

# Land Use Land Cover Change Analysis and Irrigation Water Demand Estimation in the Phewa Irrigation System Command Area

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## Abstract

Growing urbanization has led to the extensive transformation of Land Use and Land Cover (LULC) within irrigation command areas, altering land-use patterns and increasing pressure on water resources. In Nepal, changes in command areas have not been objectively recorded. The objective of this study was to evaluate historical trends and provide simulations and predictions for land use land cover change (LULCC), focusing specifically on cropland and built-up areas within the Phewa Irrigation System Command Area (PIS-CA). Landsat 7 satellite imagery for the years 2002 and 2012 and Sentinel-2 satellite imagery for 2022 and 2025 were analyzed within ArcGIS software, utilizing pixel-based supervised image classification. The study predicts urban expansion for the years 2032 and 2042 using the CA-Markov model and Land Change Modeler (LCM). Model validity was assessed by comparing actual 2022 LULC with predicted results. Input variables included topography, distance to major roads, distance to the urban core of Pokhara, and proximity to rivers and lakes. The results showed that between 2002 and 2022, cropland decreased by 152.94 hectares (51.31%) at an average annual rate of 2.56%, while the built-up area increased by 149.84 hectares (400.18%) at a rate of 20.05% per year. From 2022 to 2042, the area under cropland is projected to decrease by 57.54 hectares (39.36%) at a rate of 1.96% per year, while the built-up area is expected to increase by 69.53 hectares (35.36%) at a rate of 1.76% per year. Based on the cropland area on the classified LULC map of 2025 and the present cropping pattern in the command area of the Phewa irrigation system, the irrigation water requirement during the peak period is 1296.66 lps. Further, the predicted irrigation water requirements for the years 2032 and 2042 are 993.96 lps and 906.22 lps, respectively

*Keywords: Phewa irrigation system, Command Area, CA-Markov, crop water requirement, Land Use Land Cover (LULC)*

## 1. Introduction

Land use refers to the purpose that land is utilized, while land cover is the combination of biological and physical conditions of land (Chapagain et al., 2018). (LULC) refers to the numerical change in a specified LULC either in increasing or in decreasing trend within the planet. (Lambin et al., 2001) defined change detection as the phenomenon of finding numerical dynamics in a body or process by viewing it at different time periods. (LULC) is a changeable phenomenon that brings vital dynamics in environment on a global scale (Lambin et al., 2001). Globally, 62 % of land areas have transformed significantly from naturally vegetated areas to a growing proportion of land use changes to croplands and urban and built-up areas (Afuye et al., 2024). Pokhara and Bharatpur metropolitan cities have a multi-fold increase in built-up areas from 1990 to 2018, along with decreases in agricultural lands (Rai et al., 2020). LULC changes in the 12 rapidly urbanizing cities of Nepal from 1990 to 2020 finds overall decrease in agricultural areas in Pokhara city, with increased built-up areas and vegetation from 1990 to 2020 (Devkota et al., 2023).

The Phewa irrigation system was constructed during the Rana regime to irrigate a gross command area of 373 hectares in Pokhara Valley. That was constructed by the military with government funds. The intake of the system was located at 650 m upstream (U/S) of the existing Phewa dam. Earlier, a temporary diversion was used to divert water for irrigation called Syaule Bandha. The farmers were suffering from floods due to the dam every year. The Indian Commission Mission (ICM) to Nepal built a permanent dam during 1959-1964 costing US\$ 770,000, which was located at 125 m U/S of the existing Phewa dam.

Remote sensing imagery efficiently captures up-to-date spatiotemporal LULC distributions (Rimal et al., 2018), through which trends in LULC change may be extracted, analyzed, and predicted (Liping et al., 2018), LULC mapping tools is used in changing Pattern and drivers of Land Use high rate of built-up area expansion and contraction of the cultivated land use, including a high rate of built-up area expansion and contraction of the cultivated land. Rapid urbanization has led to the fragmentation of arable land for residential purposes (Rimal et al., 2024)The Urban Sprawl model is highly effective for evaluating the current scenario and future conditions of urban sprawl (Paudel et al., 2024).

Land Use Land Cover (LULC) change is a critical factor affecting hydrology, agriculture, and natural resources, especially in irrigation command areas. The command area of this project depends heavily on a timely and adequate water supply, which is influenced by changing Land Use Land Cover (LULC) patterns over time. In recent decades command area of PIS has undergone significant transformations due to urban expansion and infrastructure development. These changes have direct implications on water demand, runoff characteristics, and overall irrigation management (Foley et al., 2005). Therefore, it is essential to analyze the historical and ongoing LULC changes in the command area and to evaluate their effect on irrigation water demand. Urban growth prediction in the command area of the Phewa Irrigation system was carried out using the Land Change Modeler (LCM) in IDRISI Selva, applying the CA–Markov models, and the irrigation demand of PIS is carried out using different empirical formulas. This study was conducted with the General Objective of analyzing the Land Use Land Cover changes in the Phewa Irrigation System (PIS) command area and to forecast the irrigation demand using the LULC scenario.

