sustainability

MDPI

Article

Changes in Cropland Status and Their Driving Factors in the Koshi River Basin of the Central Himalayas, Nepal

Basanta Paudel [1,2], Jungang Gao [1], Yili Zhang [1,2,3,*], Xue Wu [1,2], Shicheng Li [1,2] and Jianzhong Yan [4]

[1] Key Laboratory of Land Surface Pattern and Simulation, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China; paudelb@igsnrr.ac.cn (B.P.); gaojg.09b@igsnrr.ac.cn (J.G.); wux.12s@igsnrr.ac.cn (X.W.); lisc.10s@igsnrr.ac.cn (S.L.)

[2] University of Chinese Academy of Sciences, Beijing 100049, China

[3] CAS Center for Excellence in Tibetan Plateau Earth Sciences, Beijing 100101, China

[4] College of Resources and Environment, Southwest University, Chongqing 400716, China; yanjzswu@126.com

* Correspondence: zhangyl@igsnrr.ac.cn; Tel.: +86-10-6485-6505; Fax: +86-10-6485-1844

Academic Editor: Adrian Muller

Received: 2 June 2016; Accepted: 5 September 2016; Published: 13 September 2016

Abstract: In recent decades, human activities have significantly transformed land use and land cover (LULC) and the environment of the Central Himalayas region. LULC is a major component of environmental and climatic research. The aim of this study was to determine the changes in cropland status and its drivers in the Koshi River Basin (KRB) of the Central Himalayas region of Nepal between 1978 and 2010. The cropland status in 1978 was obtained from the Land Resources Mapping Project (LRMP) datasets. The cropland status in 1992 and 2010 was determined on the basis of satellite imagery, with an object-oriented classification method, together with field investigations. Advanced geographical tools were used for data processing and binary logistic regression models were used for the statistical analysis of potential driving factors of cropland change. A noticeable overall change in cropland area was found, with rapid increases from 1978 onward at differing rates and to different extents. The cropland area covered 7165 km^2 in 1978. It peaked at 7867.49 km^2 in 1992, and had reduced slightly (by 90 km^2) to 7776.66 km^2 by 2010. The change in cropland area was mainly related to four potential driving factors: topography (elevation, slope, and soil types), socioeconomics (population and foreign labor migration), climate (annual mean temperature and precipitation), and neighborhood factors (roads, rivers, and settlements). However, the effects of the different variables have occurred over various stages and at different rates. An understanding of long-term changes in cropland status in the KRB would be useful, and this could be extended to spatial reconstructions with the help of historical data, including cropland and climatic archives.

Keywords: cropland change; driving factors; logistic regression; Koshi River Basin; Nepal

1. Introduction

The primary mode of land use involves modifications brought about through human activity and the conversion of natural ecosystems to agriculture [1,2]. Efforts have been made to quantify the extent of natural [1] and anthropogenic changes [3] in cropland status at both the global and local scale [4]. In Nepal, such studies have been undertaken in relation to the drastic changes in cropland that have occurred in recent decades [5,6]. There is a long history of studies of the global impact of human activity on the environment [7]. In previous centuries, negative consequences of human activity [8] on the Earth's landscape were recognized [9], and in recent decades a rapidly increasing human amendment of land cover and its conversion has occurred [10,11]. The process of cropland change is complex and occurs over different pathways, with a diversity of magnitudes and rates [12]. It is always dynamic and occurs differently when observed at different scales [13]. In historical cropland sectors, several studies have been well documented, and have created long-term spatial datasets detailing the overall changes in cropland [1,2,14].

Mountain regions are more sensitive to land use and land cover (LULC) changes [5], and experience the impacts of even small changes more strongly than plains [15]. Such impacts are not confined solely to the mountain areas where the change occurs, but are also transmitted to lowland areas where the impacts are intensified due to the steep gradients of the mountain slopes [16]. Koshi River Basin (KRB) is a mountainous area [17] in the Central Himalayas region [18], and there has been a high population growth rate in the region in recent decades [19], but the economy remains based on subsistence agriculture [20]. Historical studies of the high Himalayan region, including the KRB, have revealed that there was a high rate of deforestation and cultivation of marginal land in the 1970s, which has resulted in many problems with regard to economic development and environmental protection [21–23]. However, some later studies of the KRB region have indicated a reversal in the trend of deforestation and a decline in cropland area throughout the region [24,25].

The processes of cropland change in terms of the pathway, size, and driving factors of change vary over time and space [5]. In this study, actively cultivated agricultural land was regarded as cropland [5]. In recent decades, land use forms such as urbanization, shifting cultivation, deforestation, land degradation, and grazing have also been important factors in cropland changes in the KRB. Since 1978, the population has grown rapidly in the country as a whole, and particularly in this region [19]. A rapidly growing population requires commodities and food in increasing amounts from natural resources and agriculture [5], and this has been associated with an unprecedented rate of cropland expansion [26]. There have been few studies of the historical changes in the cropland of the KRB and there is a lack of spatial data. Therefore, the aim of this study was to determine the trends in cropland status, and the changing relationships with various driving factors of cropland change, in the KRB region of Nepal during the period of 1978–2010. First, we analyzed the distribution of cropland between 1978, 1992 and 2010, in the whole basin, together with the sub-basin areas. Then, we explored the changing area of cropland between 1978 and 1992, and 1992 and 2010. We conducted a changing relationship analysis in relation to various potential driving factors. Finally, we present a series of concluding remarks regarding cropland changes in the KRB that have occurred since 1978.

2. Materials and Methods

2.1. Study Area

The Koshi River Basin (KRB) is located on the border between China and Nepal and is one of the most important transboundary river basins in the high Himalayan region [17]. Our study focused on an area of 25,898.55 km^2 on the Nepal side of the border, situated at 26°51′–28°12′N, 85°22′–88°12′E in the Central Himalayas region (Figure 1). The area shares its northern border with China, and its eastern border with India. The KRB consists of three main sub-river basins, the Arun, Sunkoshi, and Tamor [17], and has vast water resources (48 billion cubic meters/year) [27]. The Tamor sub-basin is located in the eastern part of the study area, while the Arun sub-basin is in the central part and the Sunkoshi sub-basin is in the western part. There were eight dominant types of soil in the basin: (Eutric Cambisols (CMe), Gleyic Cambisols (CMg), Humic Cambisols (CMu), Chromic Cambisols (CMx), Glaciers (GG), Gelic Leptosols (LPi), Dystric Regosols (RGd), and Eutric Regosols (RGe)) [28].

Some of the highest mountains in the world, including the Earth's highest peak, Mt. Sagarmatha (Qomolangma/Everest), are located on the northern side of the basin. The annual precipitation in the basin is 1794.6 mm [18], with an average maximum monthly temperature of 32.0 °C in summer (June) and an average minimum monthly temperature of around 0 °C in winter (October) [29]. In the KRB, the range of elevation is very broad (Figure 1), it ranges vastly [30] within a short distance. The main cropping patterns of the basin are rice, maize, and millet in summer, and wheat and barley in winter, alongside vegetables and cash crops. The population density recorded between 20 and 1343 people/km^2 in 1981 and increased to 28–4416 people/km^2 in 2011 for different areas in the basin [19]. The KRB is inhabited by a different races of people, comprising both Mongoloid and Caucasoid stocks. The Sherpa and Tamang people, who are most akin to the Tibetans, live in the northern most region of the KRB, while the Rais and Limbus, collectively known as Kirantis, live in the central region. Hinduism, Buddhism, and Kirant are the major religions practiced in the region [19].

