if not adequately managed. The impacts of this phenomenon are twofold: (a) low production resulting from weeds, pest and wildlife encroachment has negative economic consequences and (b)

comparatively more time and resources are required for farm operation and management. These dynamics have discouraged farmers who own farmlands adjacent to abandoned parcels to continue farming them. Given this reinforcing trend, farmers expect that, if this issue is not addressed soon, increasingly more farmlands will be abandoned in other parts of the hill region of Nepal.

Local farming practices, social cohesiveness and social systems in the hill region have been greatly impacted by the process of land abandonment. The labour exchange system, locally known as *Parma*, is one of the important integral parts of Nepalese farming and most common in the hill region (Messerschmidt 1981). In recent years, this local practice is gradually disappearing with the decline in farming activities (KC and Race 2020). This has not only decreased the overall availability of the labour force in the region but also has jeopardised the practice of working collectively at the community level. Chaudhary et al. (2018) also recorded the disappearance of social practices such as maintenance of water sources, irrigation canals, earthen roads etc., that used to happen collectively in rural communities. In the absence of farming successors, traditional farming skills and knowledge might vanish (KC and Race 2020). Without doubt, the decline in the total farming area due to land abandonment has prominent effects on overall local food production and food security (Ojha et al. 2017). As the majority of landowners are reluctant to sell their abandoned farmland and also agree that these abandoned lands should be reutilised, this provides opportunities to rethink, evaluate and adopt other land management options that are suitable for the hill ecological region (Ruskule et al. 2013).

The broader consequences observed in this study show a similar pattern of socio-environmental consequences of farmland abandonment experienced in mountainous regions of European countries (MacDonald et al. 2000; Ustaoglu and Collier 2018). Despite some positive impacts of land abandonment on biodiversity, largely negative impacts of abandonment have been documented at the global level (Benayas et al. 2007; Li and Li 2017). Therefore, focused post-abandonment management strategies are required to prevent farmland from degradation, bring abandoned land into productive use and address the growing demand for food and bioenergy globally (Bell et al. 2020). Moreover, such management strategies should have socio-economic and environmental advantages as the adoption of management options is influenced by the willingness of the landowners and type of the abandoned farmland (Benjamin et al. 2008). In many cases, not only degraded farmlands but also relatively productive farmlands are being abandoned due to remoteness and shortage of household workforce. Therefore, consideration of biophysical characteristics of abandoned farmlands is essential to formulate management

strategies. Broadly, abandoned farmlands could be managed through two approaches. First, abandoned farmlands located in the remote region and away from human settlements could be left in the natural state to allow vegetation growth for ecological restoration and to maintain biodiversity and second, abandoned farmlands that are accessible and relatively fertile could be reused for low intensity agriculture (Bell et al. 2020). Afforestation, horticulture, livestock farming and agroforestry are some of the potential low intensity agricultural options for the reutilisation of abandoned farmlands (Hall 2018; Bell et al. 2020).

Policy Implications and Way forward

Agricultural land use, land tenure systems, and land reform have always been contested issues in the public and policy spheres in Nepal. Recently revised land use policy (2015) aims to develop a provision where no one is allowed to leave agricultural lands uncultivated without believable reasons for three consecutive years and formulate a strategy to reduce governmental support and subsidies but rather impose an additional tax if the farmlands are left uncultivated. However, the Constitution of Nepal (2015) through article 19(1): “the right to acquire, own, sell and otherwise dispose of property” allows landowners to retain their private agricultural lands in any form as fundamental rights. The current statutory land tenure system also allows landholders to keep their agricultural land as private property as long as they pay the land taxes imposed by the government. In this situation, the possibility of restoring abandoned lands into productive use at a massive scale is very low, unless provisions related to land tenure and land use policy are significantly reformed. This study also recorded that no landowners have faced any legal problems for keeping their agricultural land uncultivated.

