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DETERMINANTS OF CULTIVATED LAND ABANDONMENT IN THE HILLS OF WESTERN NEPAL

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ABSTRACT. – Determinants of Cultivated Land Abandonment in the Hills of Western Nepal. This paper deals with the change in agricultural land use pattern in the Andhi khola watershed of Syangja district, Western hills of Nepal, where the population has decreased for the last two decades, which is being the main cause of the agricultural land abandonment, resulting into increase in the fallow lands and vegetation wilderness. This phenomenon has also occurred elsewhere in other parts of the hill region of Nepal, resulting in labor deficit in the agriculture activities. Landsat images of 1999 and 2014 have been used for land use change. Topographic map has been used as the map source. DEM was generated from the contours of the topographic map to derive altitude, slope gradient and slope aspect. The Geographically Weighted Regression Model has been used for prediction of abandonment of cultivated land by location across the study region as well as to identify local variability of the strength of the explanatory variables. Changes in population and altitudinal variation are found as significant factors of agricultural land abandonment. Besides, slope gradient and slope aspect are also found as determining factors. Combined effects of accessibility, landform, land suitability, and irrigation facility on change in agricultural land use pattern are the result of greater strength of the altitudinal variation effect. The lowland areas together with easy access to market and better irrigation facilities are found suitable for the cultivation of a variety of crops. Therefore, these areas have less land abandonment as compared to the highland areas, which were used by local residents for cultivation, though marginal. It is concluded that most of the previously cultivated marginal land in the hills has released population pressure, resulting into land abandonment, which is further accelerated by institutional weaknesses.

Keywords: *depopulation, explanatory variables, Geographically Weighted Regression, land abandonment, local coefficient, outmigration.*

1. INTRODUCTION

Re-growth of natural vegetation is the result of a decline in traditional agricultural practices that can be observed worldwide (Gellrich et al. 2007) with its both positive and negative consequences. In the past, expansion of agricultural

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land even in steep mountain slope was considered one of the main causes of growing environmental degradation and poverty in the Nepal Himalaya because of rapid population growth (Ekholm 1975) but in the last two decades heavy outmigration of population from rural hill and mountain areas has resulted in growing land abandonment. It is not only because of the depopulation that the agriculture system of these areas has reduced the scope for enhancement of productivity of traditional agriculture but also due to fragile mountain environment, poor economies of scale owing to the highly fragmented and diversified biophysical condition, and resistance to adopting modern, market oriented farming practice by mountain people (Walther 1986, Vogel 1988, MacDonald et al. 2000). In Nepal, outmigration of farmers from the mountains and hills to urban centres, plain areas and foreign countries has been increased greatly over the last two decades, which are assumed to create heavy labour shortage in the agriculture. As a result, cultivated land has shrunken. Invasion of cultivated land by natural vegetation has also grown (Chidi 2015). On the other hand, this situation has also a huge adverse impact on food security and livelihood in those areas (Khanal and Watanabe 2006). The Geographically Weighted Regression (GWR) has been used to estimate a separate local coefficient based on locally available data sets at each geographic location. This technique produces a separate set of spatial regression parameters at each localized level (Leung et al., 2000; Wheeler and Tiefelsdorf, 2005; Farbar and Paez, 2007). A key feature in most parametric approaches is valid in the cases where the researcher knows the process underlying the data or when the researcher is willing to make some assumptions in order to test hypothesis (Wrenn and Sam 2014). Often, however, the researchers do not know the underlying process but they must find a way to uncover it. Thus a researcher needs a model that can flexibly capture the intricacies of the determinant processes and the potential for non-stationary equilibria over space and time. In Nepal studies on the agricultural land abandonment are extremely limited. Therefore, this study intends to describe the agricultural land abandonment situation and its associated determining factors using GWR model at local level.