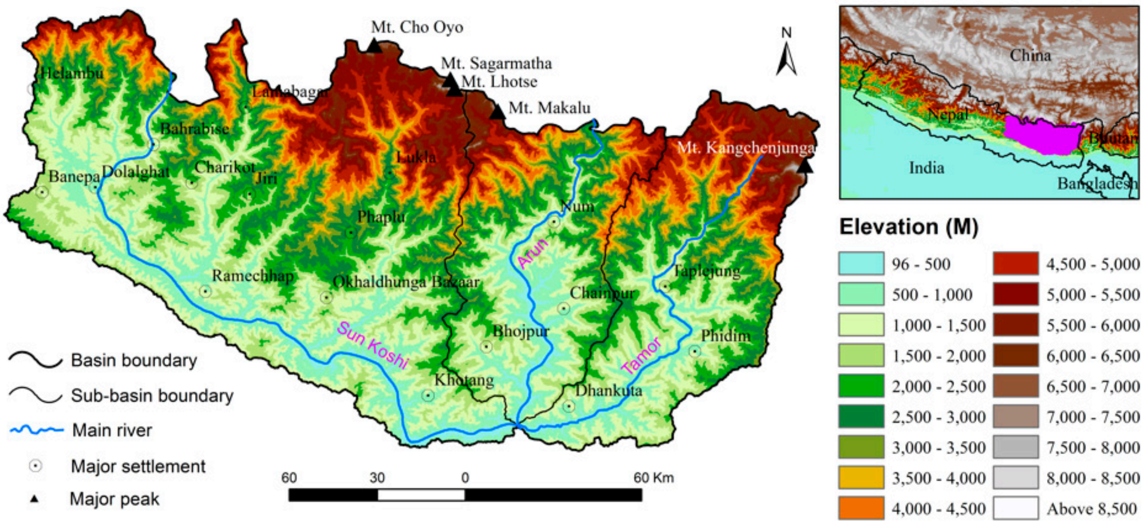


Figure 1. Location of the Koshi River Basin (KRB) in the Central Himalayas, Nepal.

2.2. Sources of Data and Analysis Tools

The datasets used in this study cover different periods. The cropland datasets for 1978/1979 were obtained from the International Center for Integrated Mountain Development (ICIMOD), which was the base dataset of the Land Resource Mapping Project [31], and was later re-digitized as ICIMOD, Nepal. These datasets were developed in 1986, but represent the situation in 1978, because the aerial photography was conducted in 1978–1979. To prepare datasets for the 1992 cropland, we used several open sources, including 30 m resolution Landsat 4 and 5 Thematic Mapper (TM) satellite imagery (Table 1), obtained from the United States Geological Survey (USGS). We selected images for the period from 1990 to 1992 and prepared the base cropland datasets for1992. Similarly, for the datasets for 2010, we selected open-source 30 m resolution Landsat 5 TM images. In this case, we used the images from 2009 to 2010 to prepare cropland datasets (Table 1).

The datasets for these three periods cover the status and spatial changes of cropland in the KRB, since 1978. Similarly, open-access Shuttle Radar Topography Mission (SRTM) 30-resolution digital elevation model data were used to show the elevation and slope of the study area, and were prepared by the US National Aeronautics and Space Administration (NASA) and released in 2015. The population data from 1991 to 2011 were obtained from the Central Bureau of Statistics, Kathmandu, Nepal [19]. Climate data from 1992 to 2010 were provided by the Department of Hydrology and Metrology in Nepal, and soil data were obtained from the soil and terrain (SOTER) database for Nepal [28]. Foreign labor migration data from 1993 to 2010 were provided by the Nepal's Ministry of Labor and Employment [32]. The river data prepared in between 1992 and 2001 was obtained from the Survey Department of Nepal, which was used for both periods (1978–1992, and 1992–2010), and road data prepared by the Survey Department of Nepal during 1992–2001 were obtained for 1978–1992 analysis, and the NASA socioeconomic data and applications center (SEDAC) released the 2010 road data which were used for 1992–2010 analysis [33]. Settlement data were prepared independently from 1992 to 2010 based on topographic maps, and satellite and Google images.

Table 1. Details of the satellite data used.

1992			
Satellite/Sensor	**Path**	**Row**	**Date**
Landsat 5 TM	139	41	5 November 1990
Landsat 4 TM	139	41	13 January 1990
Landsat 5 TM	140	41	17 November 1992
Landsat 4 TM	141	41	30 November 1991
2010			
Satellite/Sensor	**Path**	**Row**	**Date**
Landsat 5 TM	139	41	9 April 2010
Landsat 5 TM	140	41	25 April 2010
Landsat 5 TM	141	41	31 March 2010
Landsat 5 TM	141	41	9 December 2009

ERDAS Imagine 9.1 (Leica Geosystems, Atlanta, GA, USA) and ENVI 4.6.1 (Exelis Visual Information Solutions, Boulder, CO, USA) were used for the data processing and analyses and classification of all satellite imagery. The mapping work was undertaken using ArcGIS 10.1 (Environmental Systems Research Institute, Redlands, CA, USA) and the Global Positioning System (GPS) (Holux Technology, Hsinchu, Taiwan) was used for field survey work to determine latitude, longitude, and altitude. In addition, IBM SPSS Statistics 20 (IBM in Armonk, NY, USA) was used for the statistical analysis.

2.3. Generation of Cropland Maps

In this study, the definitions of level terrace, sloping terrace, valley cultivation, dry land cultivation, mixed land cultivation, and wet land cultivation, were adopted from the Land Resources Mapping Project (LRMP) 1986, and also the spatial distribution of cropland in 1978 was obtained from the LRMP dataset [31]. The same (LRMP 1986) definitions based spatial distribution of cropland was produced independently for 1992 and 2010. The processing of the data first involved a geometric correction using 1:25,000 (middle mountain regions) and 1:50,000 (high mountains regions) scale-based topographic maps from the Survey Department of Nepal, together with 2011's GPS field survey points, and we then used the ERDAS Imagine 9.1 tool for geometric correction. During the process of geometric correction, we achieved an acceptable root mean squared error (RMSE) of less than 0.6 pixels [34] in both 1992 and 2010. After geometric correction we mosaicked all images. For a high degree of accuracy and easy analysis of the objects in the image, we used a false-color composite method (RGB 5, 4, and 3 bands), and this image was clipped by the basin boundary for further analysis of the basin area only. An object-oriented classification method was then used to determine the area of cropland cover based on the ENVI 4.6.1 tool. On the basis of object characteristics in the basin, we developed several object related classes during the object-oriented classification, i.e., cropland, built-up area, forest land, water bodies, grass land, shrub land, and bare land. After these steps were completed, we extracted the cropland layers to select using a table of attributed results. The visual interpretation method [35] was then used to extract the preliminary results for a comprehensive amendment of the field investigation conducted in several parts of the KRB in 2011. Similarly, we used high-resolution Google Earth images from 2010 as reference data. These images are commonly used for LULC research to correct misclassifications of study areas [30,36]. We used them to revise the results, by removing and adding misclassified cropland areas from the overall area of the basin.

Furthermore, we used the 1992 and 2010 cropland datasets to conduct an accuracy assessment of the KRB cropland area in 1992 and 2010. To achieve this, 250 points were acquired through a random sampling method in both cases (1992 and 2010). We used high-resolution Google Earth images from 2010 as reference data for 2010, and 1:25,000 (middle mountain regions) and 1:50,000 (high mountains regions) scale-based topographic maps from the Survey Department of Nepal as reference data for 1992. The topographical maps were prepared during the period of 1992–2001, and have been widely used for historical LULC accuracy assessments [37]. On the basis of the high-resolution Google Earth images in 2010, we made an accuracy assessment of the cropland cover in 2010, where we achieved greater than 81%. The corresponding figure for 1992 was 77%. By overlaying the cropland layers of different years (1978, 1992 and 2010), we were able to determine the cropland expansion and contraction during the periods of 1978–1992, and 1992–2010. Later, we converted all of the datasets into binary classes (i.e., cropland and non-cropland) for a logistic regression model in raster format, with a 30 m grid resolution.

2.4. Selection of the Potential Driving Factors of Cropland Change

To determine the potential driving factors of cropland changes in the KRB, we selected 10 variables in each period (1978–1992, and 1992–2010), each of which could be placed into one of four categories (Topography, Socioeconomic, Climate, and Neighborhood) (Table 2). Previous LUCC studies have indicated that this number of selected drivers would be sufficient [30,36,38]. These variables were chosen based on their effects as described in previous studies in the Himalayas [17,30,39,40]. Figure 2 shows the variables used for the 2010 analysis, which were similar to those used in the earlier period, and were selected as potential driving factors in logistic regression models.