Three important policy insights are identified based on the findings of this study. First, the consolidation of fragmented land parcels to address the issue of farmland abandonment can be one novel approach in the context of the Nepalese hill region. Muller and Munroe (2008) also argue that land consolidation through land market transactions could potentially reduce cropland abandonment. A study from China suggested that a land consolidation program implemented to consolidate scattered parcels improved farmers’ living conditions and rural employment (Li et al. 2018b; Xu et al. 2019a). Recently, The Minister for Land Management, Cooperatives and Poverty Alleviation of Nepal (MoLCPA) has proposed a concept note to establish a “Land bank” at the local level, as policy reform that will help to consolidate scattered abandoned lands and increase access of farmers to land without transferring ownership of the land. As the majority of landowners in the study area are reluctant to sell their abandoned farmland,

this approach would encourage landholders to lease their fallow lands to the land bank for renting to farmers who are willing to utilise the land for farming. This mechanism would help preserve the farmlands, increase the scale of farm production, and create local employment reducing the trends of out-migration (Corbelle-Rico et al. 2012; Li et al. 2018b). Second, participation of rural youth in agricultural activities is very low. Therefore, future policy responses should address the issue of labour shortage by creating a favourable environment for younger people to engage in agricultural activities and prioritise more investment in the agricultural sector (Ojha et al. 2017). Furthermore, agricultural investment to improve irrigation facilities, rural road connectivity, access to agricultural credit and technical and extension support would further reinforce other policies to address the issue of farmland abandonment as well as providing local employment.

Finally, since the jurisdictions of land management and agricultural development do not fall into a sole governmental body, the success of any policy action greatly depends on the cooperation and coordination between government agencies involved (Khanal et al. 2020). Six different ministries (MoLCPA, Ministry of Agriculture and Livestock Development (MoALD), Ministry of Energy, Water Resources and Irrigation, Ministry of Forests and Environment, Ministry of Labor, Employment and Social Security, Ministry of Finance) and their departments are directly or indirectly associated with formulating and implementing policies and provisions related to land management and agriculture development. Though MoLCPA is primarily responsible for land management projects, the MoALD is primarily responsible for agriculture-related programs. The role of other ministries is also crucial for achieving the desired policy outcomes. Therefore, an effective sectoral coordination mechanism among government agencies that have overlapping roles and responsibilities is crucial for effective land management practices (Nepal et al. 2020).

Conclusion

This study estimated the extent of farmland abandonment and the major drivers responsible for farmland abandonment in three districts of hill ecological region of Nepal by adopting a mixed methods research approach. The study explored farmers’ perceived reasons for and the impact of the occurrence of farmland abandonment in their locality, based on their experience. The findings demonstrate that agricultural land abandonment is happening at an unprecedented rate in the hill region with around 40% of agricultural lands in the hill region being abandoned, especially in upland areas.

Binary Logistic Regression analysis revealed that the probability of farmland abandonment is greatly influenced by biophysical and socio-demographic factors compared to other economic and farm resource factors. Biophysical factors such as land fragmentation, distance between home and parcel, availability of irrigation, slope, and poor land quality were significantly responsible for land abandonment. Similarly, size of the family, education of household members, and migration, both domestic and abroad, were other important drivers of farmland abandonment in the hill region. Taken together, this suggests that marginal resource quality and demographic changes in the study area, as well as alternative economic opportunities elsewhere, are strongly linked to land abandonment.

These trends are confirmed by the perceptions of householders in the study area. Farmers believe that the major reasons for farmland abandonment are shortages of workforce due to migration, higher preferences of the younger generation towards non-farm employment, and unavailability of wage labour or sharecroppers. These results show that farmers' perceptions about reasons for and impacts of land abandonment and the BLR analysis are closely aligned, indicating the robustness of this study.

In the current context, where the majority of recorded farmland abandonment is <10 years old, and where most of the landowners are unwilling to sell these lands, concerned stakeholders and policy-makers should explore alternative approaches to reutilise these abandoned farmlands and mitigate the negative impacts of abandonment. From an institutional perspective, the existing overlapping roles and responsibilities of government bodies involved in land management and agriculture development, create an impediment for effective formulation and implementation of these plans. Coordination and cooperation mechanisms between these government agencies are critical to overcome existing policy and institutional hurdles, achieve desired land management outcomes and address farmland abandonment.