## 2. Methodology

### 2.1 Research Design

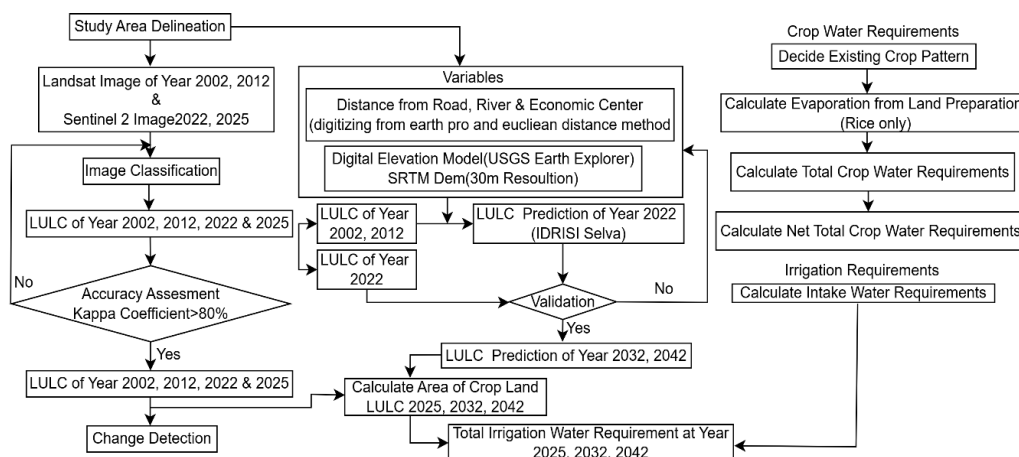


Fig. 1: Methodological flow chart used for research

### 2.2 Study Area

The study area lies in the central part of the Pokhara Valley, within Kaski District of the Gandaki province of Nepal, approximately 200 km west of Kathmandu. The irrigation system proposed under this study is PIS, which is in the downstream (D/S) of the Phewa Lake, Ward No. 17 of Pokhara Metropolitan City. It is bordered by the Seti River, Phushre Khola, Raniban, and Phewa Lake. Renowned for its fertile soils, abundant water resources, and convenient access to major urban centers, this area is among the most significant agricultural zones in the region. The irrigation system has perennial water feeding from Phewa Lake. The irrigation system is to irrigate a Gross command area of 373 hectares and a Net command area of 320 hectares within the downstream (D/S) of Phewa Lake, with a conveyance (discharge) capacity of 9.0 cumecs through two main canals, with a hydropower plant established at the tail end to generate electricity of 1000 kW. There are two main canals, namely Nuwakote Kulo on the right side and Biruwa Kulo on the left side.

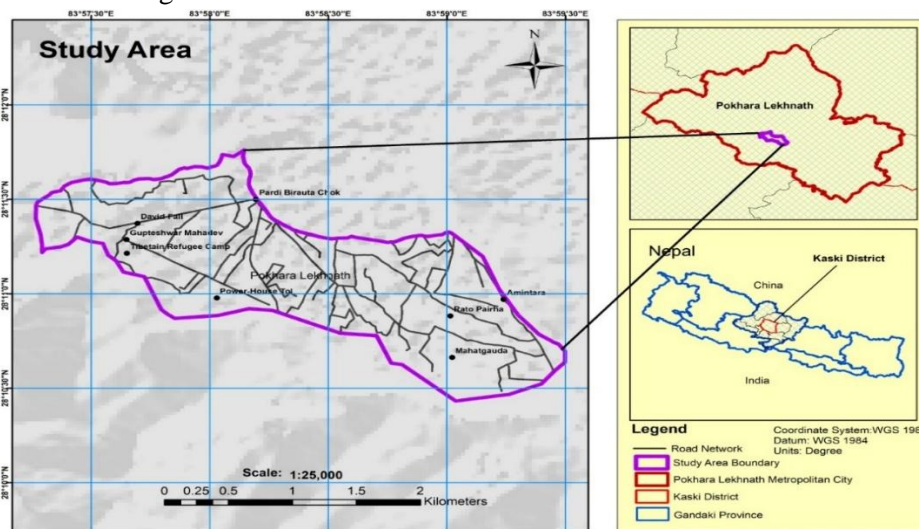


Fig. 2 : Location of study area

### 2.3 Dataset Used

The principal dataset for this study consisted of Landsat imagery, which was collected from the Google Earth Engine Source <https://developers.google.com/earth-engine/datasets/catalog/landsat>. In addition, the boundary shapefile of the Phewa Irrigation System (PIS) command area was prepared using the Command Area Field Survey Report (PIS–2067 BS) published by the Department of Irrigation. Likewise, the secondary data were acquired from (Department of Irrigation, 1990), rainfall data from the Office of Hydrology and Meteorology-Pokhara, and the road network, economic center, and distance from river data were acquired from Google Earth. A detailed description of the collected data is presented in Tables 1 and 2.

