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Research Article

Landscapes in Transition: A Study of Agricultural Land Use Change in Inner Terai of Nepal

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Abstract

Agricultural land use has raised concerns about the sustainability of locally led food systems. With urbanization in Chitwan district, cropland has been haphazardly used for different purposes. However, spatial-temporal cropland use changes in municipalities have not been explored. This research assesses the land use and land cover changes in six municipalities of Chitwan over two decades (2001 to 2021). Landsat images and the Google Earth platform were used to classify the land use. The study mainly focuses on the conversion of cropland to seven other land uses categories, and vice versa. The findings reveal a significant increase in built-up areas, particularly between 2011 and 2021, at the expense of agricultural land. The key drivers of these changes include the political system change notably the introduction of federalism and local governance in 2015, which has led to rapid migration, infrastructure development, and the expansion of urban centers. These land use changes pose challenges for sustainable agricultural land management, with cropland being replaced by built-up. Nevertheless, advancements in agricultural technologies have also converted other land use categories to cropland. This study emphasizes the urgent need for locally adaptable land use policies in line with national agricultural development strategies. The findings assist policymakers in developing sustainable land use strategies that maintain agricultural productivity while accommodating urban expansion. Timely intervention from the policy level is critical to protecting agricultural land and promoting a resilient, self-sufficient agricultural system in the face of ongoing urbanization and demographic changes.

Keywords: Crop land change; Land use; Chitwan; municipality; built-up

Introduction

The global population is increasing at an alarming rate, so is urbanization. Urban areas occupy more than 50% of the total population in the world (Devkota *et al.*, 2023). Although Nepal is one of the least urbanized countries, it has an urban growth rate of 18.2% and belongs to the top ten fast- growing urbanization countries. Chitwan is one of the developed districts in Nepal and has undergone haphazard urbanization. The facility of market centers, easy access to roads, and improved infrastructure has attracted immigrants in Chitwan from hilly regions and other parts of Nepal (Raut *et al.*, 2020; Bakrania, 2015). Thus, agricultural land is being compromised for urban growth that led to a considerable change in land use and land cover (Liu *et al.*, 2019). The change of agricultural land into built-up is a great barrier for sustainable agriculture, food security and land management.

Agricultural land use changes are determined by many factors including migration. Lately, agricultural sector contribution to Gross Domestic Product (GDP) has been reduced to 24 percent and an increase in remittance has been observed (CBS, 2021). It clearly indicates the increased emigration that led to stoppage of farming activities trigger the change of farmland to either underutilized or plotting for land sale. The decrease in agricultural sector contribution thus could be the reason for cropland use being reshaped by urbanization, infrastructure development and agricultural diversification (Dhakal, 2022). In Terai region, the trend of conversion of agricultural land to built-up, commercial and residential area is evident as compared to hills and mountain region (Raut *et al.,* 2020). Chitwan district serves as a representative example of these shifts in agricultural land use due to its rapid urbanization. Contrary to this, agricultural land intensification is also noticed in Chitwan, because of increased irrigation facilities, availability of improved seed, better road access, introduction of farm machinery, and government support.

Studies on agricultural land use change at national and district levels exist, however little research has been conducted at municipality level to understand the dynamics of agricultural land conversion. Moreover, the extent and nature of land use transformation in local level of Chitwan has not been explored from agriculture perspective.

One of the key factors of agricultural land use change is land tenure security threat, making it difficult for government to plan and implement sustainable land use policies (Nepal and Marasini, 2018). Lack of clarity on land use policy leads to weak implementation affecting food security, sustained food supply, and economic stability (FAO, 2020). In addition, land fragmentation and land plotting have increasingly exacerbated the challenge of farmland use (Timilsina *et al.,* 2019). All these factors are crucial to take into consideration and understand the agricultural land use change in Chitwan. Analyzing the spatio-temporal land use change scenario would help assisting in devising strategies that balance urban growth and formulate policies in line with sustainable land management and agricultural development. By focusing on Chitwan, which is a commercial agricultural hub in Nepal, this research provides critical insights into the effects of urbanization on agriculture, a sector that remains vital to the local economy.

Specifically, the study aims to examine the transition of agricultural land use and land cover (LULC) for 20-years (2001–2021) in different municipalities of Chitwan district. The researchers identified the need to understand the broader dynamics of land use change for developing sustainable agricultural development strategies, particularly at local level. The study envisions in filling the knowledge gap on agricultural land use change particularly to bring clarity on the impacts of urbanization in developing countries on agricultural land use change.

Research Methodology

Description of the Study Area

This study was conducted in six municipalities of Chitwan district which lies in the inner Terai region of Nepal characterized by flat and fertile land (Table 1). The district covers an area of approximately 2,218 square kilometers and ranges in elevation from about 150 meters to 815 meters above sea level. The six study municipalities under study are Bharatpur, Rapti, Khairahani, Ratnanagar, Kalika, and Madi are known for their fertile lands, favorable climate, and well-established agricultural practices. These areas rely heavily on agriculture for livelihood, with diverse crops cultivated, better irrigation systems in place, and the added influence of migration shaping the agricultural and socio-economic landscape. Icchakamana Rural Municipality, which also lies in Chitwan district is excluded from the study due to its unique topography and infrastructure, compared to other municipalities.

Table 1: Area, population and households of six municipalities in Chitwan.

Municipality	Population	Households	Ag Households	Total area of holdings (Ha)
Bharatpur	369,377	96,591	37094	14311.9
Rapti	66,617	15,215	10299	4350.8
Kalika	52,164	12,258	8580	2739.9
Ratnanagar	89,905	22,403	10903	3662.8
Khairahani	67,385	16,395	10022	4163.8
Madi	38,295	10,120	8132	4482.4

Source: (CBS, 2021)

Bharatpur Metropolitan City is located in the central part of Chitwan and is the administrative and economic center of the district. The Narayani lift irrigation, Khageri irrigation and groundwater are the sources of irrigation in Bharatpur. Bharatpur is a rapidly urbanizing city with a better road network that connects it to other municipalities and major parts of Nepal.

Rapti Municipality is situated to the east of Khairahani Municipality of Chitwan. Khairahani is located to the east of Bharatpur and Ratnanagar Municipality is located to the southwest of Bharatpur whereas Kalika Municipality is located to the north-east of Bharatpur. Madi Municipality is located to the south of Bharatpur. Flowchart showing LULC area change detection process is shown in Fig. 1.

Data Acquisition and Image Preprocessing

Maps were prepared in digital format through digitization and overlay analysis as conducted in ArcGIS 10.1 environment.