This study showed that farmland abandonment is happening not only in developed European countries but also in less-developed and food-insecure Asian countries like Nepal. In the context of growing food demand, with escalating global populations, the reduction in total agricultural lands due to farmland abandonment has become a critical issue globally. Therefore, the determinants of this land-use change and the future trajectories for adaptation require robust studies to develop policy and management options which can effectively protect arable and productive agricultural lands from abandonment and degradation at the global scale.

Understanding the drivers of land abandonment across different temporal, spatial and social contexts will provide insights to abate the extent of this land use change and help to mitigate the severity of its negative impacts on the

environment and society. Farmland abandonment is not a final state of land use change but a transitional stage leading to different pathways and outcomes. Therefore, it is important to identify the post-abandonment management options, considering attributes of abandoned farmlands and land-owners, to alleviate the negative impacts of abandonment and utilise the opportunities unfolded by land abandonment.

Availability of Data and Material

(Available).

Code Availability

(R software code available)

Acknowledgements This research is a part of PhD study of the lead author funded by the University Of New England from the International Postgraduate Research Award. We are very grateful to the farmers who participated in this research, government officials and local people of the study region.

Authors' Contributions YRS, PK and OC: Conceptualisation; YRS: Methodology, Software, Formal Analysis, Data Curation and Writing-Original Draft; PK and OC: Writing-Review & Editing, Supervision; RBO and PK: Data analysis support.

Funding This study was funded by the University of New England from the International Postgraduate Research Award for the first author.

Compliance with Ethical Standards

Conflict of Interest The authors declare no competing interests.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

- Alcantara C, Kuemmerle T, Baumann M, Bragina EV, Griffiths P, Hostert P, Knorn J, Muller D, Prishchepov AV, Schierhorn F, Sieber A & Radeloff VC (2013) Mapping the extent of abandoned farmland in Central and Eastern Europe using MODIS time series satellite data. *Environ Res Lett* 8:035035. <https://doi.org/10.1088/1748-9326/8/3/035035>
- Alix-garcia J, Kuemmerle T, Radeloff VC (2012) Prices, Land Tenure Institutions, and Geography: a Matching Analysis of Farmland Abandonment in Post-Socialist Eastern Europe. *Land Econ* 88:425–443
- Beilin R, Lindborg R, Stenseke M, Pereira HM, Llausas A, Slatmo E, Cerqueira Y, Navarro L, Rodrigues P, Reichelt N, Munro N, Queiroz C (2014) Analysing how drivers of agricultural land abandonment affect biodiversity and cultural landscapes using case studies from Scandinavia, Iberia and Oceania. *Land Use Policy* 36:60–72
- Bell SM, Barriocanal C, Terrer C, Rosell-mel   A (2020) Management opportunities for soil carbon sequestration following agricultural land abandonment. *Environ Sci Policy* 108:104–111