The same data for the topography related variables (elevation, slope, and soil) were used in both periods (1978–1992 and 1992–2010) because, in the context of the KRB, there was little potential for these variables to change between the two periods. The SRTM elevation and slope data obtained from the NASA for the region released in 2015, and the soil (SOTER) data released in 2009 were used in the study. Different socioeconomic data (population and foreign labor migration) were used in the two different periods. For population, we used district wise 30 m resolution population density data from 1991 to 2011 as potential driving variables for 1978–1992 and 1992–2010, respectively. Data for foreign labor migration, i.e., Nepalese people who moved to a foreign country for work [32], were used as a potential driver for the 1992–2010 period. We did not use this driver for 1978–1992, due to a lack of good-quality data. Climate-related variables for 1992 and 2010 (mean annual temperature and precipitation) were selected as potential drivers for 1978–1992 and 1992–2010, respectively. For the neighborhood-related potential driving factors (roads, rivers, and settlements), the same river data (prepared between 1992 and 2001) were used in both periods. Road data prepared between 1992 and 2001 were used for the 1978–1992 period, and 2010 road data were used for the 1992–2010 period. Settlement data for 1992 and 2010 were used to analyze the 1978–1992 and 1992–2010 periods, respectively. We selected major settlements as the main neighborhood factors driving cropland change, and included urban centers within this category. Finally, these variables were collected from different sources in each period; they were first converted into the 30 m resolution raster format and then exported to SPSS file format to run the logistic regression model.

Table 2. Selected variables for logistic regression models of cropland change in the KRB.

Category	Descriptions	Unit	Resolution (m)	Proxy for
Topography	Elevation	m	30	Elevation
	Slope		30	Degree of slant
	Soil	m	30	Soil type
Socioeconomic	Population density	people/km^2	30	Trend of population change
	Foreign labor migration	people/km^2	30	Labor status
Climate	Mean annual temperature	°C	30	Mean temperature
	Mean annual precipitation	mm	30	Mean precipitation
Neighborhood	Distance to a road	m	30	Accessibility
	Distance to a river	m	30	Accessibility
	Distance to a settlement	m	30	Accessibility

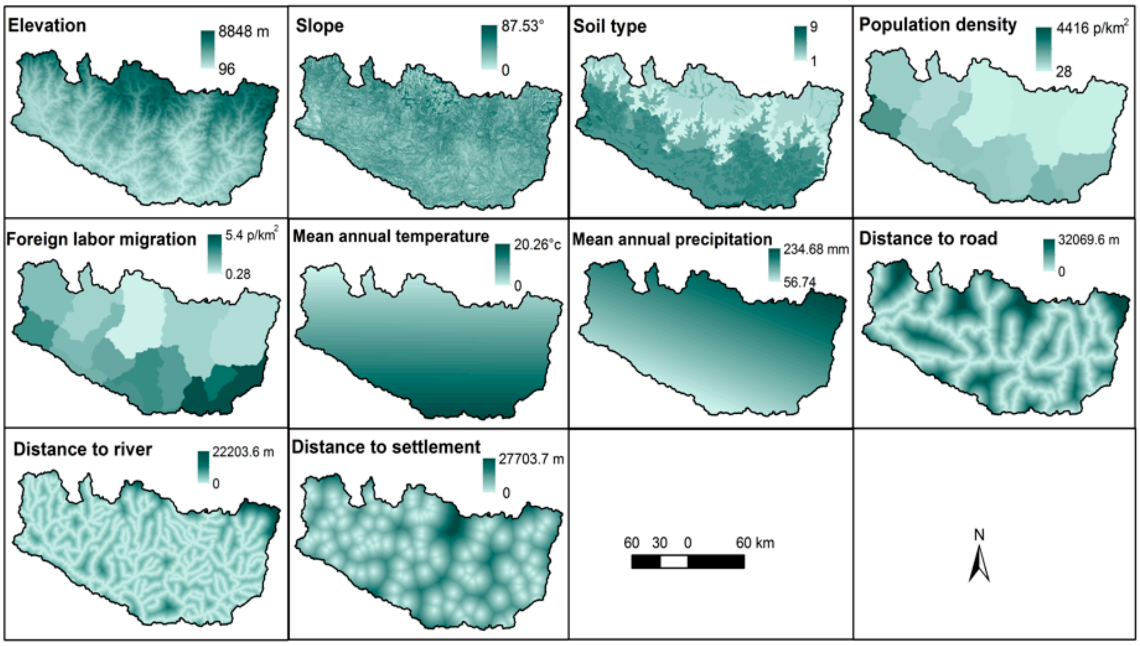


Figure 2. Selected variables driving changes in cropland area in the KRB in 2010.

Topography-related factors have an important role in changing the status of cropland. Usually, an increase in elevation and slope makes farming quite difficult and the costs become higher. In addition, cropland appears more on flat land and less vertical slopes. The role of soil types (nutrients and organic matter content) is also vital [36], and is directly related to changes in cropping activities and the area of cropland. These three potential topography-related driving factors (elevation, slope, and soil type) were selected to determine the actual changes in cropland area in the KRB.

Population and foreign labor migration were selected as the major potential socioeconomic driving factors of cropland change in the KRB. The rapid population growth has directly led to a high demand for food and cropland [41], which has further intensified cropland expansion. Similarly, foreign labor migration also significantly influences changes in cropland area. The annual temperature and precipitation during both periods investigated is likely to have had a large impact on changes in cropland area in the KRB, and were selected as climate-related potential driving factors of cropland change.

Neighborhood factors play an important role in changes to the overall cropland status. The distance to roads and rivers is a major influence on cropping activities and cropland area. In recent decades, the development of roads and infrastructure in Nepal and the KRB area has increased rapidly [42]. Many locations in the basin area now have easy access to roads and transportation, which was confirmed during the field investigation for LULC verification in different parts of the KRB in 2011. With the availability of good transportation and the development of several local markets, some local people have changed their occupation from farmers in order to pursue other opportunities, such as farming to business, farming to constructional work, and farming to other fixed salary based services, which was observed during the field survey in 2011. Meanwhile, others have focused more of their time on cropland cultivation, especially

2.5. Spatial Sampling

Dependent variables have the potential to become spatially auto-correlated [30], which contravenes the independent speculation of logistic regression and creates the potential for bias in the overall results [43]. Large amounts of data (i.e., 9252 × 5000 grid cells in the population layer, and 10 different layers in each period in the KRB), make it difficult for spatial and statistical analysis to cover all individual values [36], and this has also been observed in several other studies [30,38]. These problems are dealt with by the collective approach of systematic and random sampling [30]. We adopted this method in the study and implemented spatial sampling.

Subsequently, the land use map at the end of the each period was selected for systematic sampling, where the cropland areas between 1978–1992 and 1992–2010 were coded in a binary form, as 1 for an expanded cropland area and 0 for other land categories. Only expanded cropland areas (code 1) were included in the spatial sampling. Similarly, during the period of 1992–2010 (contraction), the cropland area was coded in the same way in a binary form, as −1 for a contracted cropland area and 0 for other land categories, and only the contracted cropland area (code −1) was used for spatial sampling. For the high performance and accuracy of a model [36], the area of cropland in the base year should be set off the land use map. The number of points with 1 and −1 codes was less than the number with code 0. Therefore, for unbiased results from all of the estimated parameters in the models [44], we also selected a procedure to undertake further random sampling in the area of other land categories (0 code). Thus, an equal number of points coded 0 and 1, and 0 and −1 were selected. During 1978–1992 and 1992–2010 (expansion), there were, respectively, 562 and 332 sampling points for KRB. There were 368 in 1992–2010 (contraction). Afterwards, all potential drivers (10 layers), corresponding to the value from each stage, were extracted from layers to points.