2. METHODS AND MATERIALS

2.1 The Study Area

The study is confined to the Andhi Khola watershed area in Syangja district of Nepal’s Western Hill. The study area lies in 27°56'20" to 28°13'46" N and 83°35'07" to 83°57'00" E. This watershed area covers 480.9 square kilometers, the elevation of which ranges from 520 m to 2468 m over 35 kilometer horizontal distance. The upper parts of the study area are steep hill slopes with streams and streamlets between the hill flank and mostly deposited flat fertile land along the mainstream and tributaries in the lower areas. The area lies in the Monsoon climate regime. It gets 3200 mm of average annual rainfall, of which about 80 per cent is contributed by the summer monsoon and the rest by the winter Mediterranean cyclones. Temperature ranges from 5˚C to 32˚C. There are cold, dry winter and wet hot summer months. The intensive subsistence farming of the area is similar to that of other hill areas of Nepal. Besides, some of the local people also take on commercial farming and trade business particularly in low-lying areas and around local towns, which are accessible by road links. However during the recent decades, foreign remittance has been an important income source. During the last decade of 2001-2011, the population growth rate in the district has shown -0.93, as compared to the national rate of 1.35. It indicates a high rate of population outmigration, particularly the males moving to urban areas, the Tarai and foreign countries.

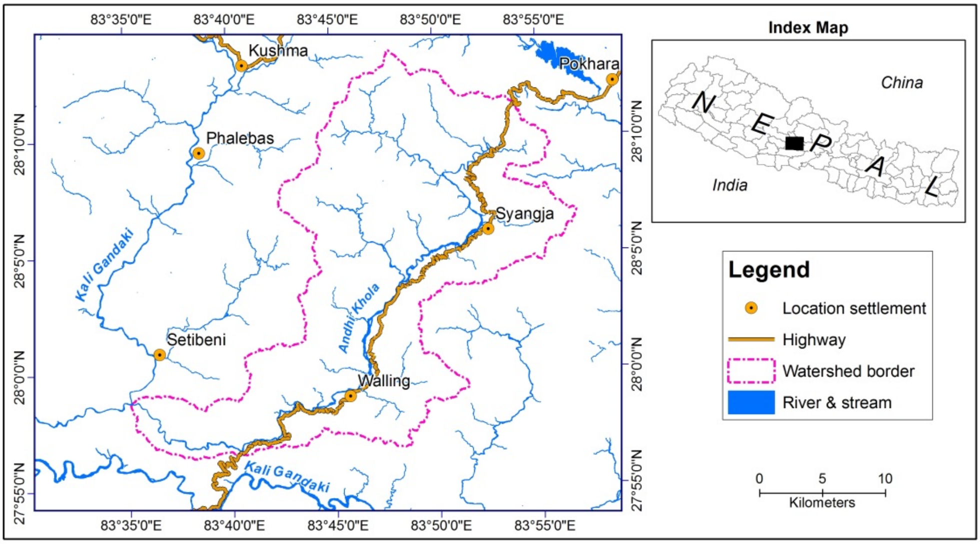

Figure 1. The study area: the Andhi Khola Watershed

2.2 The Data Generation

Population change at ward level, the smallest census unit area, has been calculated between the last two censuses of 2001 and 2011. Land use layers at 30-meter spatial resolution were derived from Landsat7 and Landsat8 images for 1999 and 2014 respectively. The supervised classification method using maximum likelihood and probability method in ERDAS Imagine 9.1 has been used for image classification. Land use has been categorized into forest, shrubs, grassland, cultivated land, sandy area and water body. Forest, shrubs and grassland are combined into vegetated area. Overall accuracy of image classification was found at 85% in 1999 and 95% in 2014. Ten meters Digital Elevation Model (DEM) was developed by nearest neighbour method on the basis of 20-meter contour interval on topographic map in ArcGIS10.1. Altitude, slope gradient and slope aspect layers were developed on the basis of DEM. All image classifications were converted into vector file in ArcGIS 10.1. Land use change has been derived for different levels such as watershed area as a whole, wards, different elevation zones, and different slope gradient zones and slope aspects by intersecting different vector layers.

Change in population, cultivated land, vegetative areas (forest, shrubs and grassland) were calculated. These data were derived to different slope gradients, slope aspects, altitudes and different wards polygons. The mean centres of each ward polygon were calculated. Distance to highway from the mean centre of each ward was derived. Field level information was gathered visiting the study area. Informal discussions with local people and concerned district level line agencies were performed.

2.3 Data Analysis

Firstly, watershed level land use change at different slope gradient, slope aspect and altitude has been analysed. Secondly, ward level observation unit has been used for statistical analysis. There were 314 observation (wards) units. Percentage change of cultivated land and population, distance from highway, average altitudes, average slope aspect and average slope gradient variables were developed. Ordinary Least Square (OLS) and Geographically Weighted Regression (GWR) models have been compared to identify the suitability of model for better estimation. GWR model has given far better result for prediction of abandonment of cultivated land. Therefore GWR model has been used for analysis and prediction.