- Benayas JR, Martins A, Nicolau JM, Schulz JJ (2007) Abandonment of agricultural land: an overview of drivers and consequences. *CAB Rev: Perspect agriculture, Vet Sci, Nutr Nat Resour* 2:1–14
- Benjamin K, Bouchard A, Domon G (2008) Managing abandoned farmland: the need to link biological and sociological aspects. *Environ Manag* 42:603–619
- Bhattacharjee, A (2012) Social science research: principles, methods, and practices. Textbooks collection. USA: Global Text Project. Retrieved from <https://open.umn.edu/opentextbooks/textbooks/79>
- Blair, D, Shackleton, CM & Mograbi, PJ (2018) Cropland Abandonment in South African Smallholder Communal Lands: land Cover Change (1950–2010) and Farmer Perceptions of Contributing Factors. *Land*, 7:121. <https://doi.org/10.3390/land7040121>
- Brøgger DR, Agergaard J (2019) The migration–urbanisation nexus in Nepal's exceptional urban transformation. *Popul, Space Place* 25: e2264
- Castillo CP, Aliaga EC, Lavallo C & Llario JCM (2020) An assessment and spatial modelling of agricultural land abandonment in Spain (2015–2030). *Sustainability (Switzerland)*, 12:560. <https://doi.org/10.3390/su12020560>
- CBS (2013). Population monograph of Nepal, 2011/12. In: STATISTICS, C. B. O. (ed) Government of Nepal, Kathmandu
- CBS (2014a) Population Monograph of Nepal 2014, Economic Demography. In: NATIONAL PLANNING COMMISSION SECRETARIAT, C. B. O. S. (ed) Ramshah Path Government of Nepal, Kathmandu, Nepal
- CBS (2014b) Population Monograph of Nepal. Volume I (Population dynamics). In: NATIONAL PLANNING COMMISSION SECRETARIAT, C. B. O. S. (ed) Government of Nepal, Kathmandu
- CBS. (2017a). *District Profile of Kavrepalanchowk*. Kathmandu: Central Bureau of Statistics, Government of Nepal https://cbs.gov.np/wp-content/uploads/2018/12/District_Profile_kavrepalanchowk_2074.pdf
- CBS (2017b) District Profile of Lamjung. Central Bureau of Statistics, Government of Nepal, Kathmandu, <https://cbs.gov.np/wp-content/uploads/2018/12/District-Profile-Of-Lamjung-2074-based-on-Local-level.pdf> Retrieved from
- CBS (2017c) Rural Municipality/Municipality's Profile of Kaski. Central Bureau of Statistics, Government of Nepal, Kaski, <https://cbs.gov.np/wp-content/uploads/2018/12/Local-body-Profile-Kaski-2074.pdf> Retrieved from
- Cedamon E, Nuberg I, Pandit BH, Shrestha KK (2017) Adaptation factors and futures of agroforestry systems in Nepal. *Agrofor Syst* 92:1437–1453
- Cerda A, Ackermann O, Terol E & Rodrigo-Comino J (2019) Impact of Farmland Abandonment on Water Resources and Soil Conservation in Citrus Plantations in Eastern Spain. *Water*, 11:824. <https://doi.org/10.3390/w11040824>
- Chaudhary S, Wang YK, Dixit AM, Khanal NR, Xu P, Fu B, Yan K, Liu Q, Lu YF, Li M (2020a) Spatiotemporal Degradation of Abandoned Farmland and Associated Eco-Environmental Risks in the High Mountains of the Nepalese Himalayas. *Land* 9:1–19. <https://doi.org/10.3390/land9010001>
- Chaudhary S, Wang YK, Dixit AM, Khanal NR, Xu P, Fu B, Yan K, Liu Q, Lu YF, Li M (2020b) A Synop Farml Abandonment Its Driv Factors Nepal Land, 9:84
- Chaudhary S, Wang YK, Dixit AM, Khanal NR, Xu P, Yan K, Liu Q, Lu YF & Li, M (2019) Eco-Environmental Risk Evaluation for Land Use Planning in Areas of Potential Farmland Abandonment in the High Mountains of Nepal Himalayas. *Sustainability*, 11:6931. <https://doi.org/10.3390/su11246931>
- Chaudhary S, Wang YK, Khanal NR, Xu P, Fu B, Dixit AM, Yan K, Liu Q & Lu YF (2018) Social Impact of Farmland Abandonment and Its Eco-Environmental Vulnerability in the High Mountain Region of Nepal: a Case Study of Dordi River Basin. *Sustainability*, 10:2331. <https://doi.org/10.3390/su10072331>