Extraction of the Study Area

A shapefile of Nepal was downloaded, and from it, the shapefiles for Chitwan and study municipalities were extracted. This step involved isolating these areas for more detailed analysis and visualization, enabling a closer examination of their geographic and demographic features.

Image Preparation of the Study Area:

Images from various years of the study area were obtained from the U.S. Geological Survey (USGS) Landsat archive for 2021 and the International Center for Integrated Mountain Development (ICIMOD) for 2001 and 2011.

Since the downloaded multispectral images of 2021 are in separate layers, they need to be stacked together. Therefore, layer stacking is applied to all the images, and the resulting image is clipped to focus solely on the study area.

Agriculture and Open Land Use Area Calculation:

After classification, the area of cropland transitioning to other land uses and vice versa is calculated for the years 2001, 2011, and 2021. This is done using pixel-based area calculations. To assess the loss and gain of cropland area, the areas of the temporally classified images are compared across consecutive time intervals.

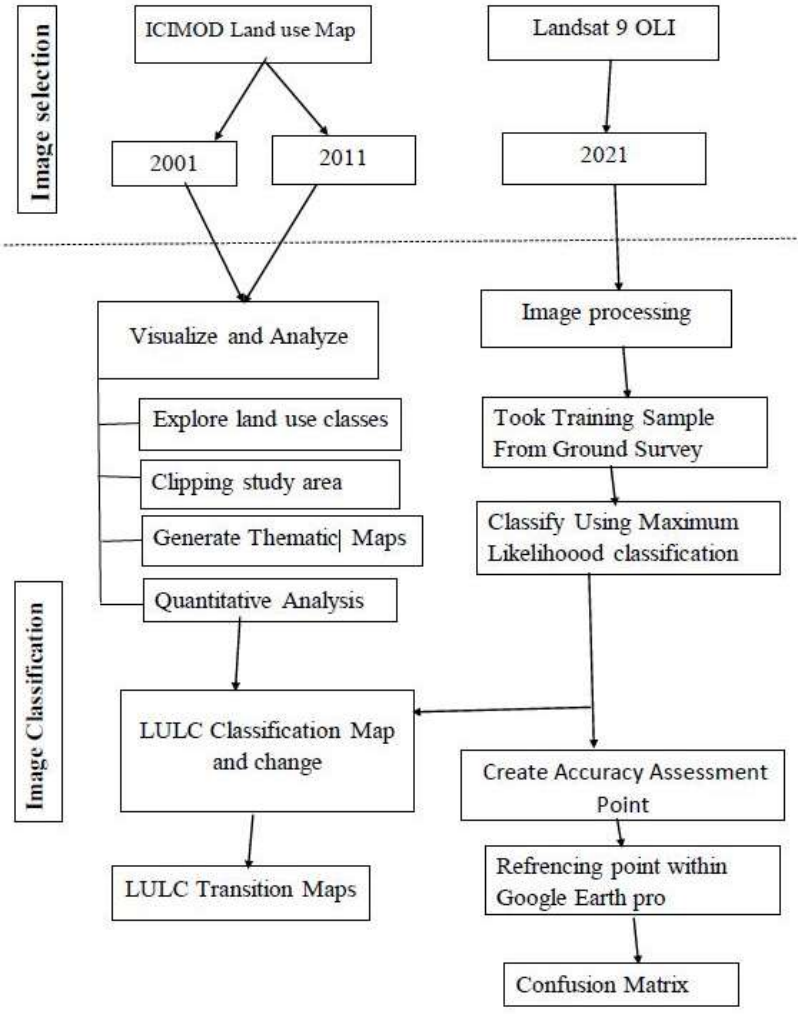

Fig. 1: Flowchart showing LULC area change detection process

Transformation Study of Cropland into other LULC Classes and Vice Versa:

The transformation of cropland into other land use categories, and vice versa, is also identified for each study decade. This involves vectorizing all land use category transitions from the classified images. By clipping the images from consecutive years, the transformations are determined. A change table is then created to provide information about the land that has been transformed into different LULC classes.

LULC Classes and Reference Data

The study area was categorized into seven land use and land cover (LULC) types: water, forest, riverbed, built-up, cropland, grassland, and other wooded land.

The accuracy of classifying remotely sensed data depends on the reference dataset used for the analysis (Zurqani *et al.*, 2018; Congalton, 1991). High-resolution imagery from Google Earth Pro was utilized to validate the results. Datasets used for reference were randomly divided into two categories: 70% used as training data for the supervised classifier algorithm used in land cover classification, while the remaining 30% were served to validation data to evaluate the accuracy of the classified maps (Rodriguez-Galiano *et al.*, 2012; Zurqani *et al.*, 2018).

Classification and Accuracy

To verify the crop land change data, field observation and Key Informant Interview (KII) were performed with the farmers, community leaders, extension agents of the respective municipalities. Municipality profiles and CBS (2021) reports were also used to authenticate the findings. The validation datasets were randomly split and used to create confusion matrices to measure user, producer, and overall accuracy.

Results and Discussion

Preliminary visits to the study sites and secondary data collection suggest that land abandonment is negligible in Chitwan, which contrasts with trends observed in the mountainous and mid-hill regions of Nepal.

Crop Land Use Area Change in Bharatpur Metropolitan City

The cropland use change from 2001 to 2011 for Bharatpur Metro City was noticeable. About 161 ha wooded land areas, 139.59 ha of riverbeds, and 79.02 ha of water bodies were converted into cropland, showing expansion of farmland (Table 2). The devastating flood of 1993 created arable land to riverbed in southern part of Chitwan (Singh, 2013), which is gradually changed into cropping land again, whereas, 369 ha of forests and 18.45 ha of grasslands were converted to farm land during the same period. A long decade Maoist insurgency which concluded in 2006 has pulled people from hill to terai area which intensify arable land in Chitwan (Fig. 2).