GWR is a local regression technique that assumes non-stationary relationships between response variable and explanatory variable. GWR generates a single equation for each spatial unit and consequently allows regression coefficients to vary across the study area. The model calibrates each spatial unit using the target one and its neighbors. The calibration follows Tobler's first law of geography where higher weights are assigned to the nearby locations according to their spatial proximity to the target location *i*. The weights indicate the fact that close locations have more influence on the calibration than locations further away (Fotheringham et al. 1998, Brunsdon, et al. 2008). The GWR model is defined as follows:

$$Y_i = \beta_0(\mu_{i,} v_i) + \sum_k \beta_k(\mu_{i,} v_i) X_{ik} + \boldsymbol{\varepsilon}_i$$

Where,

Y_i is the dependent variable at location *i*

X_{ik} is the value the of k^th explanatory variable at location *i*

$\beta_0(\mu_{i,} v_i)$ is the intercept parameter at location *i*

$\beta_k(\mu_{i,} v_i)$ is the local regression coefficient for the k^th explanatory variable at location *i*

$(\mu_{i,} v_i)$ is the coordinate of location *i*

$\boldsymbol{\varepsilon}_i$ is the random error at location *i*

In GIS platform, GWR produces local coefficient and it diagnose parameter to estimates for each spatial feature. These represent locations where each explanatory variable shows higher or lower influence in the dependent variable (Charlton 2009). To apply and perform the GWR model, the geographically weighted regression extension in the spatial statistics toolbox of ArcGIS 10.1 was used. The percentage change of cultivated land is a response variable; and population change, altitude, and distance to highway are explanatory variables. These variables were selected on the basis of collinearity among variables (Table 3). The prediction given by both OLS and GWR model were compared and GWR model has been used for detail analysis because of its higher percentage prediction capacity than OLS. GWR has the capacity to give different local coefficient value for individual observation of each explanatory variable. The local coefficient indicates the role of variable on the change of dependent variable because of the change in independent variable. So, local coefficient maps of explanatory variables have been prepared to identify the pattern of location specific strength of explanatory variables. Additionally qualitative information collected from the field and secondary sources were classified and analyzed with reference to quantitative analysis and evidence.

3. RESULTS AND DISCUSSIONS

3.1 Results

Cultivated Land Conversion: The cultivated land in the study area has decreased during the years 1999-2014. The land use conversed from one category to the other. Most of the cultivated land was transformed to vegetation area due to higher proportion of abandonment of cultivated land. Some vegetated area has been converted into cultivated land, mostly in lowland areas.

Table 1.

Land use change (1999 to 2014), Andhi Khola Watershed

Land use	Area in 1999 (ha)	Area in 2014 (ha)	Area change (ha)	Percent Change
Cultivated Land	18987.20	15325.34	3661.86	-19.29
Vegetated Area	28177.90	31882.02	3705.12	13.15
Sand & gravel	757.66	792.33	34.67	4.58
Water body	191.20	113.26	-77.94	-40.76

Higher proportion of sand and gravel was converted to cultivated land as a result of the maintenance of former cultivated land damage by heavy flood occurrence in 1996. However, it does not play a significant increase in total area of cultivated land because of the smaller area of sand and gravel as compared to cultivated and vegetated areas.

Conversion of cultivated land into vegetated area is clearly visible on the figure 2 land use map of 1999 and 2014. Land use maps of 1999 and 2014 show higher greenery has increased in most of the areas. Proportion of greenery has been increased in the north and eastern parts. Increase in cultivated land is clearly visible in south and southwest region of the study area. Similarly, decreasing greenery is also equally seen in this area.