- Cocca G, Sturaro E, Gallo L, Ramanzin M (2012) Is the abandonment of traditional livestock farming systems the main driver of mountain landscape change in Alpine areas? *Land Use Policy* 29:878–886
- Corbelle-Rico E, Crecente-Maseda R, Sante-Riveira I (2012) Multi-scale assessment and spatial modelling of agricultural land abandonment in a European peripheral region: Galicia (Spain), 1956–2004. *Land Use Policy* 29:493–501
- Cvitanovic M, Lucev I, Furst-Bjelis B, Slavuj Borcic L, Horvat S, Valozic L (2017) Analyzing post-socialist grassland conversion in a traditional agricultural landscape - Case study Croatia. *J Rural Stud*, 51:53–63
- Devkota LN, Papademetriou M, Herath E (1999) Deciduous fruit production in Nepal. Deciduous fruit production in Asia and the Pacific. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand
- Dhakal BN, Khanal NR (2018) Causes and Consequences of Fragmentation of Agricultural Land: a Case of Nawalparasi District. *Nepal Geographical J Nepal*, 11:95–112
- Estel S, Kuemmerle T, Alcántara C, Levers C, Prishchepov A, Hostert P (2015) Mapping farmland abandonment and recultivation across Europe using MODIS NDVI time series. *Remote Sens Environ* 163:312–325
- Gartaula H, Niehof A, Visser L (2012) Shifting perceptions of food security and land in the context of labour out-migration in rural Nepal. *Food Security* 4:181–194
- Gellrich M, Zimmermann NE (2007) Investigating the regional-scale pattern of agricultural land abandonment in the Swiss mountains: A spatial statistical modelling approach. *Landsc Urban Plan* 79:65–76
- Guo Y, Song W (2019) Spatial distribution and simulation of cropland abandonment in Wushan County, Chongqing, China. *Sustainability* 11:1367
- Hall SJG (2018) A novel agroecosystem: beef production in abandoned farmland as a multifunctional alternative to rewilding. *Agric Syst* 167:10–16
- Han Z, Song W (2019) Spatiotemporal variations in cropland abandonment in the Guizhou–Guangxi karst mountain area, China *J Cleaner Prod* 238:1–15. <https://doi.org/10.1016/j.jclepro.2019.117888>
- IOM 2019 Migration in Nepal - A country Profile 2019. International Organization for Migration (IOM), 768/12 Thirbam Sadak, Baluwatar-5
- Jaquet S, Kohler T, Schwilch G (2019) Labour Migration in the Middle Hills of Nepal: consequences on Land Management Strategies. *Sustainability* 11:1349
- Jaquet S, Schwilch G, Hartung-Hofmann F, Adhikari A, Sudmeier-Rieux K, Shrestha G, Liniger HP, Kohler T (2015) Does outmigration lead to land degradation? Labour shortage and land management in a western Nepal watershed. *Appl Geogr* 62:157–170
- KC B, Race D (2020) Outmigration and Land-Use Change: a Case Study from the Middle Hills of Nepal. *Land* 9:2
- Khanal NR, Nepal P, Zhang Y, Nepal G, Paudel B, Liu L, Rai R (2020) Policy provisions for agricultural development in Nepal: a review. *J Clean Prod* 261:121241
- Khanal NR, Watanabe T (2006) Abandonment of Agricultural Land and Its Consequences. *Mt Res Dev* 26:32–40
- Khanal U (2018) Why are farmers keeping cultivatable lands fallow even though there is food scarcity in Nepal? *Food Security* 10:603–614
- Khanal U, Wilson C, Shankar S, Hoang V-N, Lee B (2018) Farm performance analysis: Technical efficiencies and technology gaps of Nepalese farmers in different agro-ecological regions. *Land Use Policy*, 76:645–653
- Kolecka N, Kozak J, Kaim D, Dobosz M, Ostafin K, Ostapowicz K, Wezyk P, Price B (2017) Understanding farmland abandonment in the Polish Carpathians. *Appl Geogr* 88:62–72