2.6. Binary Logistic Regression Models for Statistical Analysis

Logistic regression is very popular and it has been extensively used in studies of LULC to assess periodic changes, because it is commonly expressed as a dependent variable [30,36]. The dependent variables were modeled for the expansion and contraction of cropland area by logistic regression, and were interpreted as binary forms of data. All of the independently selected variables in the study were standardized according to Menard [44], and were then tested for multicollinearity [45]. Before logistic regression, we implemented a Z-score standardization method for variable standardization. Finally, these standardized variables were used to build three logistic regression models. The coefficient of determination (R^2) values indicated that the critical value of one variable against all others was below the standardized value (0.80) of Menard [46]. Therefore, we applied an ArcGIS-based binary logistic regression model, where we used these variables (independent) to identify those that were statistically significant for cropland changes in the KRB. The logistic regression model is an effective method, when the dependent variable is in a binary form in the analysis of LUCC [30], and therefore this study used dependent variables in binary format. In this study, the relationship between the dependent and independent variables in the logistic regression was defined as follows:

$$Y = \log\left(\frac{P}{1-P}\right) = a + b_1X_1 + b_2X_2 + b_3X_3 + \ldots b_nX_n$$

where P is the dependent variable, which is the probability of cropland expansion and contraction; $x_1, x_2, x_3, \ldots, x_n$ are independent variables (the driving factors described in Section 2.4), and $b_1, b_2, b_3, ..., b_n$ are partial regression coefficients. After performing a logit transformation of the equation, the model was linearized, and the performance of the dependent variables in the regression continuously ranged from 0 to 1 [30]. As a result, the logistic regression model resulted in a map with a pixel value, which represented the probability of cropland expansion and contraction over the study area during the study periods. To obtain a logistic regression model for studying cropland change in this study, we carefully performed all the procedures step by step. We estimated the odds ratio for every covariate, and used the Wald statistic to test the significance of the covariates. The "percentage correctly predicted" (PCP) was used to determine the accuracy of the model [46], together with the area under the receiver operating characteristic (ROC) curve (AUC) and Nagelkerke's R^2 [44]. The AUC indicates the performance of the models [30], with a value of more than 0.9 indicating that the value is logical and high; 0.7 and 0.9 is intermediate; and less than 0.7 is relatively low [36].

3. Results

3.1. Status and Distribution of Cropland

In 1978, the extent of the overall cropland in the KRB was 27.67% of the total area. At that time, the area of the KRB covered by cropland was 7165.14 km^2 (Figure 3a). While there were agricultural activities in some areas of the southern and western parts of the basin at that time, the middle, northern, and northeastern parts contained fewer cropland areas. The northern part of the basin is almost entirely covered by high mountains, where it was not easy to cultivate crops, thus rendering these regions as mostly non-cropland areas. The status of cropland in 1992 was slightly different than in 1978. Of the total area (25,898.55 km^2) of the basin, 30.38% (7867.49 km^2) was covered by cropland in 1992 (Figure 3b). The 1992 distribution of cropland areas in the KRB was also different to that in 1978. The majority of the cropland area was located in the southern part of the basin, while in the northern high altitudinal belt of the basin there was almost no cropland area, due to the permanent glaciers. In 2010, datasets of the cropland status the area was 7776.66 km^2, i.e., slightly less than in 1992 (Figure 3c).

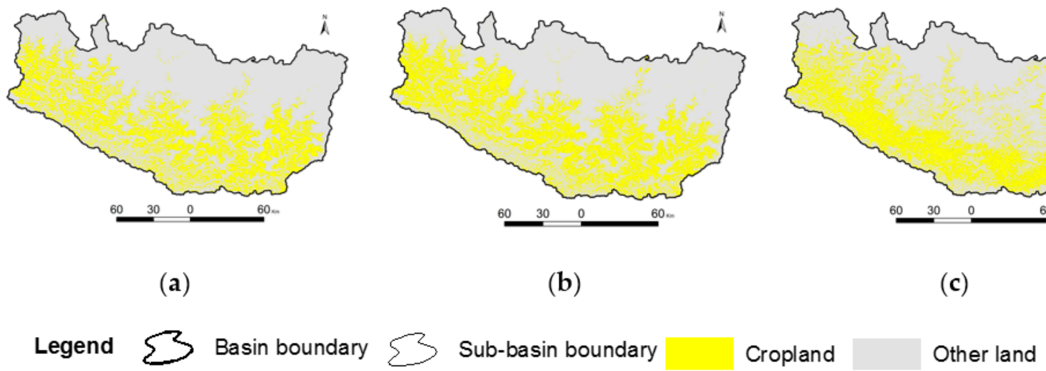


Figure 3. Cropland distribution in the Koshi River Basin (KRB) in 1978 (**a**); 1992 (**b**) and 2010 (**c**).

There were different magnitudes of cropland distribution in the three sub-basins in different years (Table 3). The major part of the KRB is covered by the Sunkoshi sub-basin; thus, the extent of cropland distribution in this sub-basin is greater than for the other sub-basin areas. In 1978, 58.70% of the total cropland area was located in the Sunkoshi sub-basin, while the Tamor and Arun sub-basins accounted fo rthe remaining 23.27% and 18.30%, respectively. In 1992, the Sunkoshi sub-basin accounted for 61.20% of the total cropland area, with the Tamor and the Arun sub-basins accounting for 20.35% and 18.45%, respectively. In comparison, the distribution of the total cropland area among the three sub-basins in 2010 was 62.33% in the Sunkoshi, 23.03% in the Tamor, and 14.64% in the Arun.

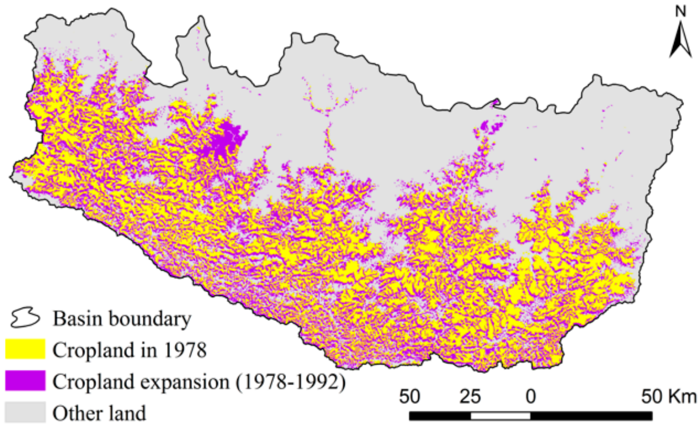
Table 3. Cropland distribution of sub-basin area of KRB (km^2).

Sub-Basin	1978	1992	2010
Tamor	1667.67	1600.80	1791.19
Arun	1291.67	1451.81	1138.69
Sunkoshi	4205.80	4814.88	4846.78
Total	7165.14	7867.49	7776.66

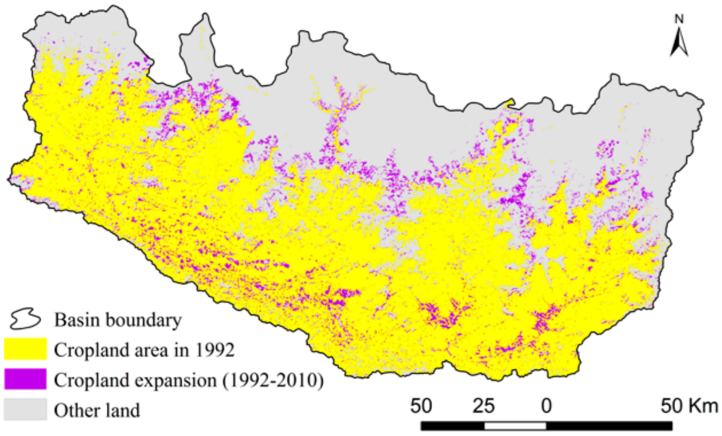
3.2. Changing Trend of Cropland Status

The magnitude and rate of historical cropland changes in the KRB have varied markedly over the years. Previous studies of LULC in Nepal as a whole have included the KRB as a major part of their research [31,47]. Aerial photographs of the cropland status of the KRB in 1978 show cropland area to cover about one-fourth of the total area of the basin. The cropland area increased from 1978 to 1992 by