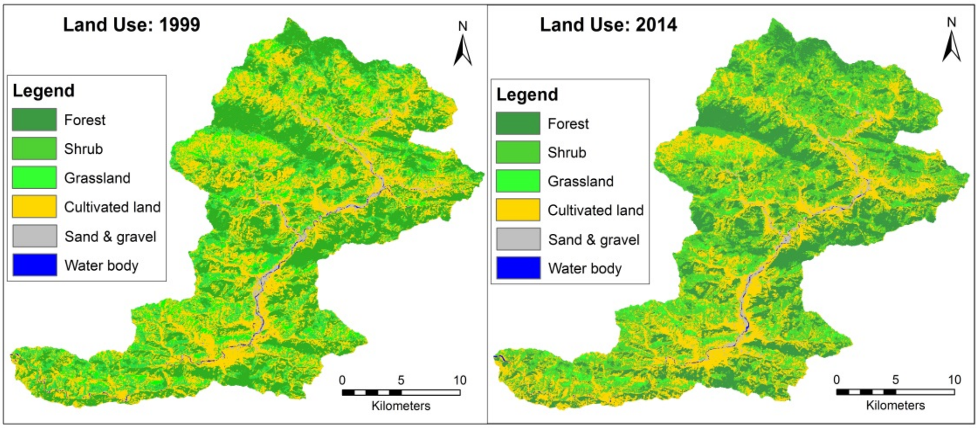

Figure 2. Land use pattern in 1999 and 2014.

Collinearity of Variables: The results of the Karl Pearson's correlation coefficients of slope gradient, slope aspect and sex ratio variables show very low value since they do not give the reliability of relation with other variables. However, slope gradient has positive correlation (r = 0.173) at a significant level of 0.01 and slope aspect has a positive correlation with population change (r = 0.17) at a significance level of 0.01. Both positive correlation coefficients are weak but highly significant. They indicate that population change is related with slope gradient and slope aspect. The correlation matrix (Table 3) indicates that population change, altitude and distance to highway have significant correlation with cultivated land change at 0.01 significance level. Population change has a positive relation while altitude and distance to highway have negative relation to cultivated land change. It means that cultivated land is changing with population change i.e. cultivated land decreases with population decrease and increases with population growth. Similarly, cultivated land change rate is negatively increasing with the increasing altitude. It means that cultivated land is decreasing with increasing altitude. Cultivated land has also similar relation with highway distance. Cultivated land decreasing rate is increasing according to the increasing distance from the highway.

Table 2.

Correlation matrix (0.01significance level)

	Cultivated land change	**Population change**	**Altitude**	**Distance to highway**
Cultivated land change	1	0.328	-0.503	-0.342
Population change	0.328	1	-0.234	-0.308
Altitude	-0.503	0.234	1	0.655
Distance to highway	-0.342	-0.308	0.655	1

Location of Sidhhartha highway is at lowland area. Therefore, the correlation coefficient of distance to highway and altitude is highly positive. Altitude has the highest relationship with cultivated land change. Population change has also negative correlation with altitude and distance to highway.

OLS and GWR Model: Variables of cultivated land change, population change, altitude and distance to highway have lower variance inflation factor (VIF) and Moran's I indicates that all variables are free of auto-correlation, which can be used for prediction model. Variable of distance from highway has been rejected in the OLS. So, only population change and altitude have been taken as explanatory variables. In GWR model only population change and altitude give the highest prediction value. Therefore, only these two variables have been used for modeling. From the table below, R^2 and adjusted R^2 value is higher in GWR than in OLS. Therefore, GWR is the best for the prediction of cultivated land. GWR model has strength of nearly 57% of predicting capacity to cultivated land change rate.

Table 3.

Comparison of OLS and GWR

Description	**OLS**	**GWR**
R^2	0.299	0.668
Adjusted R^2	0.295	0.566
Number of observation	314	314

However, other remaining variables were also tested in GWR model because of its semi-parametric technique as explanatory variables but mixing with these two variables of any other variables or any other combination of derived explanatory could not give better result than population change and altitude variables. So, GWR model used only these two variables as explanatory variables. Standard Residual of GWR model was tested to identify the whether it is free of autocorrelation or randomness. Moran's I indicates that given prediction GWR is highly reliable at 0.05 significant level. So, this study used GWR model for prediction.

Observed and Predicted Change: Figure 3A is the actual changing percentage of cultivated land between 1999 and 2014. This map indicates that cultivated land abandonment is all over the watershed area except in the south-western part. The increasing rate of land abandonment is from south to north and west to east. Only some parts of the northern region have increasing cultivated land. This area is gently sloping on the south facing slope, which is more suitable for cultivation than other hill slopes. Predicted probability value of each observation is the estimated value of dependent variable on the basis of explanatory variables.

The general pattern of figure 3B is not significantly different than observed land abandonment rate of figure 3A. The prediction of land abandonment rate is smoothly increasing toward north and east from southwest region. Some wards in the central part are predicted for increasing cultivated land because of the high rate of population increase in the urban area but it is not found in observed data. However, observed data has also shown that there is increase in cultivated land in some wards. In the northwest, the cultivated land has increased. Only one ward is predicted for increasing cultivated land. It is because of the lower rate of population increase in these wards, compared to those in the south.