Table 1: Dataset Used for LULC MAP

DATA TYPE	DATASET FOR LULC MAP			
	DESCRIPTION	DATE	SOURCE	PURPOSE
Satellite Image	Landsat7 (Resolution:30m)	June 15 to Nov 15, 2002	GEE Data Catalog	LULC Map of 2002
Satellite Image	Landsat7 (Resolution:30m)	June 15 to November 15, 2012	GEE Data Catalog	LULC Map of 2012
Satellite Image	Sentinel 2 (Resolution:10m)	June 15 to November 15, 2022	GEE Data Catalog	LULC Map of 2022
Satellite Image	Sentinel 2 (Resolution:10m)	June 15 to November 15, 2025	GEE Data Catalog	LULC Map of 2025

ASTER DEM	SRTM (Resolution 30)	2025	USGS Earth Explorer	Variable
Road Data	From Digitization	June 15 to November 15, 2022	Google Earth Pro	Variable
River Data	From Digitization	June 15 to November 15, 2022	Google Earth Pro	Variable
Economic Center	From the field and Digitization	June 15 to November 15, 2022	Field Survey and Google Earth Pro	Variable
Boundary Of Command Area	Vector Data	Field Survey Report-2067	Department of Irrigation	Boundary

Table 2: Dataset Used for Irrigation Water Demand

DATA TYPE	DATASET FOR IRRIGATION WATER DEMAND	
	SOURCE	PURPOSE
Cropping Pattern in Command	Interview With Farmer and PDSP Manual	For the crop Calendar
Evaporation Estimation (EO)	PDSP Manual-Irrigation	Crop water requirement
Climate Data (Temperature, humidity, wind, sunshine hours) Radiation)	New_locClim - Software	Evapotranspiration Calculation
Rainfall	Office of Hydrology and Meteorology-Pokhara	Effective rainfall calculation

## 2.4 Data Analysis

### 2.4.1 LULC classification, Accuracy assessment, Validation, and Change detection

Land use land cover (LULC) maps were prepared using the GIS, and the dataset was collected from the Google Earth Engine (GEE) cloud-based platform, which processes multi-temporal satellite imagery efficiently. A supervised pixel-based classification was performed in GIS using the Maximum Likelihood classifier. Landsat 7 ETM+, for LULC 2002,2012 and Sentinel-2 MSI were used for LULC 2022,2025, We focused on classifying cropland and built-up so that Landsat images selecting June 15 to November 15 images having (cloud coverage less than 10%) to minimize cloud interference were collected throughout the study period. The study area boundary was used to clip all images, and cloud contamination was removed using quality assurance (QA) bands. A median composite was generated for each study year to reduce atmospheric noise and enhance spectral consistency. Applying a supervised pixel-based image classification approach to categorize the imagery into five distinct land cover classes: water bodies, built-up areas, agricultural land, barren land, and forest land, with training samples collected from high-resolution Google Earth imagery and existing Land Use Land Cover information, which improved the accuracy of the classification (Foody, 2002). Manual editing was conducted to correct misclassified pixels and refine the classification, adjusting the boundaries between classes and ensuring that the classification accurately reflected the land cover types (Gislason, 2006). Before any categorization and change detection procedures, all raster layers were normalized in terms of spatial resolution to enable comparisons across various satellite data sources throughout time. Similar to Landsat-based data packages, the Sentinel-2 MSI data were reprojected at a 30-meter spatial resolution. As a result, LULC maps were generated for 2002, 2012, 2022, and 2025.

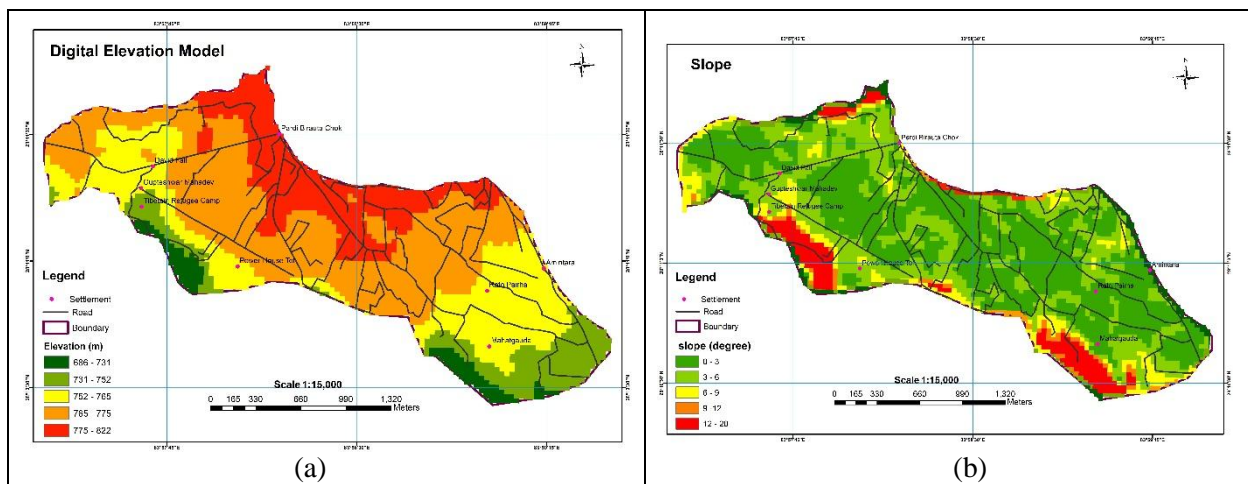
Accuracy assessment is crucial for evaluating the quality of image classification and verifying