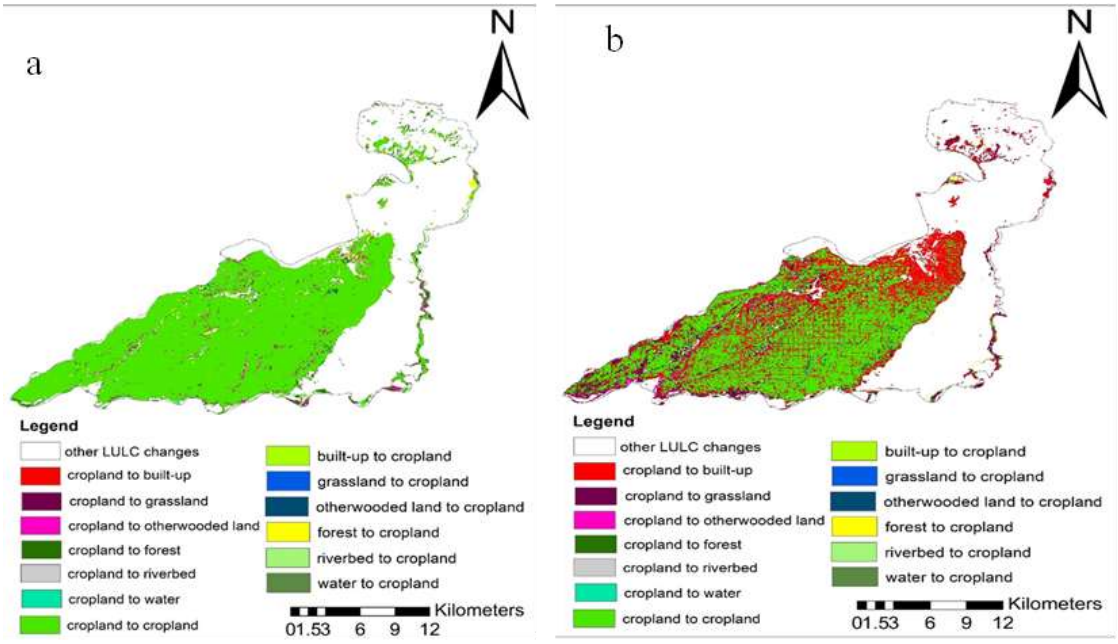

Fig. 2: Cropland changes in Bharatpur Metropolitan: a. Transition of cropland to other categories of land and vice- versa during 2001 to 2011, larger area of cropland was intact as compared to other categories; b. Transition of cropland to other categories of land and vice-versa during 2011 to 2021. During this period, cropland to built-up is found to be more that indicated the urbanization expansion.

Table 2: Crop land change in Bharatpur Metropolitan city from 2001 to 2011 and 2011 to 2021

Land use change	2001-2011 (Area-Ha)	2011-2021 (Area-Ha)
Water to cropland	79.02	59.22
Riverbed to cropland	139.59	9.36
Other wooded land to cropland	160.92	346.14
Grassland to cropland	18.45	52.38
Forest to cropland	369	185.76
Cropland to water	37.8	24.12
Cropland to riverbed	12.51	62.01
Cropland to other wooded land	672.21	586.44
Cropland to grassland	8.01	2740.32
Cropland to forest	911.52	8.37
Cropland to cropland	26745.1	13842.4
Cropland to built-up	110.61	7028.37
Built-up to cropland	4.77	1.71

Moreover, increased irrigation facilities, better roads and development of market centers have converted forest areas to farming areas. Change in water land to cropland might have several reasons in Bharatpur, possibly due to change in water flow path, which converted the water area into an agricultural area.

Table 2 also shows the crop land area change in Bharatpur Metro City from 2011 to 2021, which depicted that 59.22 ha of water bodies, 9.36 ha of riverbeds, 346.14 ha of wooded land, 52.38 ha of grassland, and 185.76 ha of forest were converted into cropland, which also indicates the increase in cropland area. However, 7028.37 ha of cropland was converted to a built-up area during 2011 to 2021. This is a huge change indicating a reduction of agricultural land as a threat to food security. It is reported that about 26% of Nepalese farmers depend on off farm activities (CBS, 2021). This might be linked to the land use change from cropland to built-up. Similarly, 2740.32 ha of cropland was changed to grasslands, indicating temporary fallow land or land underutilization.

Likewise, 24.12 ha of cropland changed to water bodies. CBS (2020) revealed that the numbers of farmers in Chitwan involved in fisheries have increased. Similarly, 62.01 ha to riverbeds, 586.44 ha to wooded areas, and 8.37 ha to forests, indicating decrease in agricultural land (Table 2).

Crop Land Use Area Change in Rapti Municipality

Crop land area change in Rapti Municipality is shown in Table 3 and Fig 3. A total of 116.37 ha of forest, 105.84 ha of riverbeds, 22.23 ha of grassland,13.86 ha of wooded land and 1.89 ha of water bodies were changed into cropland in the Rapti Municipality during 2001 to 2021 indicating increase in agricultural land. Flooding in 1993 in Eastern Chitwan created a riverbed which has been converted to cropland. During the same period, 4.14 ha of cropland converted to water bodies, 1.98 ha to riverbeds, 341.82 ha to wooded areas, 15.12 ha to grasslands, and 823.23 ha to forests. Agricultural land to forest area conversion would be for conservation perspective during that period. Meanwhile, 6152.94 ha of cropland remained unchanged, showing the stability of agricultural land. Additionally, 7.29 ha of cropland was converted to urban built-up for infrastructure development, indicating not much urbanization, while negligible (0.09 ha) of built-up areas were again converted to agricultural land in Rapti municipality.

From 2011 to 2021 Rapti Municipality revealed noticeable changes in land utilization. A total of 0.72 ha of riverbeds, 210.78 ha of wooded land, 18.27 ha of grassland, and 252.41 ha of forest were converted into cropland. A significant portion of Rapti lies in the hilly area. Prior to the introduction of agricultural technologies, much of the land remained fallow or underutilized. Later with the access of inputs and technologies, people started to cultivate land. Several agencies-based interventions (both government and non-government) in the Rapti area which attract people to farming. Some of the areas of Rapti, once relatively remote, was impacted by Maoist insurgency, which led to displacement of the community people. However, after the insurgency people again came back and started to cultivate. Additionally, improvement of irrigation facilities, better access to roads and development of market centers has played a greater role transforming converted forest areas to farming area.