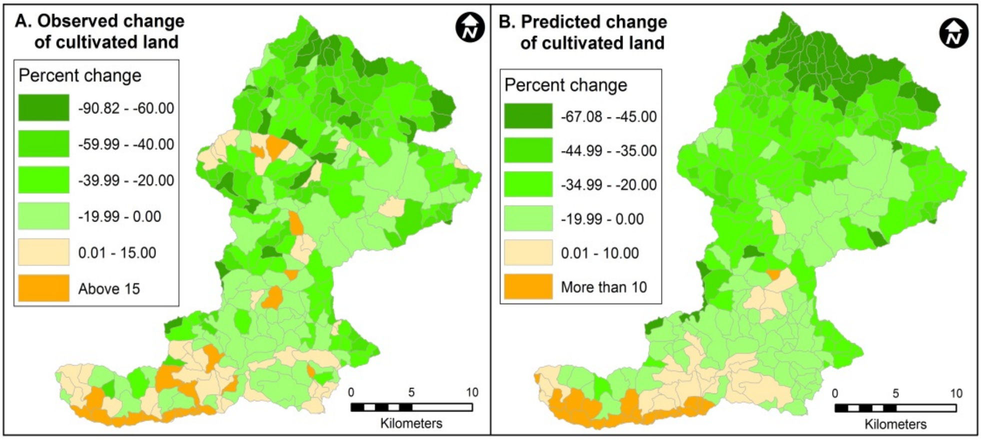

Figure 3. Observed and predicted cultivated land changes in the Andhi Khola Watershed

Local Coefficients of Explanatory Variables: Figures 4A and 4B show local coefficients of population change and altitude respectively. They are developed by geographically weighted regression model. Higher value of regression coefficient means higher strength of role played by explanatory variables on dependent variable. Positive value indicates the positive role of explanatory variables on the changing situation of dependent variables and negative value means negative role. In most of the area, population change has played positive role to the change of cultivated land. Higher strength of role of population change is in the western region from north to south. There are three big clusters of higher strength are in this region. Among them the strongest strength is in the south. Most of the area has an average positive impact. However, four small clusters have a negative impact of population change on the change of cultivated land.

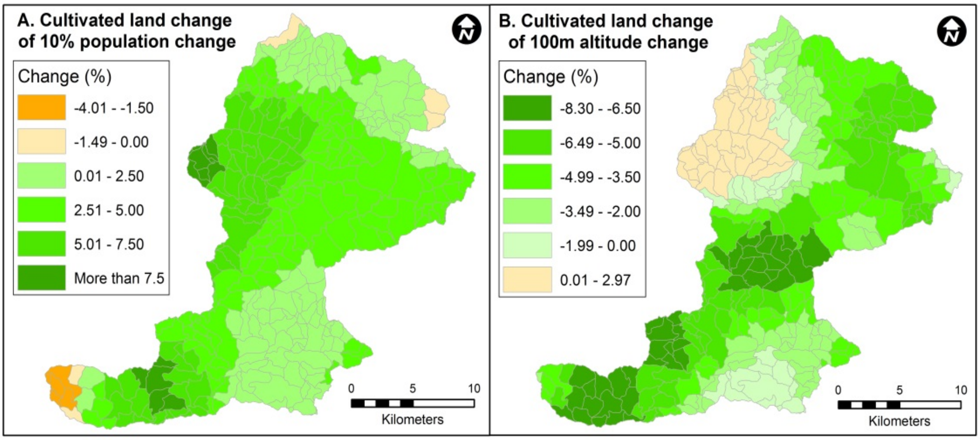

Figure 4. Local coefficients of population and altitude.

Local coefficient indicates that ten percent population decrease have more than 4 percent cultivated land decrease but some limited area have more than 7.5 percent cultivated land increase where population decreased in the same proportion. It proves that one variable may not play the same role at different location. Figure 4B indicates that in most of the areas the altitude has a negative impact on cultivated land change. Lowland areas from north to south indicate the negative role of altitude to the change of cultivated land. The higher strength of altitude is in the southern part compared to the north. However, the northwest portion indicates a positive role of the altitude. Most of the area have inverse role of two explanatory variables on cultivated land change in the study area. It means that a higher proportion of cultivated land is converting from vegetated area or abandoned land with increasing altitude. Local coefficient indicates that more than 8.3 percent of cultivated land has been abandoned with increasing altitude of 100m. A higher impact of altitude on cultivated land abandonment seems to exist along the lowland area.