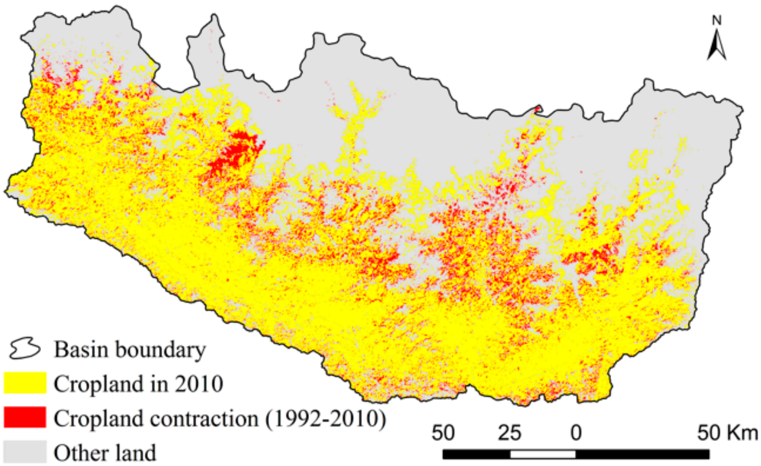
702.35 km^2 (Figure 4a). Between 1992 and 2010, in contrast, there was a slight increase in the area of cropland of 91.64 km^2 (Figure 4b), but this then decreased by 182.47 km^2 (Figure 4c). The overall total area of cropland in the basin had decreased by 90.83 km^2 in 2010 compared to the area in 1992.



(**a**)



(**b**)



(**c**)

Figure 4. Changing trends in cropland status. (**a**) Expansion 1978–1992; (**b**) expansion 1992–2010; (**c**) contraction 1992–2010.

During the 32 years studied here, the overall status of the cropland area in the KRB has varied. Over this period, cropland has extended from south to north, i.e., from low- to high-altitude areas. A comparison of the 1978, 1992, and 2010 datasets and results clearly shows that land use in the central part of the basin changed to the greatest extent, with the area of crop cultivation being less than in 1978. By 1992 and 2010, a large area of cropland cover existed. This means that agriculture practices and patterns that were once intensely distributed in lowland areas have spread to higher altitudes [5]. The three datasets show that the rate of cropland change increased between 1978 and 1992, and then decreased slightly by 2010.

3.3. The Driving Factors of Cropland Change

The results of the three logistic models are presented in Table 4. In all three models, the PCP was greater than 75, whereas it was 83.45 in 1978–1992, 81.20 in 1992–2010 (expansion), and 78.15 in 1992–2010 (contraction). The value of the AUC was between 0.75 and 0.79. The R^2 values were greater than 0.462. These results showed that the potential of the selected driving factors was well established in logistic models during the process of cropland change over the last 30 years in the KRB.

Table 4. Summary of the variables in the (expansion and contraction) logistic regression models.

Expansion Variables	Expansion Period		Contraction Period
	1978–1992	1992–2010	1992–2010
Distance to road	0.403 *	0.611 *	0.152 *
Distance to river	−0.059 *	0.390 *	0.208 *
Distance to settlement	0.485 *	0.525 *	0.306 *
Elevation	0.520 *	0.158 *	1.024 *
Slope	0.135 *	0.053 *	−0.591 *
Soil type	−0.585 *	0.501 *	−0.504 *
Mean annual temperature	−0.551 *	0.162 *	0.569 *
Mean annual precipitation	−0.215 *	0.220 *	0.156 *
Population density	0.640 *	0.804 *	−0.353 *
Foreign labor migration	—	0.204 *	0.474 *
Constant	0.203 *	0.217 *	0.154 *
N	562	332	368
PCP	83.45	81.20	78.15
AUC	0.75	0.79	0.77
R^2	0.534	0.502	0.462

Only standardized variables with $p < 0.05$ value were used in the model; * indicates a 1% significance level in the partial regression coefficient; and — indicates a driving factor that was not included in the model. Abbreviations: N = number of points; PCP = percentage correctly predicted; AUC = area under the receiver operating characteristic (ROC) curve.

Cropland expansion and contraction have been simultaneously affected by topography, socioeconomic conditions, climate, and neighborhood-related factors. However, the role of the different driving factors varied between the different periods studied. The potential driving factors of change had an effect on the different extents of cropland area during the periods of 1978–1992, and 1992–2010 (Table 5), and were ranked differently in the different periods investigated in this study. Socioeconomic factors had a major role in cropland change, with the increasing population density being ranked in 1st position during the cropland expansion in the periods of 1978–1992 and 1992–2010, while foreign labor migration was listed in fifth position as a driving factor of cropland contraction between 1992 and 2010 (Table 5).

The role of neighborhood factors was more important than the other driving forces in terms of cropland expansion, but they had a lesser role during cropland contraction. The distance to roads and settlements had a larger role than the distance to rivers during the cropland expansion period. Climate-related driving factors were ranked higher during the cropland contraction period than during expansion. Both average annual temperature and precipitation had a large role in the contraction of cropland during 1992–2010. However, the role of topography-related factors was complex and varied among the different periods, but was clearly significant in both the cropland contraction and expansion periods during the past 32 years. Overall, socioeconomic factors had the strongest effect, especially population density during the cropland expansion period, and foreign labor migration (as well as topography- and climate-related factors) in the contraction period.

Table 5. Rank order of potential drivers of cropland change in different logistic models.

Expansion Variables	Expansion Period		Contraction Period
	1978–1992	1992–2010	1992–2010
Distance to road	6	2	10
Distance to river	9	5	8
Distance to settlement	5	3	7
Elevation	4	9	1
Slope	8	10	2
Soil type	2	4	4
Mean annual temperature	3	8	3
Mean annual precipitation	7	6	9
Population density	1	1	6
Foreign labor migration	—	7	5

4. Discussion

4.1. Effects of Topography Related Drivers

Elevation, slope, and soil are important driving factors of cropland change. Cropland in the basin was mainly located on the valley floor and low mountain slopes (from 96 to 1500 amsl), which are areas directly influenced by human activities. The majority of the cropland was within 600–1500 amsl. During the field investigation of LULC in 2011, we observed high-altitude cropland areas that had been abandoned due to the difficulties of management. The statistical result of the logistic regression model showed that the role of elevation was significant, and ranked first as a potential driving factor of cropland contraction in 1992–2010, whereas it had less of an effect during the expansion period. The spatial range of cropland distribution was mainly concentrated in an area with a slope degree of 14°–30°. The slope gradient of the basin was small due to the high mountains in the area, with most of the basin's territory being hilly and mountainous land. It is difficult to conduct agricultural activities in areas with a slope of more than 25° due to the steepness of the land and the high rate of soil erosion [14]. Most of the cropland on the slopes is terraced, with crop types such as rice, millet, and maize, but farmers have little interest in farming on land with a slope of more than 25°. This was proven by our statistical analysis, where slope did not play a large role in cropland expansion, which ranked in 8th position in 1978–1992, and in 10th position in 1992–2010, but it was ranked in 2nd position for cropland contraction in the basin. Therefore, the slope of the basin also had a large role in driving cropland change.

Similarly, the status of the area covered by the CMe, CMg, CMu, and CMx soil types in the basin changed remarkably from 1978 to 2010. During 1978–1992, there was a large expansion of cropland in these areas. Of the potential drivers of cropland expansion in the period of 1978–1992, soil type ranked second, and fourth in both cases of cropland expansion and contraction in 1992–2010, with a significant value in the regression model. It had almost the same effects in both of the periods studied.

4.2. Effects of Socioeconomic Related Drivers

In the past three decades, the population of KRB has increased rapidly [19]. In general, a greater population needs more food and resources [9], and this is associated with an expansion of cropland. Historical documents show that there is a correlation between anthropogenic and cropland changes, and the changing patterns and distribution of total cropland area [48]. As the statistical results show, population density had a significant role in cropland expansion, and ranked first during the periods of 1978–1992 and 1992–2010 (expansion). Therefore, we used population density as a socioeconomic proxy to represent the changing relationships of cropland and human influences in the KRB.