the LULC outputs for 2002, 2012, 2022, and 2025 against the desired accuracy standards. In this study, the classified results were compared with real-world reference data by constructing an error matrix, enabling a systematic evaluation of classification performance. The overall accuracy of the annual classifications ranged between 81% and 87% (Rimal et al., 2018), which is generally acceptable upper-level accuracy for such a land-cover classification. These metrics provide a quantitative measure of the classification performance, helping to validate the effectiveness of the classifier and the overall methodology.

Change detection between the years 2002 and 2022 was performed to identify and quantify land cover changes. LULC changes between 2002 and 2012 were determined by analyzing five distinct classes and evaluating their interclass conversions was carried out by intersecting two LULC maps from the respective years. The same approach was then applied to assess changes from 2012 to 2022 and from 2002 to 2022. systematically monitored and analyzed changes in land cover types. quantifying spatial changes during each specified period. The study presents and analyses LULC class losses and gains, transitions between LULC categories for the period, and the overall impact of other land cover types on built- up areas.

### 2.4.2 Projecting Future Land Cover Change

Urban growth in the command area of the Phewa Irrigation System was predicted using the Land Change Modeler (LCM) in IDRISI Selva based on the CA–Markov approach. LULC maps for 2002, 2012, and 2022 derived from Landsat imagery were used to analyze historical land cover transitions. Key driving factors, relevant to the local context, such as slope and elevation (derived from DEM), distance to major roads and the urban core of Pokhara, and distance to the economic Center, distance to rivers and lakes were incorporated to explain spatial drivers of urban expansion. Before being used in the MLP model in the Land Change Modeler, the spatial driver layers were converted to raster form and normalized as shown in Fig 3 ((a), (b), (c), (d), and (e)), respectively, below:



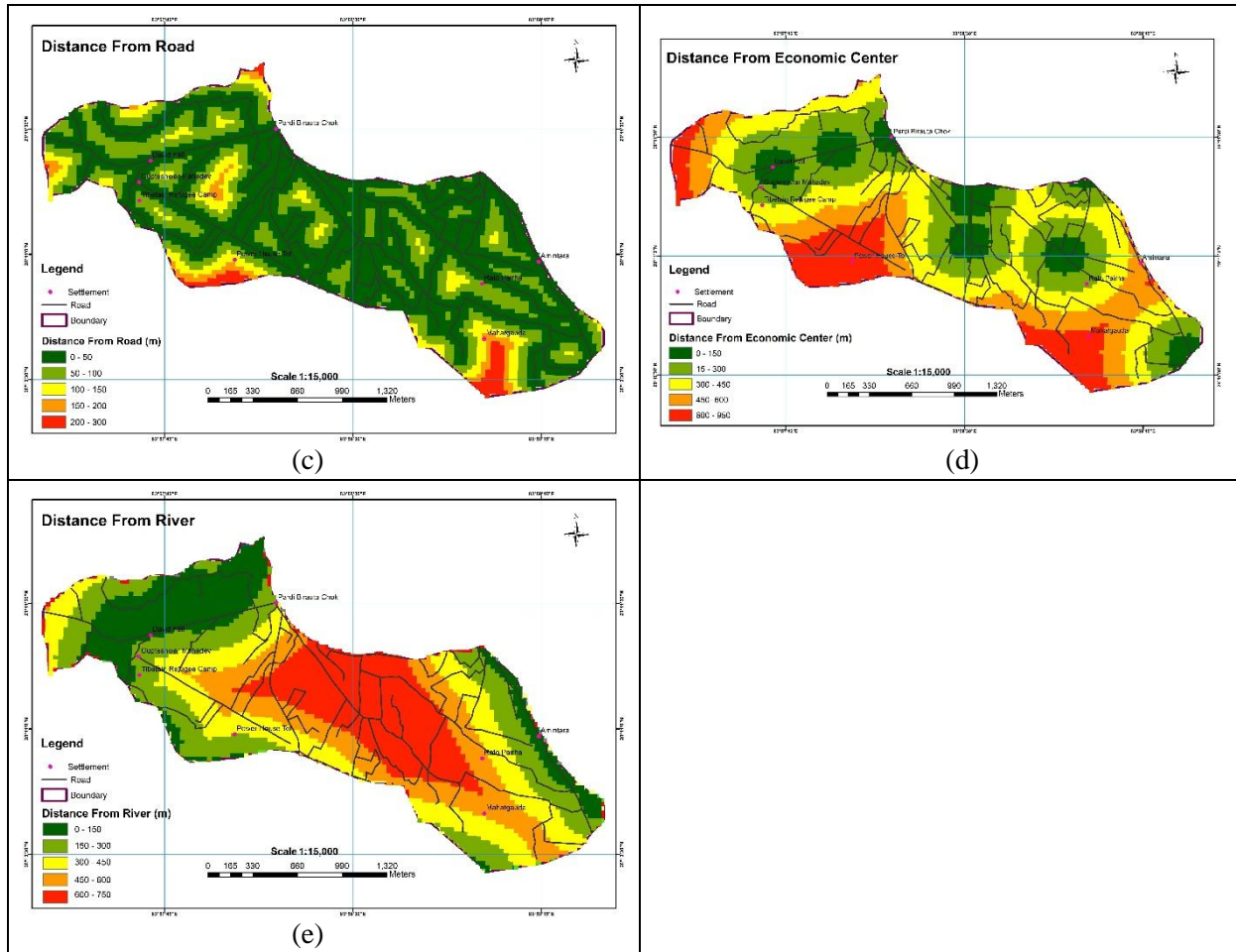


Fig. 3 : Variables

Transition potential was generated using a Multi-Layer Perceptron (MLP) neural network, while the Markov chain estimated the extent of future urban growth by 2032,2042. Since the LULC maps from 2002, 2012, and 2022 are more suited for simulating long-term transitions, they have been used for the CA-Markov model's calibration and validation procedures. However, the 2025 LULC map was created using supervised classification to depict the existing land cover and estimate the amount of water needed for irrigation. Spatial allocation of changes was performed using the Cellular Automata model, producing clustered urban growth patterns consistent with observed trends in the PIS command area.

### 2.4.3 Present and Future Irrigation Water Demand

Cropland area of the Phewa irrigation system was obtained from LULC maps of the year 2025 and projected for the years 2032,2042. The irrigation water demand was calculated based on the existing cropping pattern in the Phewa irrigation system, which was identified through field visits and interviews with farmers. Based on the information collected, and with reference of guidelines provided by the Department of Irrigation (1990). The NewLoc Clim provided consistent climate parameters (monthly means of minimum, maximum, and average daily temperature, precipitation, potential evapotranspiration, wind speed, water vapor pressure, and sunshine fraction or sunshine hours. These parameters are needed for FAO Penman-Monteith  $ET_0$  calculation. Effective rainfall was calculated using the WECS Guideline No 1(1998), which is the base for estimating Crop water requirement.

The baseline climatic water demand is calculated using the FAO Penman-Monteith (Equation1), which serves as the standard for representing water loss from a well-watered grass surface.

$$ET_0 = \frac{0.408\Delta R_n + \gamma \frac{900}{T+273} U_2 (e_s - e_a)}{\Delta + \gamma(1+0.34U_2)} \quad (1)$$

The  $ET_0$  is adjusted using a dimensionless crop coefficient ( $K_c$ ), to account for specific physiological characteristics and growth stages.

$$ET_c = K_c * ET_0 \quad (2)$$

For rice, significant water is required for puddling and saturation land preparation (LP) and to compensate for deep percolation (DP)

Rice (LP): 50mm to 150mm depending on the seasonal sequence

$$DP = \text{Loss Rate (mm/day)} * \text{Duration} \quad (3)$$

The portion of rainfall available to the crop is derived from the 80% reliable rainfall calculated using the MIP method.

For Rice

If  $P_{80} < 5 \text{ mm}$ :  $P_e = 0 \text{ mm}$ , If  $10 < P_{80} < 100 \text{ mm}$ :  $P_e = \min(0.85 * P_{80}, ET_c + DP) \text{ mm}$

If  $P_{80} > 100 \text{ mm}$ :  $P_{80} = \min(0.7 * P_{80}, ET_c + DP) \text{ mm}$

For Dry Crop

$$P_e = 0.70 * P_{80} \quad (4)$$

For Rice

$$\text{NIR} = \text{Crop Evapotranspiration} + \text{land Preparation} + \text{Evaporation during land preparation} + \text{Deep Percolation} - \text{Effective Rainfall} \quad (5)$$

For Dry crop

$$\text{NIR} = \text{Crop evapotranspiration} - \text{Effective rainfall} \quad (6)$$

Where:

NIR =Net irrigation requirement,  $ET_0$  =Reference evapotranspiration in mm/day,  $R_n$ =Net radiation at the crop surface MJ/m<sup>2</sup>/day  $\gamma$  =Soil heat flux density MJ/m<sup>2</sup>/day, T=Mean daily air temperature at 2 m height °C,  $U_2$  = Wind speed at 2 m height m/s,  $e_s - e_a$  = Saturation vapor pressure deficit kPa,  $\Delta$  = Slope of the vapour pressure curve,  $P_e$  = Effective Rainfall mm,  $P_{80}$  =Rainfall at 80% reliability mm