3.2 Discussions

Population Change: Migration is an essential and inevitable component of the economic and social life. Properly managed migration can be beneficial for both individual and societies. Foreign employment emerged as a strong attraction among Nepalese in the mid 1990s because of the political instability which was perpetuated by the rapid expansion of the people's war, the construction boom in East Asia and Persian Gulf region creating employment opportunities for skilled and unskilled labour, and rapid expansion of information system to convey easily messages regarding employment opportunities. Political instability remained elusive for a long time in Nepal. That is why there still remains a strong attraction for foreign employment among young population. As a result, the number of Nepalese who obtained official permission to work overseas more than doubled in a single year from 1996/97 to 1997/1998. It is estimated that around 2.27 million were in foreign employment in 2007 (NCCR/NIDS 2008). The high population growth rate after 1960s resulted in an increased population density from only 38 persons per square kilometre in 1911 to 157 in 2001. The annual population growth rate between 1991 and 2001 was 2.24 percent per year (CBS 2002) while between 2001 and 2011 the annual growth rate of Nepal is only 1.35 percent. The percentage of the absent population in the 2011 census reflected a surge in numbers, with an increase by 152 percent between 2001 and 2011 and accounting for 7.3 per cent of the total population (Government of Nepal, 2011). Among the total migration of the country, a higher proportion is from rural hilly and mountain areas than from the more accessible and plain areas of Nepal.

Hill Farming Practices: Over the centuries, farmers have been adopting a system of land use compatible with their environment such as shifting cultivation. But such traditional farming system has not been able to cope with the rapid growth of both human and livestock population. Over the recent decades, land degradation and destruction in mountain ecosystems are becoming increasingly widespread. The traditional farming system and cultivation in steep hill slopes have accelerated the rate of erosion and degradation. Agricultural productivity especially in the hills and mountains is declining due to the erosion of fertile surface soils every year. Joshy et al. (1997) consider land degradation in specific terms as the decline in soil quality caused through its misuse by humans resulting in the decline in soil productivity. Land degradation affects the entire production system based on land and in turn, the very livelihood system of the population. The production potential of the land is reduced along with the further encroachment of the forest and marginal lands. The intensification of cropping practices further depletes the fertility of the soils. Higher proportion of land abandonment in steeper slope and higher altitude areas also proves the same situation in the study area. People in the mountain and hilly regions of Nepal have limited access to land, to knowledge and information about technology and to credit. The land resources they possess are often of poorest quality and prone to degradation. All these factors lead to unsustainable management of land resources and encroachment into marginal land, which in turn leads to a vicious cycle of further poverty and land degradation.

Determinants of Cultivated Land Abandonment: According to FAO (2006) determinants of agricultural land abandonment are natural constraints, land degradation, socioeconomic factors, demographic structure, and institutional factors. This study has taken only altitude and population change as determining factors because of the reliability problems of correlation among dependent and explanatory variables. However, these two variables give better explanation of dependent variable in this study. GWR model has the capacity to predict the location specific role of explanatory variable. The overall explanation of population change on cultivated land change is positive but some areas have negative impact of this variable. Some studies reveal that population change has not always positive result in agricultural land abandonment (Ellis 2004, Gray and Bilsborrow 2014, and Izquierdo et al. 2011), which is clearly visible in this study. Altitude is another important physical explanatory variable for agricultural land abandonment. Although the general situation of land abandonment is that it increases with increasing altitude, in the north-eastern portion cultivated land increased with increasing altitude because of the less steep slope gradient compared to similar altitude areas. Another factor is the south facing sunny slope, which is suitable for cropping. Climatic factors are also determined by altitude. A lower altitude river basin is flat so it is more productive than higher hilly slopes and these areas also have more irrigation facilities. Temperature decreases with increasing altitude. Colder higher altitude areas have longer growing season than lower altitude area. So, higher altitude area has less potential for multiple cropping. In general, production potential is higher at lower altitudinal region compared to higher altitude areas. Naturally, the carrying capacity of human occupancy is decreasing with increasing altitude (Chidi 2009).