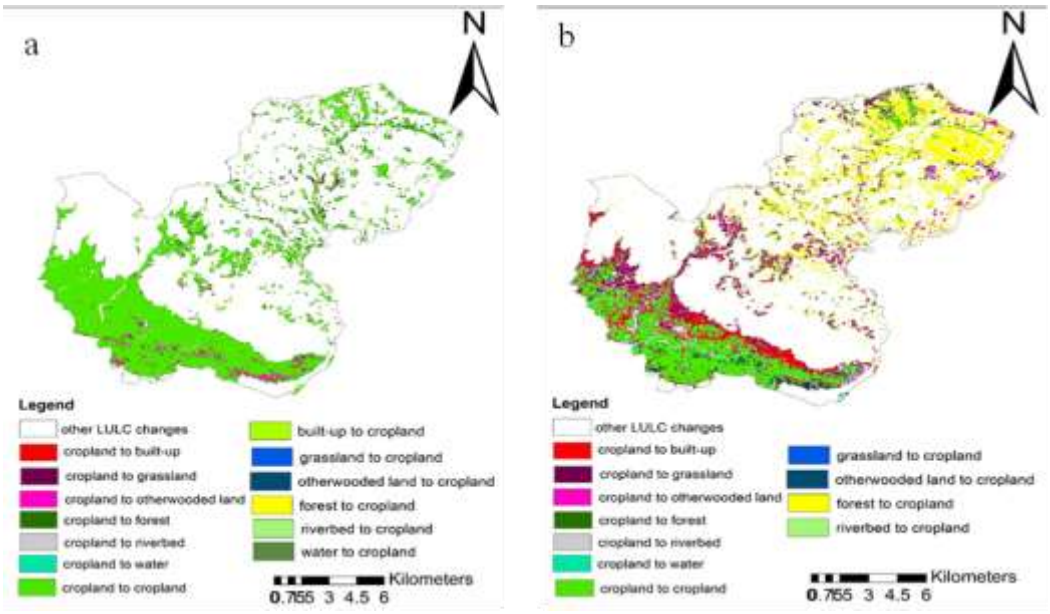

Fig. 3: Cropland change in Rapti Municipality: a. Transition of cropland to other categories of land and vice- versa during 2001 to 2011, b. Transition of cropland to other categories of land and vice-versa during 2011 to 2021.

Table 3: Crop land change in Rapti Municipality from 2001 to 2011 and 2011 to 2021.

Land use change	2001-2011 (Area-Ha)	2011-2021 (Area-Ha)
Water to cropland	1.89	NA
Riverbed to cropland	105.84	0.72
Other wooded land to cropland	13.86	210.78
Grassland to cropland	22.23	18.27
Forest to cropland	116.37	252.41
Cropland to water	4.14	440.82
Cropland to riverbed	1.98	220.77
Cropland to other wooded land	341.82	716.85
Cropland to grassland	15.12	867.51
Cropland to forest	823.23	11.25
Cropland to cropland	6152.94	2594.61
Cropland to built-up	7.29	799.29
Built-up to cropland	0.09	NA

Note: Water to cropland and built-up to crop land cannot be estimated as ICIMOD downloaded land use map did not classify some classes for this area. If we estimate through Landsat Image, we cannot take training samples for land use cover estimation due to poor visibility.

However, 440.82 ha of cropland transitioned back to water bodies, promotion of aquaculture in Bhandara and Birendranagar area near to the government Fish Development Centre. About 221 ha of cropland was converted to riverbeds, 716.85 ha to sparsely wooded areas, 867.51 ha to grasslands, and 11.25 ha to forests. Meanwhile, 2594.61 ha of cropland remained unchanged, demonstrating stability in agricultural land. Additionally, 799.29 ha of cropland was converted into built-up areas, showing the impact of urbanization and infrastructure development.

Crop Land Area Change in Khairahani Municipality

The land use and land cover transitions in Khairahani Municipality highlight notable changes in land utilization as shown in Fig. 4 and Table 4. Different categories of land were converted to cropland and vice- versa. Cropland was converted to other categories of land, where 6.48 ha was changed to water bodies, 16.56 ha to riverbeds, 770.13 ha to sparsely wooded areas, 1.26 ha to grasslands, and 239.58 ha to forests. Likewise, a total of 15.48 ha of water bodies, 144 ha of riverbeds, 11.7 ha of sparsely wooded land, 0.18 ha of grassland, and 29.16 ha of forest were converted into cropland, indicating agricultural expansion. Meanwhile, 6263.28 ha of cropland remained unchanged, demonstrating stability in agricultural land use. Urbanization is seen in 22.77 ha of cropland and only about half of built-up areas were reclaimed for agricultural purposes.

The land use and land cover change in Khairahani Municipality highlight notable changes. A total of 15.48 ha of water bodies, 144 ha of riverbeds, 11.7 ha of wooded land, 0.18 ha of grassland, and 29.16 ha of forest were converted into the cropland, indicating farmland expansion. On the other hand, 6.84 ha of cropland converted back to

water bodies, 16.56 ha to riverbeds, 770.13 ha to wooded areas, 1.26 ha to grasslands, and 239.58 ha to forests, reflecting ecological transitions and natural processes. Meanwhile, 6263.28 ha of cropland remained unchanged, demonstrating stability in agricultural land use. Additionally, 22.77 ha of cropland was changed to built-up for infrastructure development, while 0.45 ha of built-up areas were reclaimed for agricultural purposes.

During 2011 to 2021, Khairahani Municipality LULC shows notable change. A total of 470.43 ha of other wooded land, 2.16 ha of grassland, and 32.22 ha of forest were changed into cropland, reflecting an expansion of agricultural land. On the other hand, 129.87 ha of cropland converted back to water bodies, 132.84 ha to riverbeds, 1029.78 ha to other wooded land, 254.25 ha to grassland, and 0.36 ha to forest. However, 2617.29 ha of cropland remained unchanged. Moreover, 1527.21 ha of cropland was converted into built-up areas.

Crop Land Area Change in Ratnanagar Municipality

Table 5 indicates the change in land use and land cover for Ratnanagar Municipality. A total of 13.41 ha of water areas, 62.19 ha of riverbeds, 21.69 ha of other wooded land, 1.44 ha of grassland, and 10.8 ha of forest were changed into cropland. Likewise, 7.92 ha of cropland changed into water bodies, 15.75 ha into riverbeds, and 552.06 ha into other wooded land. About 2 ha of cropland was changed into grassland, and 309 ha shifted to forest land. About 6072.48 ha, remained unchanged, reflecting stability. About 21 ha of cropland was converted into built-up areas.