### 3. Results and Discussion

#### 3.1 LULC Map 2002

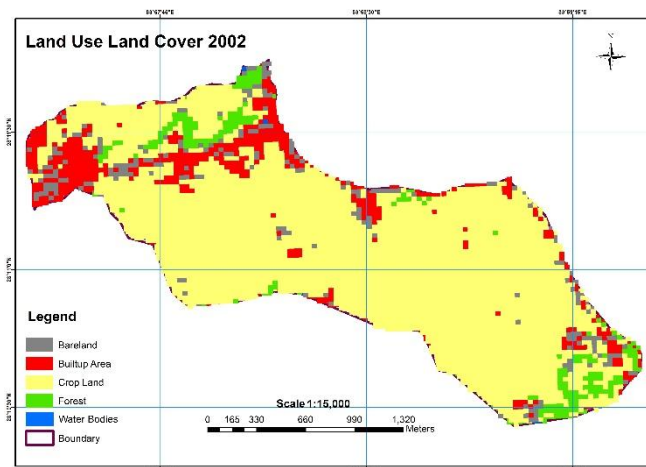


Fig. 4: LULC 2002

The 2002 LULC Fig 4 reveals the spatial distribution of land cover types within PIS-CA In 2002 Crop land was the predominant land cover, encompassing 298.35 Hectares, or 79.98% .Out of the total area 373 Hectare, Built-up area covered 37.35 Hectare (10.01%), while Forest land occupied 17.73 Hectare (4.75%), Barren Land and Water Bodies were the least prevalent, covering 19.44 Hectare

(5.21%) and 1.8 Hectare (0.05%) respectively.

These results indicate that the coverage of water bodies is very small, implying that most of the area is dominated by cropland with minimum urban development, compared to the net command area of 320 hectares during the design period of the Phewa Irrigation System (PIS). Cropland coverage decreased by 6.77% up to the year 2002. The accuracy assessment showed an overall accuracy of 82.75% and a Kappa coefficient of 0.80, suggesting the high reliability of the classification results.

### 3.2 LULC Map 2012

The 2012 LULC map Fig. 5 indicates significant changes from 2002. Crop land decreased to 242.15 Hectare (65.09 %), while Built-up areas expanded to 79.31 Hectare (21.26%), reflecting a significant Change in the command area of PIS into built-up area and other infrastructure development. Barren Land increased to 36.92 Hectare (9.88%), and Water Bodies slightly increased to 7.93 Hectare (2.12%), and Forest Land decreased to 6.12 Hectare (1.64%).

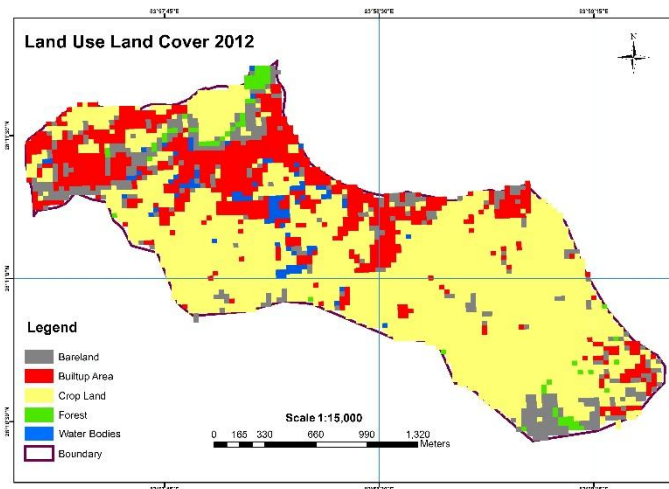


Fig. 5: LULC 2012

These changes in land cover indicate that the coverage of Forest land is decreased notable in the Mahatgaunda area. Well-defined erosion fronts clearly indicate the increase in Barren land compared to LULC 2002. This result aligns with studies (Rimal et al., 2015) in Pokhara Valley. The assessment showed an overall accuracy of 84.81% and a Kappa coefficient of 0.82, suggesting the high reliability of the classification results.

### 3.2 LULC Map 2022

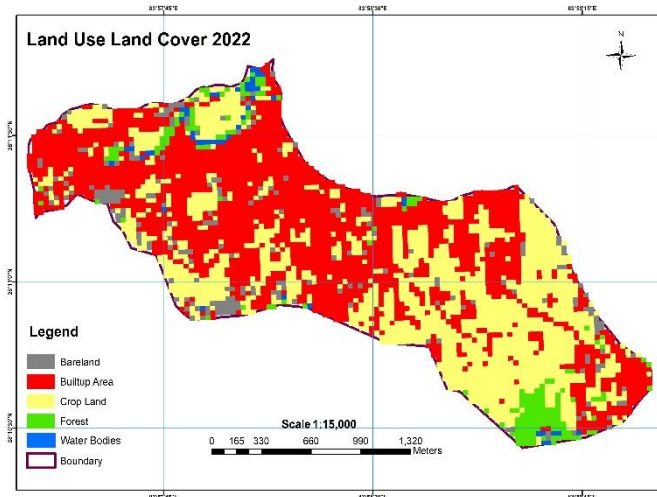


Fig. 6: LULC 2022

The 2022 LULC map Fig. 6 indicates significant changes from 2012. Crop land decreased to an area of 145.26 Hectares (38.94%) out of a total of 373 Hectares, while Built-up areas expanded to 187.191 Hectares (50.19%), reflecting the command area of the PIS area dominated by Built up area. Similarly, barren land 19.29 Hectares (5.17%), forest land 16.83 Hectares (4.51%), and water bodies with an area of 4.42 Hectares (1.19%), respectively.