- Kuemmerle T, Muller D, Griffiths P, Rusu M (2009) Land use change in Southern Romania after the collapse of socialism. *Regional Environ Change* 9:1–12
- Lambin EF, Meyfroidt P (2011) Global land use change, economic globalization, and the looming land scarcity. *Proc Natl Acad Sci* 108:3465–3472
- Lasanta T, Arnáez J, Oserín M, Ortigosa LM (2001) Marginal Lands and Erosion in Terraced Fields in the Mediterranean Mountains. *Mt Res Dev* 21:69–76
- Levers C, Schneider M, Prishchepov AV, Estel S, Kuemmerle T (2018) Spatial variation in determinants of agricultural land abandonment in Europe. *Sci Total Environ* 644:95–111
- Li S, Li X (2017) Global understanding of farmland abandonment: a review and prospects. *J Geographical Sci* 27:1123–1150
- Li S, Li X (2019) The mechanism of farmland marginalization in Chinese mountainous areas: evidence from cost and return changes. *J Geographical Sci* 29:531–548
- Li SF, Li XB, Sun LX, Cao GY, Fischer G, Tramberend S (2018a) An estimation of the extent of cropland abandonment in mountainous regions of China. *Land Degrad Dev* 29:1327–1342
- Li Y, Wu W, Liu Y (2018b) Land consolidation for rural sustainability in China: practical reflections and policy implications. *Land Use Policy* 74:137–141
- Macdonald D, Crabtree J, Wiesinger G, Dax T, Stamou N, Fleury P, Lazpita JG, Gibon A (2000) Agricultural abandonment in mountain areas of Europe: environmental consequences and policy response. *J Environ Manag* 59:47–69
- Maharjan A, Kochhar I, Chitale VS, Hussain A, Gioli G (2020) Understanding rural outmigration and agricultural land use change in the Gandaki Basin, Nepal. *Appl Geogr* 124:102278
- Malla G (2008) Climate change and its impact on Nepalese agriculture. *J Agric Environ* 9:62–71
- Manandhar S, Vogt DS, Perret SR, Kazama F (2011) Adapting cropping systems to climate change in Nepal: a cross-regional study of farmers' perception and practices. *Regional Environ Change* 11:335–348
- Messerschmidt DA (1981) "Nogar" and Other Traditional Forms of Cooperation in Nepal: significance for Development. *Hum Organ* 40:40–47
- Meyfroidt P, Schierhorn F, Prishchepov AV, Muller D, Kuemmerle T (2016) Drivers, constraints and trade-offs associated with recultivating abandoned cropland in Russia, Ukraine and Kazakhstan. *Glob Environ Change-Hum Policy Dimens* 37:1–15
- MoAD (2020) Statistical Information on Nepalese Agriculture 2075/76 [2018/19]. Ministry of Agriculture and Livestock Development, Government of Nepal, Kathmandu, Nepal
- Muller D, Kuemmerle T, Rusu M, Griffiths P (2009) Lost in transition: determinants of post-socialist cropland abandonment in Romania. *J Land Use Sci* 4:109–129
- Muller D, Munroe DK (2008) Changing Rural Landscapes in Albania: cropland Abandonment and Forest Clearing in the Postsocialist Transition. *Ann Assoc Am Geographers* 98:855–876
- Munroe DK, van Berkel DB, Verburg PH, Olson JL (2013) Alternative trajectories of land abandonment: causes, consequences and research challenges. *Curr Opin Environ Sustain* 5:471–476
- Nepal P, Khanal NR, Zhang Y, Paudel B, Liu L (2020) Land use policies in Nepal: an overview. *Land Degrad Dev* 31:2203–2212
- Niroula G, Thapa GB (2007) Impacts of land fragmentation on input use, crop yield and production efficiency in the mountains of Nepal. *Land Degrad Dev* 18:237–248
- Novara A, Gristina L, Sala G, Galati A, Crescimanno M, Cerdà A, Badalamenti E, la Mantia T (2017) Agricultural land abandonment in Mediterranean environment provides ecosystem services via soil carbon sequestration. *Sci Total Environ* 576:420–429