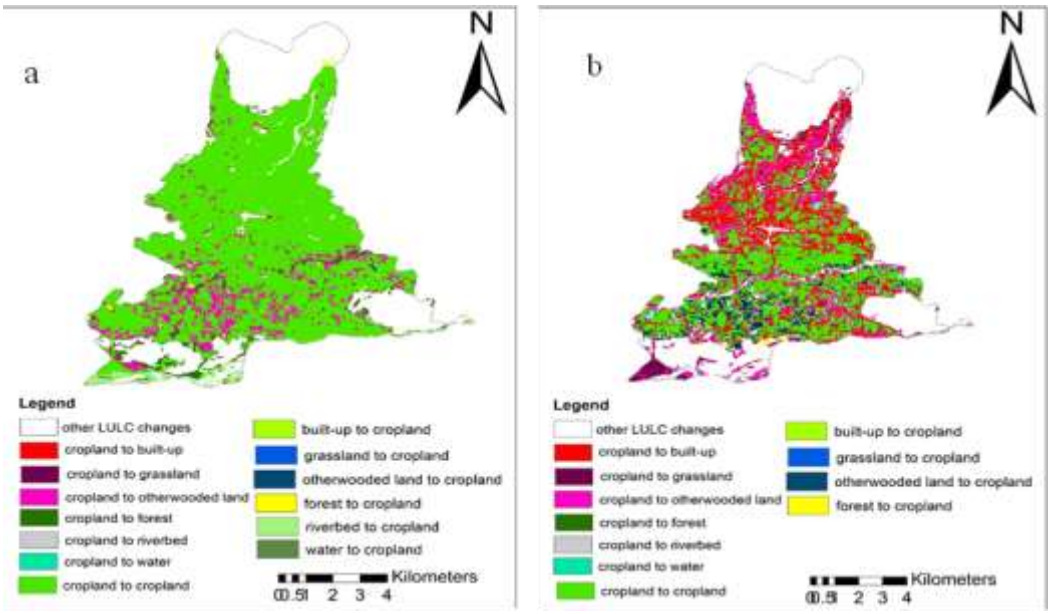

Fig. 4: Cropland changes in Khairahani Municipality: a. Transition of cropland to other categories of land and vice-versa during 2001 to 2011, b. Transition of cropland to other categories of land and vice-versa during 2011 to 2021. In 2021 massive change in cropland to built-up is found as compared to previous decade of 2001 to 2011.

Table 4: Crop land use change in Khairahani Municipality from 2001 to 2011 and 2011 to 2021.

Land use change	2001-2011 (Area-Ha)	2011-2021 (Area-Ha)
Water to cropland	15.48	NA
Riverbed to cropland	144	NA
Other wooded land to cropland	11.7	470.43
Grassland to cropland	0.18	2.16
Forest to cropland	29.16	32.22
Cropland to water	6.84	129.87
Cropland to riverbed	16.56	132.84
Cropland to other wooded land	770.13	1029.78
Cropland to grassland	1.26	254.25
Cropland to forest	239.58	0.36
Cropland to cropland	6263.28	2617.29
Cropland to built-up	22.77	1527.21
Built-up to cropland	0.45	0.09

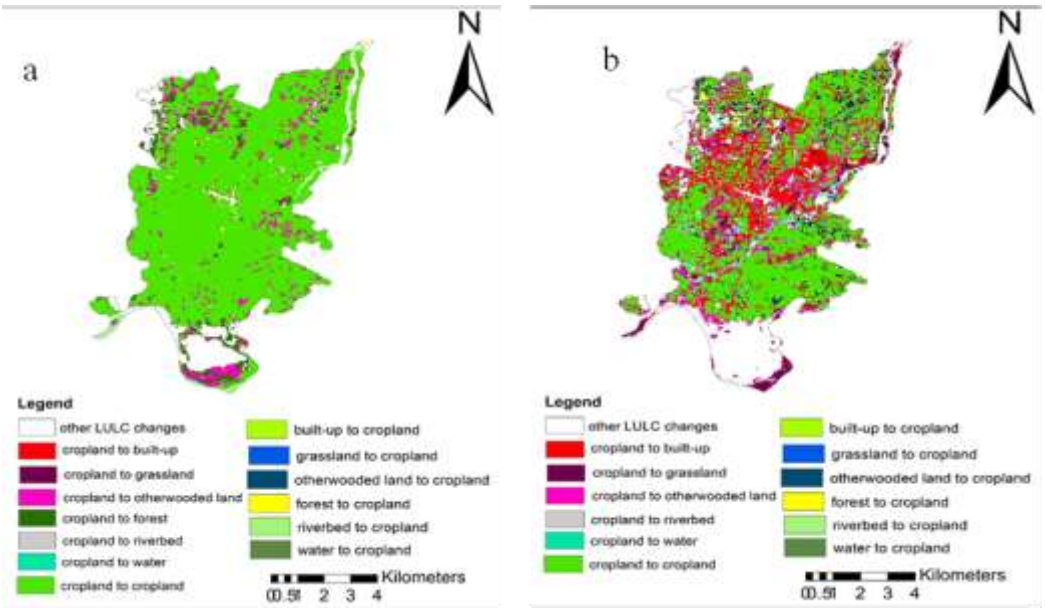

Fig. 5: Cropland changes in Ratnanagar Municipality: a. Transition of cropland to other categories of land and vice- versa during 2001 to 2011, slight conversion of cropland to built-up is found, with more area of cropland; b. Transition of cropland to other categories of land and vice- versa during 2011 to 2021, dense built-up areas replaced the cropland area during this period.

Table 5: Crop land change in Ratnanagar Municipality from 2001 to 2011 and 2011 to 2021.

Land use change	2001-2011 (Area-Ha)	2011-2021 (Area-Ha)
Water to cropland	13.41	0.09
Riverbed to cropland	62.19	2.61
Other wooded land to cropland	21.69	264.87
Grassland to cropland	1.44	0.36
Forest to cropland	10.8	48.15
Cropland to water	7.92	325.53
Cropland to riverbed	15.75	29.88
Cropland to other wooded land	552.06	706.59
Cropland to grassland	1.89	324.18
Cropland to forest	309.06	NA
Cropland to cropland	6072.48	2947.59
Cropland to built-up	21.24	1107.9
Built-up to cropland	0.81	0.36

During 2011 to 2021 about 265 ha of other wooded land and 48.15 ha of forest were transformed into cropland in Ratnanagar Municipality. A small area of 0.09 ha of water was converted into cropland, and 2.61 ha of riverbed also shifted to cropland. A total of 325.53 ha of cropland turned into water bodies, while 29.88 ha shifted to riverbed areas. Moreover, 706.59 ha of cropland transitioned into other wooded land, and 324.18 ha was converted into grassland and 2947.59 ha of cropland remained stable. The conversion of cropland to built-up areas accounted for 1107.9 ha, while 0.36 ha of built-up land was changed back to cropland. A previous study reported the forest has been a source of underutilized crops (Timilsina *et al.*, 2022). The consumption of these foods helps people for food sufficiency for some months.

In Ratnanagar, riverbeds to cropland change was particularly high between 2001 and 2011, likely due to the gradual transformation of riverbeds into farmland following the 1993 flood. Moreover, Ratnanagar region has rivers and streams like Khayar Khola, Rapti, Khageri river which frequently change their water flow routes. This shift results in the conversion of both cropland and riverbeds and vice versa.

Crop Land Area Change in Kalika Municipality

The land use and land cover change in Kalika Municipality show notable changes as shown in Fig 6 and Table 6. About 451 ha of forest, 18.63 ha of riverbeds, 13.14 ha of other wooded land, 23.85 ha of grassland changed to cropland. However, 0.36 ha of cropland changed to riverbeds, 208.62 ha to other wooded areas, 8.01 ha to grassland, and 440.1 ha to forest. Additionally, 3544.65 ha of cropland remained unchanged, showing agricultural stability, while 2.97 ha of cropland was changed to built-up areas.