Data for the movement abroad of young Nepalese people as laborers show that migration is increasing each year, which is also apparent in the KRB district [42,49]. Generally, agricultural activities require human resources for cultivation and management of the cropland, and cropping production. The increasing trend of labor migration away from Nepal has directly driven changes in cropland status, primarily toward a contraction of cropland area. During the period of 1992–2010, there was a slight reduction in cropland area, which implies that with a lack of sufficient human resources, cropland has been converted to fallow land and grassland in recent years. This is indicated by the results of our regression statistic, which indicated that migration was the fifth largest driving factor of cropland contraction in the basin. Therefore, the migration abroad of young Nepalese people as laborers has a direct relationship with cropland change.

4.3. Effects of Climate Related Drivers

The mean temperature in the Himalayas region from the mid-1950s has been rising at a significant rate [50]. There has been an increase of +0.3 °C in the mean temperature in each decade, with a warming rate almost three times greater than the global rate [51]. The trend in the KRB and surrounding areas between 1971 and 2009 showed an increase in mean temperature at a rate of +0.25 °C every 10 years. In the period between 1974 and 1992, the rate of increase peaked at +0.9 °C. The average annual precipitation was 1729.01 mm between 1971 and 2009 [52]. These continuously warming trends may have had either a direct or an indirect relationship with the changes in cropland status. In the KRB, there have been different seasonal changes in the bio-physical aspects of climate over the past 30 years [52]. As a result, the cropland area of the basin has undergone major changes, and the cropping calendar of agricultural farming has also undergone considerable changes due to the increase in mean temperature and variations in the date of monsoonal rainfall [53].

The major crops grown in the basin are maize, millet, barley, rice, buckwheat, soya bean, black gram, pea, horse gram, and cow pea, while other leguminous crops and vegetables are grown in the hill regions. Maize, barley, buck wheat, potato, and cardamom are the major crops grown in the mountain regions of the KRB [54]. The relationship between climate and changes in cropland status have both positive and negative aspects, with the latter outweighing the former. Some crops are suited to growth under higher temperatures, but most crops are negatively affected by rising temperature. The main impact of climate warming is an increased susceptibility to various crop diseases, and this has had an effect on production and on changes in cropland status. If farmers lose their means of production, they are not likely to be interested in growing more crops in the area. The consequence of this is a trend toward cropland decline and a conversion to other land uses. In support of this, the statistical results indicated a large role (ranked third as a potential driver in 1978–1992 and the 1992–2010 contraction period) of temperature on the expansion and contraction of cropland. However, the precipitation effects ranked seventh, sixth, and ninth during 1978–1992, 1992–2010 (expansion), and 1992–2010 (contraction), respectively. This means the effects of precipitation were slightly larger during the expansion period than the contraction period. The abandonment of cropland has been increasing in both hill areas and mountain regions in the KRB, with a conversion to other land uses (e.g., grassland, and bushes) in recent years. The spatial datasets of the basin showed a slight decrease in total cropland area between 1992 and 2010. In recent decades, local people have been changing their cropping patterns to introduce permanent crops such as tea and coffee, and other horticulture and agro-forestry activities, so as to adapt to the changing climatic conditions of the region.

4.4. Effects of Neighborhood Related Drivers

In the past few decades, the number of roads in Nepal and the KRB area has increased rapidly [42]. Many locations in the basin area now have easy access to roads and transportation, which was confirmed during the LULC field investigation in 2011. With the availability of good transportation links and development of several market centers, the distance from cropland to settlements has shortened. Local people have focused more of their activities on cropland cultivation, especially the farming of vegetables and cash crops, which has increased rapidly. This means that farmers are now using formerly barren land for a variety of agricultural activities, which has resulted in the expansion of cropland throughout the entire basin area.

The statistical results of our regression model showed that there was a significant role for the variables of distance to road and distance to settlement on cropland expansion. Distance to settlement and distance to road were ranked 5th and 6th, respectively, among the potential driving factors in 1978–1992. This significantly increased during the cropland expansion in 1992–2010, where distance to settlement and distance to road ranked third and second, respectively. In the cropland contraction period, the distance to settlement and distance to road ranked seventh and tenth, respectively. Therefore, we concluded that there were larger effects of the distance to road and settlement on the cropland expansion, as compared to the contraction. The accessibility of rivers was highest for cropland on slopes distributed in the range of 0°–14°, with most of the surrounding area previously covered by cropland. Our statistical analysis has shown the average role of distance to river for cropland expansion and contraction during the past 32 years, which was ranked ninth, fifth, and eighth in 1878–1992, 1992–2010 (expansion), and 1992–2010 (contraction), respectively.

4.5. Management, Policy Implications, and Uncertainty

In this study, we found that population density is a crucial factor influencing cropland expansion in the KRB. Similarly, the role of the neighborhood factors (distance to a road and settlement) was significant in the process of cropland expansion. The trends toward an increasing population and decreasing distance between settlement and cropland were strongly correlated with cropland expansion. The distance of croplands from roads has played a vital role in the intensification of population density and cropland expansion. Similarly, the role of labor shortages due to foreign labor migration has influenced cropland contraction in the basin. Therefore, the role of socioeconomic factors is great and it should be emphasized in sustainable development plans for cropland management and the cropping system. The trend toward an increasing annual temperature and decreasing precipitation in the basin area has created drought problems [52]. This has directly affected the agricultural activities of the farmers, especially the lack of water in recent decades, with cropland being abandoned at an increasing rate. To control the increasing rate of cropland abandonment, government and concerned organizations need to build irrigation systems in the basin area. Furthermore, there is a need to raise the awareness level of local people to prevent haphazard cultivation on unsuitable slopes and at elevations where there is a higher rate of soil erosion, and there is a need to encourage them to plant suitable crops that limit soil erosion. A well-organized integrated land management and land use policy should be established by the government, to manage and develop systematic cropping patterns, and cropland use.

For effective LULC management, several land use laws and policies have been developed by the government of Nepal [55] (e.g., Birta Abolition Act 1959, Land Survey and Measurement Act 1963, Land Act 1964, Range Land Nationalization Act 1974, Trust Corporation (Guthi) Act 1976, Land Revenue Act 1977, Land Acquisition Act 1977 [56]), and in 2012 new land use policies were also developed [57]. These policies have mainly focused on the appropriate use of land based on its geographical location, soil structure, and other relevant factors. In the agricultural sector, the Nepal government developed a National Agricultural Policy 2004, an Irrigation Policy 2004, and an Agricultural Perspective Plan (1995–2015). These policies have focused on the effective management of cropland and irrigation, but have lacked implementation, with the problems not being solved appropriately. Furthermore, these policies are more concerned with increasing agricultural production and productivity, and with the need to develop a commercially competitive agriculture, than with the need to further conserve biodiversity and natural resources, and to control fragmentation, the degradation of cropland and soil erosion in cropland areas.

The National Land Use Project of the Nepal government is developing integrated land use planning, which is an essential and potentially priority issue in cropland management. The project is concerned with emphasizing land zoning, including agricultural, residential, forest, commercial, industrial, public, and other areas, which will help to effectively manage all land uses together with cropland. Furthermore, government needs to focus more on agricultural production and food security, and to provide agricultural subsidies to the farmers, especially for irrigation, fertilizer, and hybrid seeds.

The relative importance and combination of the different driving factors considered in this study varied between the periods studied, which affects short and long-term cropland management. It is necessary for the government of Nepal and other organizations to take into account the sustainable management of cropland in the policy implementation phase. Therefore, we also need to determine how to control the rapidly-growing population in the KRB area, and in the whole country, which would be an effective way to control the haphazard expansion of cropland. At the same time, we need to implement scientific and rational land use and land management policies that are favorable to both farmers and the sustainable development of the agricultural sector, as well as the country as a whole. In addition, the trend toward the foreign migration of labor has accelerated in the basin area [42,49], which has resulted in abandoned land, due to labor shortages [58]. There is a need to reduce the extent of young Nepalese human resources migrating for work and to make adjustments for this issue in the National Agricultural Policy, by creating employment within the country.

This study obtained aerial photography dating back to 1978 to show the status and long term trend of cropland changes in the basin. The historical research results and recent studies indicated an inverse relationship between forestland degradation and cropland expansion [47,59], which was not considered in our study because of the unavailability of deforestation datasets for the basin. Gross domestic product (GDP), natural hazards, and the urbanization process may also have an impact on changes in cropland status. It is recommended that further studies are undertaken using more parameters to determine the potential driving factors of cropland change in the KRB.