These changes in land cover indicate that the coverage of built-up area increased by 107.88 Hectors (28.86%). After the restructuring of the nation, the pace of urbanization seems to have grown dramatically (Joshi, 2023). Forest land was increased in the Mahatgaunda area compared to the LULC map of 2012. We can clearly see that the (erosion front) barren land in the map 2012 is covered by forest in the next 10-year interval. The accuracy assessment showed an overall accuracy of 88.88% and a Kappa coefficient of 0.88, suggesting the high reliability of the classification results.

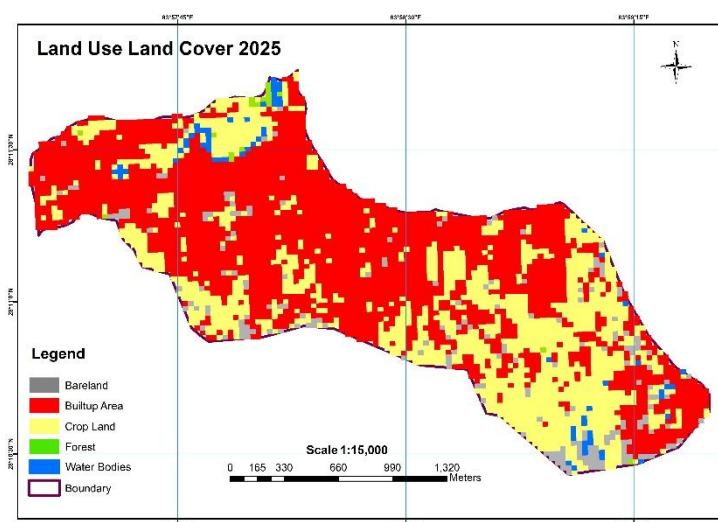


Fig. 7: LULC 2025

### 3.4 LULC Map 2025

The 2025 LULC map, as shown in Fig. 7, shows further changes in land cover. Built-up area remains the largest category with an area of 220.58 (59.14%) Hectares, with Crop land decreased to 126.8 Hectares (34.00%), out of a total of 373 Hectares, while Built-up areas expanded to 187.191 Hectares (50.19%), reflecting the Command area of PIS area dominated by Built-up area. Similarly,

barren land 18.04 Hectares (4.84%), forest land 6.27 Hectares (1.68%), and water bodies 1.35 Hectares (0.36%), respectively. The increase in Built-Up Areas and decrease in Agricultural Land reflect ongoing urbanization and land conversion. An increase in built-up area within 3 years is 50.19% to 59.14% indicate rapidly increase in infrastructure and built-up in that area.

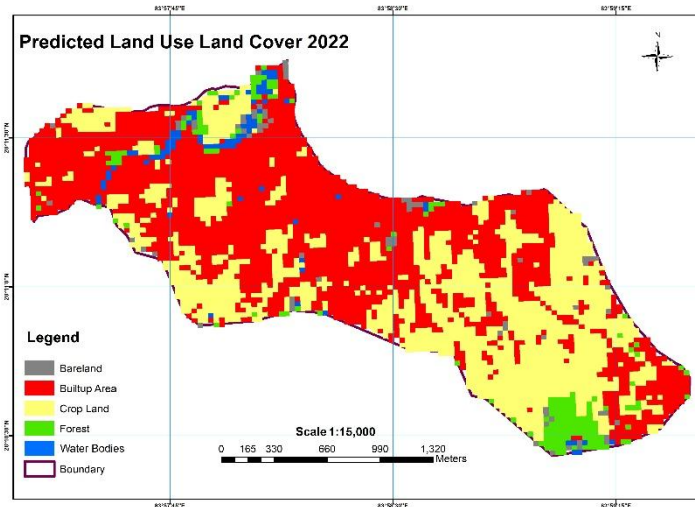


Fig. 8: Predicted LULC 2022

### 3.5 Model validation for simulated LULC

A LULC area transition possibility matrix was used for the LULC map of 2022, which was predicted through an integrated CA–Markov model (Fig.8).

The comparison between simulated and classified LULC maps shows good consistency, particularly for cropland (39.14% vs. 38.94%) and forest (4.39% vs. 4.51%). Built-up area was slightly overestimated in the simulation (52.65% vs. 50.19%), while barren land (1.83% vs. 5.17%) and water bodies (2.00% vs. 1.19%) showed notable deviations. The kappa index agreement results for the predicted LULC of 2022 and the actual LULC of the same year showed that there were small differences and a high level of consistency between the two LULC maps. The kappa coefficients 0.85, and overall accuracy 85.57% were observed. There was a high level of agreement, which confirmed that the accuracy was reasonable for future land use prediction. The model was acceptable for making predictions for 2032 and 2042.