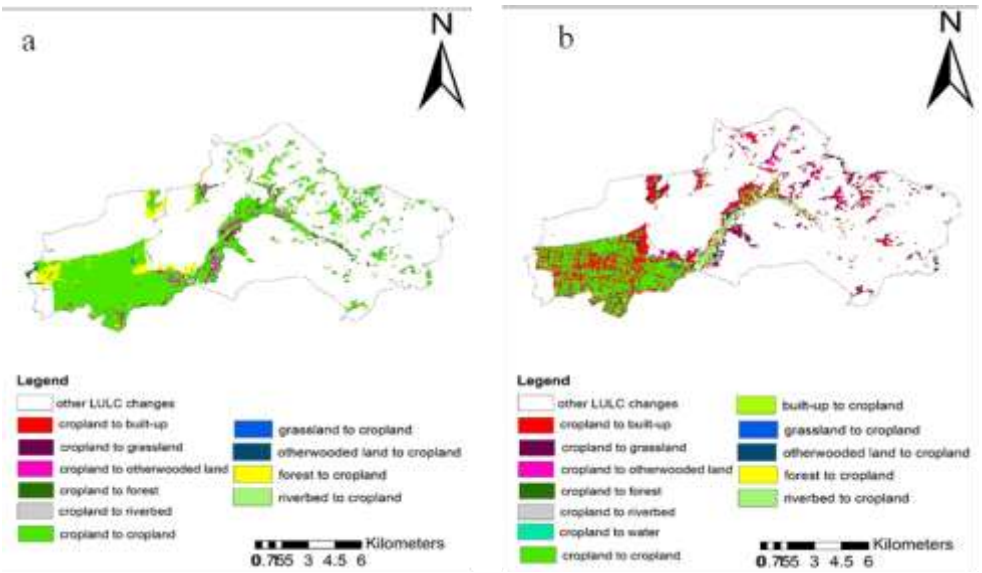

Fig. 6: Cropland change in Kalika Municipality: a. Transition of cropland to other categories of land and vice- versa during 2001 to 2011, b. Transition of cropland to other categories of land and vice- versa during 2011 to 2021. Cropland is found to be replaced with built-up more during 2011-2021 periods as compared to 2001-2011.

Table 6: Crop land change in Kalika Municipality from 2001 to 2011 and 2011 to 2021.

Land use change	2001-2011 (Area-Ha)	2011-2021 (Area-Ha)
Water to cropland	NA	NA
Riverbed to cropland	18.63	0.18
Other wooded land to cropland	13.14	94.77
Grassland to cropland	23.85	1.26
Forest to cropland	450.99	74.61
Cropland to water	NA	257.85
Cropland to riverbed	0.36	68.22
Cropland to other wooded land	208.62	203.49
Cropland to grassland	8.01	486
Cropland to forest	440.1	5.85
Cropland to cropland	3544.65	1457.82
Cropland to built-up	2.97	1083.15
Built-up to cropland	NA	0.09

Note: Water to crop, cropland to water, built-up to cropland were not detectable.

A total of 94.77 ha of other wooded land and 74.61 ha of forest were converted into cropland, reflecting an increase in farmland. On the other hand, 257.85 ha of cropland changed to water bodies, 68.22 ha to riverbeds, 203.49 ha to other wooded land, 486 ha to grassland, and 5.85 ha to forest. Whereas, 1457.82 ha of cropland remained unchanged, while 1083.15 ha of cropland were changed into built-up areas.

Kalika Municipality has many seasonal rivers which change their course during the rainy season. These shifting streams often create new flow paths, leading to the destruction of agricultural land. As a result, croplands gradually changed into riverbeds from 2011 to 2021, causing notable loss of farmland each year which requires conservation of agricultural land.

Crop Land Use Area Change in Madi Municipality

The land use and land cover transitions in Madi Municipality reveal various shifts in land use as shown in Fig 7 and Table 7. A total of 45.81 ha of water bodies, 453.51 ha of riverbeds, 6.48 ha of other wooded land, 9.9 ha of grassland, and 8.1 ha of forest were converted into cropland, indicating the expansion of agricultural land. In contrast, 8.19 ha of cropland transitioned to water bodies, 80.73 ha to riverbeds, 68.49 ha to other wooded land, 7.11 ha to grassland, and 74.34 ha to forest, reflecting both natural processes and ecological changes. Additionally, 7822.89 ha of cropland remained unchanged, showing agricultural continuity, while 3.6 ha of cropland was converted into built-up areas, reflecting urbanization.

The crop land use and land cover transitions in Madi Municipality show diverse changes in land use. A total of

47.34 ha of grassland, 33.66 ha of forest, 12.78 ha of riverbeds, 9.72 ha of other wooded land were converted into cropland, expanding agricultural land (Table 7).

On the other hand, 853.2 ha of cropland shifted to water bodies showing development of aquaculture in Madi Municipality in the last decade. Similarly, 123.21 ha crop land to riverbeds, 1342.26 ha to other wooded land, and 1258.29 ha to grassland reflecting regulation of community forest. Additionally, 1.17 ha of cropland was converted to forest, 2886.84 ha of cropland remained unchanged. In Madi Municipality, land use and land cover have experienced significant transitions, reflecting diverse changes in land utilization.

On the other hand, 853.2 ha of cropland were transformed into water bodies, indicating a rise in aquaculture development within the Municipality over the past decade. Furthermore, 123.21 ha of cropland shifted to riverbeds, 1,342.26 ha to other wooded land, and 1,258.29 ha to grassland, reflecting the ongoing regulation of community forests. A minor portion, 1.17 ha, was converted from cropland to forest. Additionally, 2,886.84 ha of cropland remained unchanged. Despite Madi being considered a remote municipality in Chitwan, it has seen notable urbanization, with approximately 919 ha of cropland being converted into built-up urban areas.

Riverbed to cropland changed was high in 2001 to 2011, maybe due to the 1993-flood induced riverbed gradual conversion to crop land. Madi region has rivers and streams, these rivers and streams change their course every year converting cropland or riverbed.