5. Conclusions

The findings of our study of changes in the cropland stages in the KRB show that there has been a trend for cropland area to increase between 1978 and 1992, followed by a slight decrease in 2010, which was directly or indirectly linked to various driving factors. The fragile and adverse climatic condition of the Himalayas region also contributed to these changes in cropland. The changing trend in cropland area in the KRB was not limited solely to human factors, but was also related to environmental factors. Socioeconomic factors (population and foreign labor migration) were the main drivers of cropland change in the basin. This clearly reflects the rapid rate of population growth, and the increasing trend toward foreign labor migration into the basin and into the whole country. Similarly, topography and climate factors, including elevation, slope, soil type, temperature, and precipitation play a role in cropland changes in the basin. Land use policies also play an important role in cropland change and in the future trends and direction.

This study of cropland change in the central Himalayas region of the KRB in Nepal will assist further research into future changes and patterns. From our results, it was clear that the cropland area was mostly located in the southern part of the basin. There might have been both seen and unseen driving factors that changed the cropland area over the period studied here. Future studies need to develop more datasets covering shorter time intervals. In addition, there is a need to focus on further socioeconomic activities and datasets in order to determine more fully the principal scenarios and driving factors of cropland change, taking into account this region's geographical location and ecological diversity, which is globally unique.

Acknowledgments: This research was financially supported by the Chinese Academy of Sciences—The World Academy of Sciences (CAS—TWAS) President's Fellowship Programme for international PhD students; the Natural Science Foundation of China (Grant No. 41371120); the Koshi Basin Programme (by the Department of Foreign Affairs and Trade (DFAT) of the Australian Government fund); and the Post-doctoral Science Foundation of China (O7Z76033Z1). We greatly appreciate the assistance of the International Centre for Integrated Mountain Development, Nepal for sharing their valuable datasets. The authors are grateful to the editor and anonymous reviewers for their constructive comments and suggestions.

Author Contributions: Yili Zhang and Basanta Paudel had the original idea for this research. Jungang Gao, Xue Wu, Basanta Paudel and Yili Zhang was responsible for data collecting and preparation. Basanta Paudel was analysis data and writing of the manuscript. Yili Zhang, Shicheng Li and Jianzhong Yan reviewed the manuscript. All authors have read and approved the final manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Ramankutty, N.; Foley, J.A. Estimating historical changes in global land cover: Croplands from 1700 to 1992. *Glob. Biogeochem. Cycles* **1999**, *13*, 997–1027. [CrossRef]
2. Pongratz, J.; Reick, C.; Raddatz, T.; Claussen, M. A reconstruction of global agricultural areas and land cover for the last millennium. *Glob. Biogeochem. Cycles* **2008**, *22*, 1–16. [CrossRef]
3. Heilig, G.K. Anthropogenic factors in land-use change in China. *Popul. Dev. Rev.* **1997**, *23*, 139–168. [CrossRef]
4. Brovkin, V.; Boysen, L.; Arora, V.K.; Boisier, J.P.; Cadule, P.; Chini, L.; Claussen, M.; Friedlingstein, P.; Gayler, V.; van denHurk, B.J.J.M.; et al. Effect of anthropogenic land-use and land-cover changes on climate and land carbon storage in cmip5 projections for the twenty-first century. *J.Clim.* **2013**, *26*, 6859–6881. [CrossRef]
5. Paudel, B.; Zhang, Y.; Li, S.; Liu, L.; Wu, X.; Khanal, N.R. Review of studies on land use and land cover change in Nepal. *J. Mt. Sci.* **2016**, *13*, 643–660. [CrossRef]
6. Thapa, R.B.; Murayama, Y. Examining spatiotemporal urbanization patterns in Kathmandu valley, Nepal: Remote sensing and spatial metrics approaches. *Remote Sens.* **2009**, *1*, 534–556. [CrossRef]
7. Goudie, A. *The Human Impact on Natural Environment*; MIT Press: Cambridge, MA, USA, 2000.
8. Foley, J.A.; DeFries, R.; Asner, G.P.; Barford, C.; Bonan, G.; Carpenter, S.R.; Chapin, F.S.; Coe, M.T.; Daily, G.C.; Gibbs, H.K. Global consequences of land use. *Science* **2005**, *309*, 570–574. [CrossRef] [PubMed]
9. Marsh, G.P. *Man and Nature*; University of Washington Press: Seattle, WA, USA, 1965.
10. Chen, G.Q.; Han, M.Y. Virtual land use change in china 2002–2010: Internal transition and trade imbalance. *Land Use Policy* **2015**, *47*, 55–65. [CrossRef]
11. Thapa, R.B.; Murayama, Y. Scenario based urban growth allocation in Kathmandu Valley, Nepal. *Landsc. Urban Plan.* **2012**, *105*, 140–148. [CrossRef]
12. He, F.; Li, S.; Zhang, X. Reconstruction of cropland area and spatial distribution in the mid-northern Song dynasty (AD1004–1085). *J. Geogr. Sci.* **2012**, *22*, 359–370. [CrossRef]
13. Khanal, N.R.; Watanabe, T. Abandonment of agricultural land and its consequences. *Mt. Res. Dev.* **2006**, *26*, 32–40. [CrossRef]
14. Li, S.; He, F.; Zhang, X. A spatially explicit reconstruction of cropland cover in China from 1661 to 1996. *Reg. Environ. Chang.* **2016**, *16*, 417–428. [CrossRef]
15. Khanal, N.R. Land Use and Land Cover Dynamics in the Himalaya: A Case Study of the Madi Watershed, Western Development Region, Nepal. Ph.D. Thesis, Tribhuvan University, Kirtipur, Nepal, 2002.
16. Becker, A.; Bugmann, H. *Global Change and Mountain Regions: The Mountain Research Initiative*; International Geosphere-Biosphere Programme (IGBP), Royal Swedish Academy of Science: Stockholm, Sweden, 2001.
17. Zhang, Y.; Gao, J.; Liu, L.; Wang, Z.; Ding, M.; Yang, X. Ndvi-based vegetation changes and their responses to climate change from 1982 to 2011: A case study in the koshi river basin in the middle himalayas. *Glob. Planet. Chang.* **2013**, *108*, 139–148. [CrossRef]
18. Zhang, Y.; Fang, Y.; Wei, D.; Chen, N.; Shang, G.; Dong, H.; Hu, P.; Gao, J.; Wang, Z.; Yang, X.; et al. Physical environment in Koshi River Basin. In *Resources, Environment and Development of Koshi River Basin*; Sichuan Sicence and Technology Press: Chendu, China, 2014; pp. 137–143.