- Ojha HR, Shrestha KK, Subedi YR, Shah R, Nuberg I, Heyojoo B, Cedamon E, Rigg J, Tamang S, Paudel KP, Malla Y, MCmanus P (2017) Agricultural land underutilisation in the hills of Nepal: investigating socio-environmental pathways of change. *J Rural Stud* 53:156–172
- Pandey R (2019) Farmers' perception on agro-ecological implications of climate change in the Middle-Mountains of Nepal: a case of Lumle Village, Kaski. *Environ Dev Sustainability* 21:221–247
- Paudel B, Pandit J, Reed B (2013) Fragmentation and conversion of agriculture land in Nepal and Land Use Policy 2012. University Library of Munich, Germany
- Paudel B, Wu X, Zhang Y, Rai R, Liu L, Zhang B, Khanal NR, Koirala HL, Nepal P (2020) Farmland abandonment and its determinants in the different ecological villages of the Koshi river basin, central Himalayas: Synergy of high-resolution remote sensing and social surveys. *Environ Res* 188:109711
- Paudel KP, Sujata T, Shrestha KK (2014) Transforming land and livelihood: analysis of agricultural land abandonment in the mid hills of Nepal. *J For Livelihood* 12:11–19
- Pazur R, Lieskovsky J, Feranec J, Otahel J (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. *Appl Geogr* 54:118–128
- Pepe G, Mandarino A, Raso E, Scarpellini P, Brandolini P & Cevasco, A (2019) Investigation on Farmland Abandonment of Terraced Slopes Using Multitemporal Data Sources Comparison and Its Implication on Hydro-Geomorphological Processes. *Water* 11:1552. <https://doi.org/10.3390/w11081552>
- Prishchepov AV, Radeloff VC, Baumann M, Kuemmerle T & Müller D (2012) Effects of institutional changes on land use: agricultural land abandonment during the transition from state-command to market-driven economies in post-Soviet Eastern Europe. *Environ Res Lett* 7:10:024021 <https://doi.org/10.1088/1748-9326/7/2/024021>
- Queiroz C, Beilin R, Folke C, Lindborg R (2014) Farmland abandonment: threat or opportunity for biodiversity conservation? A global review. *Front Ecol Environ* 12:288–296
- Rai R, Zhang YL, Paudel B & Khanal NR (2019) Status of Farmland Abandonment and Its Determinants in the Transboundary Gandaki River Basin. *Sustainability* 11:5267. <https://doi.org/10.3390/su11195267>
- REY BENAYAS JM, MARTINS A, NICOLAU JM & SCHULZ, JJ (2007) Abandonment of agricultural land: an overview of drivers and consequences. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*, 2:14. <https://doi.org/10.1079/PAVSNNR20072057>
- RStudio team (2020) RStudio: Integrated Development for R. RStudio, PBC, Boston, MA
- Ruskule A, Nikodemus O, Kasparinskis R, Bell S, Urtane I (2013) The perception of abandoned farmland by local people and experts: Landscape value and perspectives on future land use. *Landsc Urban Plan* 115:49–61
- Schwilch G, adhikari A, Jaboyedoff M, jaquet S, Kaenzig R, liniger H, Penna IM, Sudmeier-rieux K & Upreti BR (2017) Impacts of outmigration on land management in a Nepali Mountain Area. In: SUDMEIER-RIEUX K, FERNÁNDEZ M, PENNA IM, JABOYEDOFF M & GAILLARD JC (eds.) *Identifying Emerging Issues in Disaster Risk Reduction, Migration, Climate Change and Sustainable Development: Shaping Debates and Policies*. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-33880-4_11
- Shi T, Li X, Xin L, Xu X (2018) The spatial distribution of farmland abandonment and its influential factors at the township level: a case study in the mountainous area of China. *Land Use Policy* 70:510–520
- Shi TC, Li XB, Xin LJ & Xu XH (2016) Analysis of Farmland Abandonment at Parcel Level: a Case Study in the Mountainous Area of China. *Sustainability*, 8:989. <https://doi.org/10.3390/su8100988>