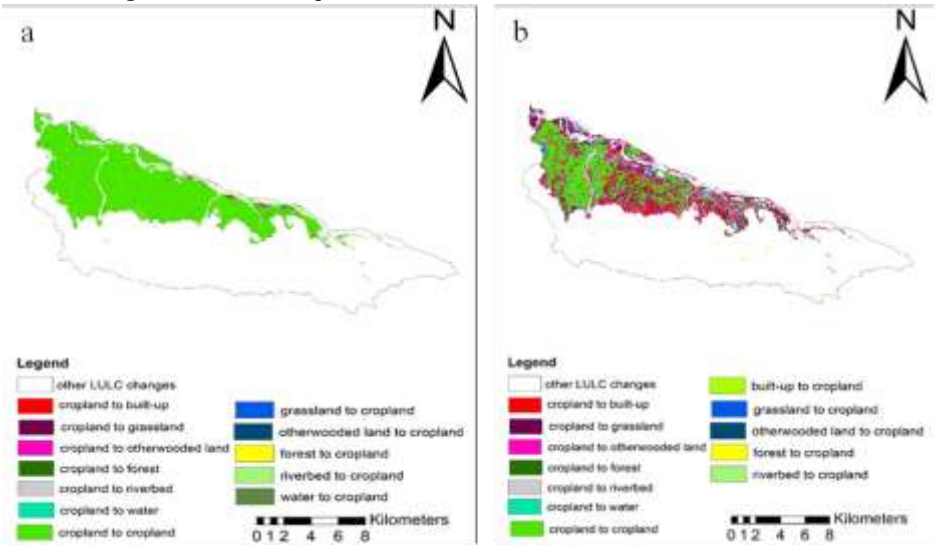

Fig. 7: Cropland change in Madi Municipality: a. Transition of cropland to other categories of land and vice- versa during 2001 to 2011, b. Transition of cropland to other categories of land and vice- versa during 2011 to 2021. Where other land use change categories remained intact, built-up is found to replace cropland during 2011-2021 period.

Table 7: Crop land change in Madi Municipality from 2001 to 2011 and 2011 to 2021.

Land use change	2001-2011 (Area-Ha)	2011-2021 (Area-Ha)
Water to cropland	45.81	NA
Riverbed to cropland	453.51	12.78
Other wooded land to cropland	6.48	9.72
Grassland to cropland	9.9	47.34
Forest to cropland	8.1	33.66
Cropland to water	8.19	853.2
Cropland to riverbed	80.73	123.21
Cropland to other wooded land	68.49	1342.26
Cropland to grassland	7.11	1258.29
Cropland to forest	74.34	1.17
Cropland to cropland	7822.89	2886.84
Cropland to built-up	3.6	918.99
Built-up to cropland	NA	0.63

Lately, Madi has been declared as a fisheries zone by the Government of Nepal. The increase in water land from 8 ha to 853 ha from 2001-2011 to 2011-2021 might be the reason for expanding aquaculture.

Chitwan's municipalities have made significant changes in cropping land to other categories over the last 20 years, from 2001 to 2021. In the last decade 2011-2021, all the municipalities have an increased built-up area of 7028 ha in Bharatpur, 1527 ha in Khairahani, 1107.9 ha in Ratnanagar, 1083 ha in Kalika, 918.99 ha in Madi and 799 ha in Rapti.

The findings revealed a significant increase in built-up areas at the expense of agricultural land, a trend consistent with studies by Rimal *et al.* (2020); Wang *et al.* (2020), and Rai *et al.* (2020). The changes in cropping land to built-up between 2011 and 2021 were largely influenced by the establishment of new local government units in 2015 (Rimal *et al.,* 2020). The development of new market centers further contributes to the transformation of land use in the region. Moreover, the reduction in agricultural land in Nepal is largely due to unclear and poorly implemented land use policies. Rapid migration, especially by the younger generation. To address this, stronger government regulation and political commitment, particularly at the local level are needed to enforce land use laws effectively. While much of the hill and mountain land remains barren and population growth is declining (CBS, 2021), there is increasing population pressure in the Terai district, Chitwan. This underscores the need for better land use strategies to manage demographic shifts and protect agricultural land.

Key factors for the marked increment in agricultural land could be access to irrigation, agricultural inputs (such as improved seeds, fertilizers, and mechanization) and better access to road leading markets. Further, the establishment of a cancer hospital, medical colleges, and health facilities in recent decades back has transformed the region into a medical and educational hub, attracting migrants.

Although land cover and land use change is a critical factor, land use intensification is also equally important in the agriculture commercial hub area of Chitwan. Timely assessments of agricultural land use changes will enable the creation of balanced plans that preserve agricultural land while accommodating urban growth, ensuring a stable food supply for the growing population.

Chitwan agriculture is also influenced by agricultural research and extension institutions like Agriculture and Forestry University, National Maize Research Centre, National Cattle Research Centre and several other government and non-government institutions, alongside recent infrastructural developments like road access and market centers, have contributed to changes in land use and farming practices in the region.

We used Focus Group Discussion for the qualitative assessment of land use change, for which we discussed with the farmers, agriculture extension agents, local community leaders to explore the agricultural land use pattern in the study area. Based on the discussion, it was found that the introduction of commercial banana farming in eastern Chitwan, particularly northern part of Ratnanagar, Khairahani, Rapti and Kalika Municipality have changed the land use pattern. There have been tremendous changes in irrigation facilities in the last decade, particularly due to renovation of farmers managed irrigation system, construction of new irrigation system, and establishment of deep boring and pump set irrigation system. This has intensified the use of previously underutilized land which resulted in the increased in cropping frequency of both upland and lowland.

Key Informant Interview (KII), local residents of Khairahani argued that Government regulation, people awareness and their voice has displaced more than 30 brick kilns that occupied more than 200 ha of land is now slowly reverting back to cropland. Increase in the area of spring rice, winter maize, and polyhouse culture for vegetable farming is evident in Chitwan, indicating the commercialization of agriculture. In addition, local government subsidy programs have encouraged farmers for commercial farming such as fisheries. The expansion of aquaculture in different places of Chitwan led to the conversion of arable land to water bodies.

However, land adjacent to Chitwan national park and community forest has been left temporary fallow due to wildlife encroachment, yet still has been a source of underutilized crops such as fiddle head fern and air potato, that plays a vital role for food sufficiency among buffer zone communities (Timilsina *et al.,* 2022).

Sharma (2021), emphasized conversion of riverbed to cropland and vice versa mainly due to Narayani and Rapti river flood and erosion. Additionally, the deposition of sand and silt can lead to the formation of new riverbeds, which becomes unsuitable for farming. Respondents claimed that political propaganda and people's speculation about relocating Nepal's capital to Chitwan has fueled the land price inflation leading to conversion of arable land into plotting for residential and commercial purposes. Compared to Hill, Terai region has negligible barren land, which may be due to easiness in using farm machinery in plain areas of Terai as compared to sloppy regions of hills. Despite the problem of labor scarcity in the Terai region, the easy mechanization tools make intercultural operation easy for farmers during labor scarcity.