19. Central Bureau of Statistics. *National Population and Housing Census 2011*; National Report for the Government of Nepal; National Report for the Government of Nepal; National Planning Commission Secretariat, Central Bureau of Statistics: Kathmandu, Nepal, 2012.
20. Ives, J.D.; Messerli, B. *Himalayan Dilemma*; United Nations University Press: New York, NY, USA, 1989.
21. Collins, R.; Jenkins, A. The impact of agricultural land use on stream chemistry in the middle hills of the Himalayas, Nepal. *J. Hydrol.* **1996**, *185*, 71–86. [CrossRef]
22. Regmi, M.C. *Land Tenure and Taxation in Nepal*; Ratna Pustak Bhandar: Kathamandu, Nepal, 1978.
23. Regmi, M.C. *Landownership in Nepal*; University of California Press: Berkeley, CA, USA, 1976.
24. Zhang, Y.; Gao, J.; Liu, L. Land-use/land-cover change in the Koshi River Basin. In *Resources, Environment and Development of Koshi River Basin*; Sichuan Sicence and Technology Press: Chendu, China, 2014; pp. 157–165.
25. Virgo, K.; Subba, K. Land-use change between 1978 and 1990 in Dhankuta district, Koshi hills, Eastern Nepal. *Mt. Res. Dev.* **1994**, *14*, 159–170. [CrossRef]
26. Ye, Y.; Fang, X.; Ren, Y.; Zhang, X.; Chen, L. Cropland cover change in Northeast China during the past 300 years. *Sci. China Ser. D Earth Sci.* **2009**, *52*, 1172–1182. [CrossRef]
27. Bharati, L.; Gurung, P.; Jayakody, P.; Smakhtin, V.; Bhattarai, U. The projected impact of climate change on water availability and development in the Koshi Basin, Nepal. *Mt. Res. Dev.* **2014**, *34*, 118–130. [CrossRef]
28. Dijkshoorn, K.; Huting, J. *Soil and Terrain Database for Nepal*; ISRIC—World Soil Information: Wageningen, The Netherlands, 2009.
29. Agarwal, A.; Babel, M.S.; Maskey, S.; Shrestha, S.; Kawasaki, A.; Tripathi, N.K. Analysis of temperature projections in the Koshi River Basin, Nepal. *Int. J. Climatol.* **2016**, *36*, 266–279. [CrossRef]
30. Gao, J.-G.; Zhang, Y.-L.; Liu, L.-S.; Wang, Z.-F. Climate change as the major driver of alpine grasslands expansion and contraction: A case study in the mt. Qomolangma (everest) national nature preserve, Southern Tibetan Plateau. *Quat. Int.* **2014**, *336*, 108–116. [CrossRef]
31. Land Resource Mapping Project. *Land Utilization Report*; Government of Nepal, Land Resource Mapping Project, Kenting Earth Science Canada and Department of Topography: Kathmandu, Nepal, 1986.
32. Ministry of Labour and Employment. *Labour Migration for Employment, a Status Report for Nepal: 2013/2014*; Department of Foreign Employment, Ministry of Labour and Employment, Government of Nepal: Kathmandu, Nepal, 2014.
33. Center for International Earth Science Information Network—CIESIN—Columbia University; Information Technology Outreach Services—ITOS—University of Georgia. *Global Roads Open Access Data Set, Version 1 (Groadsv1)*; NASA Socioeconomic Data and Applications Center (SEDAC): Palisades, NY, USA, 2013.
34. Kardoulas, N.; Bird, A.; Lawan, A. Geometric correction of spot and landsat imagery: A comparison of map-and gps-derived control points. *Photogramm. Eng. Remote Sens.* **1996**, *62*, 1173–1177.
35. Wang, Q.; Chen, J.; Tian, Y. Remote sensing image interpretation study serving urban planning based on GIS. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2008**, *37*, 453–456.
36. Dong, G.; Xu, E.; Zhang, H. Spatiotemporal variation of driving forces for settlement expansion in different types of counties. *Sustainability* **2016**, *8*, 39. [CrossRef]
37. Bahadur, K.C.K. Improving landsat and irs image classification: Evaluation of unsupervised and supervised classification through band ratios and dem in a mountainous landscape in Nepal. *Remote Sens.* **2009**, *1*, 1257–1272. [CrossRef]
38. Li, X.; Wang, Y.; Li, J.; Lei, B. Physical and socioeconomic driving forces of land-use and land-cover changes: A case study of Wuhan City, China. *Discret. Dyn. Nat. Soc.* **2016**, *2016*, 8061069. [CrossRef]
39. Zhang, Y.; Liu, L.; Nei, Y. *Land Cover Mapping in the Hkkh Region: Results from Qomolangma National Nature Preserve (Regional Hkkh Partnership Program Report)*; Institute of Geographic Sciences and Natural Resources Research: Beijing, China, 2009; pp. 1–36.
40. Ameztegui, A.; Brotons, L.; Coll, L. Land-use changes as major drivers of mountain pine (*Pinus uncinata* Ram.) expansion in the Pyrenees. *Glob. Ecol. Biogeogr.* **2010**, *19*, 632–641. [CrossRef]
41. Tilman, D.; Balzer, C.; Hill, J.; Befort, B.L. Global food demand and the sustainable intensification of agriculture. *Proc. Natl. Acad. Sci. USA* **2011**, *108*, 20260–20264. [CrossRef] [PubMed]
42. Central Bureau of Statistics. *Nepal Living Standards Survey 2010/11*; The Government of Nepal, Central Bureau of Statistics: Kathmandu, Nepal, 2011.

43. Xiao, R.; Su, S.; Mai, G.; Zhang, Z.; Yang, C. Quantifying determinants of cash crop expansion and their relative effects using logistic regression modeling and variance partitioning. *Int.J. Appl. Earth Obs. Geoinform.* **2015**, *34*, 258–263. [CrossRef]
44. Menard, S. Six approaches to calculating standardized logistic regression coefficients. *Am. Stat.* **2004**, *58*, 218–223. [CrossRef]
45. Rawlings, J.O.; Pantula, S.G.; Dickey, D.A. *Applied Regression Analysis: A Research Tool*; Springer Science & Business Media: Berlin, Germany, 1998.
46. Menard, S. *Applied LogisticRegression Analysis*; SAGE Publications: Thousand Oaks, CA, USA, 2002.
47. Uddin, K.; Shrestha, H.L.; Murthy, M.S.R.; Bajracharya, B.; Shrestha, B.; Gilani, H.; Pradhan, S.; Dangol, B. Development of 2010 national land cover database for Nepal. *J. Environ. Manag.* **2015**, *148*, 82–90. [CrossRef] [PubMed]
48. Goldewijk, K.K. Estimating global land use change over the past 300 years: The hyde database. *Glob. Biogeochem. Cycles* **2001**, *15*, 417–433. [CrossRef]
49. Sijapati, B.; Limbu, A. *Governing Labour Migration in Nepal: An Analysis Existing Policies and Institutional Mechanisms*; Himal Books: Kathmandu, Nepal, 2012.
50. Yao, T.; Thompson, L.G.; Mosbrugger, V.; Zhang, F.; Ma, Y.; Luo, T.; Xu, B.; Yang, X.; Joswiak, D.R.; Wang, W.; et al. Third pole environment (TPE). *Environ. Dev.* **2012**, *3*, 52–64. [CrossRef]
51. Qiu, J. The third pole. *Nature* **2008**, *454*, 393–396. [CrossRef] [PubMed]
52. Qi, W.; Zhang, Y.; Gao, J.; Yang, X.; Liu, L.; Khanal, N.R. Climate change on the southern slope of Mt. Qomolangma (everest) region in nepal since 1971. *J. Geogr. Sci.* **2013**, *23*, 595–611. [CrossRef]
53. Gao, J. Land Cover Change and Its Relationship with Climate Chage in Koshi River Basin of Central Himalaya. Ph.D. Thesis, Institute of Geographic Sciences and Natural Resources Research, Graduate University of Chinese Academy of Sciences, Beijing, China, 2012.
54. Ministry of Agriculture Development. *Statistical Information on Nepalese Agriculture, Time Series Information*; Government of Nepal, Ministry of Agriculture Development: Kathmandu, Nepal, 2013.
55. Sharma, K.; Khanal, S. A review and analysis of existing legal and policy issues related to land tenure and agriculture in Nepal. *Kathmandu Univ. J. Sci. Eng. Technol.* **2010**, *6*, 133–141. [CrossRef]
56. Food and Agriculture Organization. *Land Use Policy and Planning*; Food and Agriculture Organization of the United Nations UN Complex: Pulchowk, Nepal, 2010.
57. Government of Nepal. *National Land Use Policy NLUP*; Ministry of Land Reform and Management: Kathmandu, Nepal, 2012.
58. Xie, H.; Wang, P.; Yao, G. Exploring the dynamic mechanisms of farmland abandonment based on a spatially explicit economic model for environmental sustainability: A case study in Jiangxi province, China. *Sustainability* **2014**, *6*, 1260–1282. [CrossRef]
59. Mahat, T.; Griffin, D.; Shepherd, K. Human impact on some forests of the middle hills of Nepal, Part 2. Some major human impacts before 1950 on the forests of Sindhu Palchok and Kabhre Palanchok. *Mt. Res. Dev.* **1986**, *6*, 325–334. [CrossRef]

© 2016 by the authors; licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC-BY) license (http://creativecommons.org/licenses/by/4.0/).