- Sikor T, Müller D, Stahl J (2009) Land Fragmentation and Cropland Abandonment in Albania: implications for the Roles of State and Community in Post-Socialist Land Consolidation. *World Dev* 37:1411–1423
- Sil Â, Fernandes PM, Rodrigues AP, Alonso JM, Honrado JP, Perera A & Azevedo, JC (2019) Farmland abandonment decreases the fire regulation capacity and the fire protection ecosystem service in mountain landscapes. *Ecosystem Serv* 36:100908. <https://doi.org/10.1016/j.ecoser.2019.100908>
- Sroka W, Polling B, Wojewodzic T, Strus M, Stolarczyk P & Podlinska O (2019) Determinants of Farmland Abandonment in Selected Metropolitan Areas of Poland: a Spatial Analysis on the Basis of Regression Trees and Interviews with Experts. *Sustainability* 11:3071. <https://doi.org/10.3390/su11113071>
- Su GD, Okahashi H & Chen, L (2018) Spatial Pattern of Farmland Abandonment in Japan: identification and Determinants. *Sustainability* 10:3676. <https://doi.org/10.3390/su10103676>
- Sunam RK, McCarthy JF (2016) Reconsidering the links between poverty, international labour migration, and agrarian change: critical insights from Nepal. *J Peasant Stud* 43:39–63
- Suziedelyte Visockiene J, Tumeliene E, Maliene V (2019) Analysis and identification of abandoned agricultural land using remote sensing methodology. *Land Use Policy* 82:709–715
- Terres JM, Scacciafichi LN, Wania A, Ambar M, Anguiano E, Buckwell A, Coppola A, Gocht A, Källström HN, Pointereau P, Strijker D, Visek L, Vranken L, Zobena A (2015) Farmland abandonment in Europe: identification of drivers and indicators, and development of a composite indicator of risk. *Land Use Policy* 49:20–34
- Thapa G, Paudel G (2002) Farmland degradation in the mountains of Nepal: a study of watersheds ‘with’ and ‘without’ external intervention. *Land Degrad Dev* 13:479–493
- Timans R, Wouters P, Heilbron J (2019) Mixed methods research: what it is and what it could be. *Theory Soc* 48:193–216
- Ustaoglu E, Collier MJ (2018) Farmland abandonment in Europe: an overview of drivers, consequences, and assessment of the sustainability implications. *Environ Rev* 26:396–416
- Vidal-Macua JJ, Ninyerola M, Zabala A, Domingo-marimon C, Gonzalez-Guerrero O, Pons X (2018) Environmental and socio-economic factors of abandonment of rainfed and irrigated crops in northeast Spain. *Appl Geogr* 90:155–174
- Vinogradovs I, Nikodemus O, Elferts D, Brūmelis G (2018) Assessment of site-specific drivers of farmland abandonment in mosaic-type landscapes: A case study in Vidzeme, Latvia. *Agriculture, Ecosyst Environ* 253:113–121
- Wang Y, Li X, Xin L, Tan M (2020) Farmland marginalization and its drivers in mountainous areas of China. *Sci Total Environ* 719:135132
- Wertebach TM, Holzel N, Kampf I, Yurtaev A, Tupitsin S, Kiehl K, Kamp J, Kleinebecker T (2017) Soil carbon sequestration due to post-Soviet cropland abandonment: estimates from a large-scale soil organic carbon field inventory. *Glob Chang Biol* 23:3729–3741
- Wisdom J, Creswell JW (2013) Mixed methods: integrating quantitative and qualitative data collection and analysis while studying patient-centered medical home models. Agency for Healthcare Research and Quality, Rockville
- Xu D, Deng X, Guo S, Liu S (2019a) Labor migration and farmland abandonment in rural China: empirical results and policy implications. *J Environ Manag* 232:738–750
- Xu DD, Deng X, Huang K, Liu Y, Yong ZL & Liu SQ (2019b) Relationships between labor migration and cropland abandonment in rural China from the perspective of village types. *Land Use Policy* 88:10. <https://doi.org/10.1016/j.landusepol.2019.104164>
- Yan JZ, Yang ZY, Li ZH, Li XB, Xing LJ, Sun LX (2016) Drivers of cropland abandonment in mountainous areas: a household decision model on farming scale in Southwest China. *Land Use Policy* 57:459–469
- Yu Z, Lu C (2018) Historical cropland expansion and abandonment in the continental U.S. during 1850 to 2016. *Glob Ecol Biogeogr* 27:322–333
- Yu ZL, Liu L, Zhang H, Liang JS (2017) Exploring the Factors Driving Seasonal Farmland Abandonment: a Case Study at the Regional Level in Hunan Province, Central China. *Sustainability* 9:187
- Zhang Q, Song C, Chen X (2018) Effects of China’s payment for ecosystem services programs on cropland abandonment: a case study in Tiantangzhai Township, Anhui, China. *Land Use Policy* 73:239–248
- Zhang Y, Li XB, 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
- Zhang Y, Li XB, Song W, Thai L (2016) Land abandonment under rural restructuring in China explained from a cost-benefit perspective. *J Rural Stud* 47:524–532