Conclusion and Policy Implication

The study analyzed land use and land cover transition in Chitwan municipality over the 20 year period, 2001 to 2021, focusing on cropping land change. The findings revealed a

notable increase in built-up areas at the expense of agricultural land. On the other side, the results also showed the considerable change of different land categories into cropland, this finding equally indicates the scope of agriculture. Evidence shows that intensification of underutilized land is possible by increasing the availability of agricultural inputs and technologies. However, the policy could be in place to ensure sustainable land use. Besides cropland, proper utilization of riverbeds, forests and water land could support a sustained food system. Loss of agricultural land, increase in land price, and human wildlife conflict are some to the challenge of land management. The study findings are crucial for policymakers focused on agricultural land use in urban and peri-urban areas of Nepal.

Conflict of Interest

The authors declared that there is no conflict of interest.

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Appendices

Appendix 1: Accuracy measurement of LULC for 2021, Bharatpur

Land use class	Water	Forest	Riverbed	Built-up	Cropland	Grassland	Other Wooded Land	Total	User's Accuracy	Kappa
Water	10	0	0	0	0	0	1	11	0.91	0
Forest	4	90	6	5	2	3	2	112	0.80	0
Riverbed	0	1	10	1	0	0	0	12	0.83	0
Built-up	0	3	11	76	7	1	1	99	0.77	0
Cropland	1	4	4	8	138	6	3	164	0.84	0
Grassland	0	1	1	3	4	76	4	89	0.85	0
Other wooded land	1	0	0	0	0	3	17	21	0.81	0
Total	16	99	32	93	151	89	28	508	0.00	0
Producers Accuracy	0.63	0.91	0.31	0.82	0.91	0.85	0.61	0	0.82	0
Kappa	0	0	0	0	0	0	0	0	0	0.77

Appendix 2: Accuracy measurement of LULC for 2021, Rapti

Land use class	Water	Forest	Riverbed	Built-up	Cropland	Grassland	Other wooded land	Total	Users Accuracy	Kappa
Water	13	0	0	0	0	0	2	15	0.87	0.00
Forest	4	181	12	2	4	8	3	214	0.85	0.00
Riverbed	0	1	13	1	0	0	0	15	0.87	0.00
Built-up	0	0	4	17	0	1	0	22	0.77	0.00
Cropland	4	4	5	3	104	5	1	126	0.83	0.00
Grassland	0	0	0	0	2	46	0	48	0.96	0.00
Other wooded land	0	0	0	1	0	3	56	60	0.93	0.00
Total	21	186	34	24	110	63	62	500	0.00	0.00
Producer Accuracy	0.62	0.97	0.38	0.71	0.95	0.73	0.90	0.00	0.86	0.00
Kappa	0	0	0	0	0	0	0	0	0.00	0.81

Appendix 3: Accuracy measurement of LULC for 2021, Khairahani

Land use class	Water	Forest	Riverbed	Built-up	Cropland	Grassland	Other wooded land	Total	Users' Accuracy	Kappa
Water	12	0	1	0	1	1	0	15	0.80	0
Forest	0	42	4	0	1	0	1	48	0.88	0
Riverbed	1	2	10	0	0	0	0	13	0.77	0
Built-up	2	1	9	80	2	1	2	97	0.82	0
Cropland	5	2	12	3	146	8	4	180	0.81	0
Grassland	0	0	2	0	0	36	1	39	0.92	0
Other wooded land	3	1	9	0	0	6	91	110	0.83	0
Total	23	48	47	83	150	52	99	502	0.00	0
Producers Accuracy	0.52	0.88	0.21	0.96	0.97	0.69	0.92	0	0.83	0
Kappa	0	0	0	0	0	0	0	0	0.00	0.79

Appendix 4: Accuracy measurement of LULC for 2021, Ratnanagar.

Land use class	Water	Forest	Riverbed	Built-up	Cropland	Grassland	Other wooded land	Total	User Accuracy	Kappa
Water	28	2	0	0	0	1	0	31	0.90	0.00
Forest	2	14	0	0	0	0	1	17	0.82	0.00
Riverbed	0	2	8	0	0	0	0	10	0.80	0.00
Built-up	1	2	10	73	1	1	0	88	0.83	0.00
Cropland	8	1	14	17	191	5	2	238	0.80	0.00
Grassland	1	0	1	1	1	27	1	32	0.84	0.00
Other wooded land	0	1	2	1	0	10	73	87	0.84	0.00
Total	40	22	35	92	193	44	77	503	0.00	0.00
Producer Accuracy	0.7	0.64	0.23	0.79	0.99	0.61	1	0	0.82	0.00
Kappa	0	0	0	0	0	0	0	0	0.00	0.76

Appendix 5: Accuracy measurement of LULC for 2021, Kalika

Land use class	Water	Forest	Riverbed	Built-up	Cropland	Grassland	Other wooded land	Total	Users Accuracy	Kappa
Water	18	3	0	1	0	0	0	22	0.82	0.00
Forest	9	176	3	10	2	6	5	211	0.83	0.00
Riverbed	0	1	18	2	1	0	0	22	0.82	0.00
Built-up	0	1	0	39	3	0	1	44	0.89	0.00
Cropland	0	0	1	2	50	2	0	55	0.91	0.00
Grassland	0	0	0	0	9	46	5	60	0.77	0.00
Other wooded land	1	0	0	1	4	10	70	86	0.81	0.00
Total	28	181	22	55	69	64	81	500	0.00	0.00
Producers Accuracy	0.64	0.97	0.82	0.71	0.72	0.72	0.86	0.00	0.83	0.00
Kappa	0	0	0	0	0	0	0	0	0.00	0.79

Appendix 6: Accuracy measurement for LULC for 2021, Madi

Land use class	Water	Forest	Riverbed	Built-up	Cropland	Grassland	Other Wooded land	Total	Users' Accuracy	Kappa
Water	33	0	3	0	0	0	0	36	0.91	0
Forest	5	178	15	5	1	4	2	210	0.84	0
Riverbed	0	3	8	0	0	0	0	11	0.72	0
Builtup	0	1	3	23	0	1	1	29	0.79	0
Cropland	1	1	8	5	53	2	0	70	0.75	0
Grassland	1	0	6	0	3	48	0	58	0.82	0
Other wooded land	3	0	2	4	3	5	74	91	0.81	0
Total	43	183	45	37	60	60	77	505	0.00	0
Producer Accuracy	0.76	0.97	0.17	0.62	0.88	0.80	0.96	0.00	0.82	0
Kappa	0	0	0	0	0	0	0	0	0.00	0.77