The highway provides a major access in the study area, which passes through lowland area. Major urban centres are located along the highway. On the one hand, the highway is a major influencing factor for human concentration because of land suitability and accessibility, and the development of market centres along the highway on the other. This situation has resulted in population movement from higher altitudes to lower areas. Lowland areas with higher carrying capacity have played a lower role as a push factor for migration. Although, GWR model has taken only altitude and population change as explanatory variables, many factors related to altitude have resulted in a combined impact on cultivated land change. Ward level generalization of slope gradient and slope aspect did not indicate a clear relationship with cultivated land change but a micro level analysis of other research in the study area has proved that these two variables are also another important factor of changing situation of cultivated land (Chidi 2015). The impact of resource scarcity or other environmental factors on a household's decision to send migrants is not well studied, except perhaps in the case of land resources.

There is ample historical evidence to suggest that scarcity of land resources has led to waves of outmigration to new lands, as occurred in European history and is repeated from the cores to the peripheries of many developing countries. Land scarcity is a key driver of migration in Uganda (Tukahirwa, 2002). VanWey (2003 and 2005) finds that both a lack of land and a large amount of land have motivated migration in Thailand and Mexico. The Sloping uplands generally contain marginal lands due to different constraints, which change according to the ways land is used. It can be managed in ways that support the process of marginal land up-gradation. When sloping uplands are viewed from the economic perspective, they are less favourable for agriculture. However, sloping land agriculture can have many values and potentials not available in the plain land agriculture and farmers can make use of these comparative advantages. Thus, even though opportunities exist to improve farming and livelihood on marginal lands, it has not happened so far in the Asian uplands (Pratap 2004), which is quite applicable in Nepal. The problem is not of technology as such but it is more institutional, such as limited research and development investment in upland farming research, socio political neglect of the marginalized upland societies, low capacity of communities, and inappropriate development planning (Pratap 2004). The uplands of Nepal are passing through a dynamic stage of demographic scenario, whereby cropland scarcity and less job opportunities in the uplands have resulted in out-migration from the uplands to growing economies in the urban plains and foreign countries. Heavy land abandonment in such a short period of time has resulted due to the past occupancy of marginal land because of high population pressure. Lack of consideration of local conditions (bottom up approach) and government negligence of service facilities for hill agriculture are major problems in Nepal. Till this date, neither academic nor government and nongovernment organizations have any consideration for this local reality in Nepal.

4. CONCLUSION

Depopulation after the decades of 1990s in the hills of Nepal is increasing day by day because of the outmigration of population. Sudden release of population pressure on hilly marginal agriculture areas has resulted in a fast rate of land abandonment. Higher proportion of abandoned land is being covered by natural vegetation such as grassland, shrubs and forest. It has many implications for hilly people and environmental consideration.

It has been found that outmigration of rural population has caused an increase in agricultural land abandonment. However, some more accessible areas have inverse relation of outmigration. Some areas have increasing cultivated land with increasing population but these areas are very limited and these areas should be verified properly. Altitude is also another important determining factor of land abandonment. Land abandonment is increasing with increasing altitude. In the lowlands there is more fertile flat land with access to highway and major market centres. Population concentrates also along the highway. These areas have increased cultivated land with increasing population. Therefore altitude itself is not a single factor of determining population change and abandonment of agricultural land. Some areas in the northeast part of the study area have increased cultivated land with increasing altitude. It is because of the other suitable factors for cultivation such as slope gradient and slope aspect. Different local coefficient in a single model is possible by using GWR model, which develops local regression coefficient using local situation of the variables. The GWR model reveals that only two variables, population change and altitude, have 56.6 percent impact on cultivated land change in the study area. There are also other variables such as slope gradient and slope aspect but ward level generalization of these variables has problems of reliability for prediction model. However, micro level analysis in the study area has proved that there is a close relation between the cultivated land abandonment and the slope gradient and slope aspect.

The marginal lands have experienced much land abandonment situation in the study area. This is however common in the mountain regions across the world. Negligence of government for proper implementation of programs to promote hill agriculture has further accelerated the higher rate of land abandonment just after the depopulation in hill agriculture. The formulation of land use policies and their implementation with regard to control over arable land abandonment together with provisions of infrastructure and facilities for local resource utilization is essential to support rural livelihood, thereby to check outmigration of population in the areas such as the Andhi Khola watershed of western Nepal.

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