Table 3: Accuracy Assessment Table (Kappa Test)

Class	Barren	Built-up	Crop	Forest	Water body	Total User	User Accuracy
<b>Barren</b>	18	1	1	1	2	23	0.783
<b>Built-up</b>	2	45	1	1	1	50	0.9
<b>Crop</b>	0	2	20	3	1	26	0.769
<b>Forest</b>	0	1	1	45	1	48	0.938
<b>Waterbody</b>	1	0	0	5	50	56	0.89
<b>Total</b>	21	49	23	55	55	203	
<b>Producer Accuracy</b>	0.857	0.918	0.870	0.818	0.909		
<b>Kappa</b>	85.4409						

### 3.5.1 LULC change analysis between 2022, 2032, and 2042

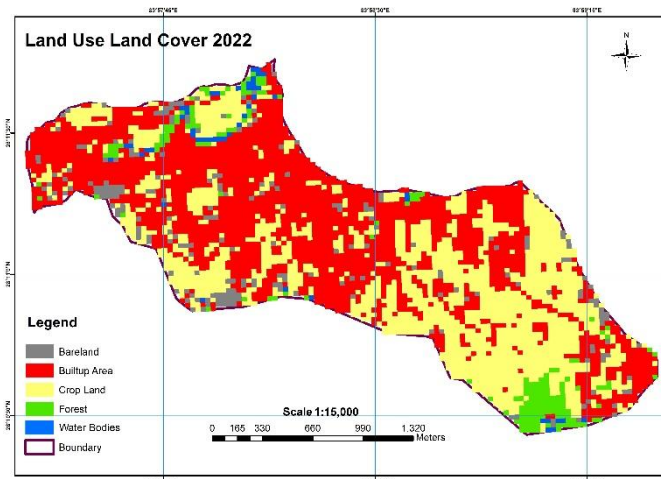


Fig. 9: LULC 2022

From 2022 to 2032 the area under the crop land, forest, water bodies is decreased by 48.96 Hectors (13.08%), 6.17 Hectors (1.65%), and 1.56 Hectors (0.45%), respectively (Fig.9). On the other hand, built up area and barren land increased by 50.48 Hectors (13.58%) and 5.83 Hectors (1.56%), respectively (Table 5). From 2032 to 2042, the LULC change prediction indicated that the area under built-up increased by 5.11%, which represented 19.05 Hectors, whereas the cropland area decreased 2.30%, which represented 8.58 Hectors (Fig.10). Forest land and barren land decreased by 8.58Hectors (2.23%) and 3.8 Hectors (1.02%), respectively (Table 4). From 2002 to 2022, with similar predicted trends for 2022 and 2042. This result indicates the expansion of built-up area and the shrinkage of agricultural land. This study’s findings are consistent with (Rimal et al., 2020) urban expansion over prime arable lands, where most cities were originally founded. from 2002 to 2022, with similar predicted trends for 2022 and 2042.

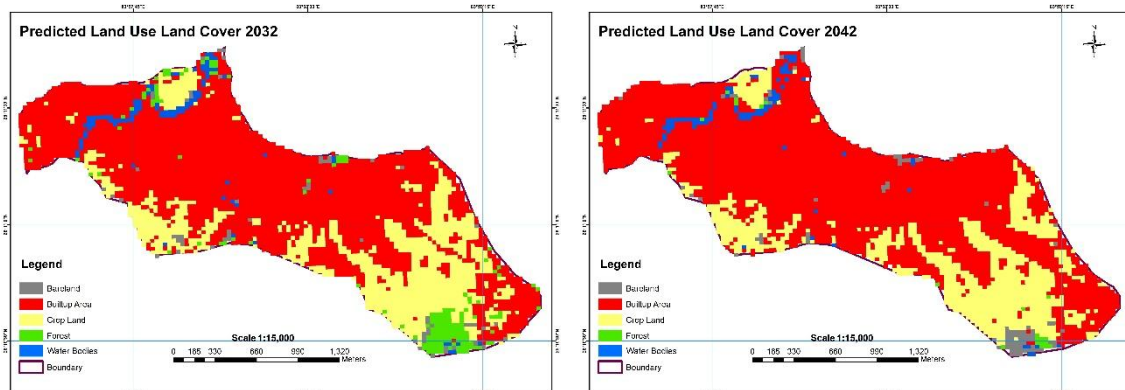


Fig. 10: Predicted LULC 2032 and 2042

### 3.6 Irrigation water

Fig.11 gives the area of cropland in the years 2025, 2032, and 2042. The existing cropping pattern in the Phewa Irrigation System was identified through field visits and interviews with farmers and guideline provide by the Department of Irrigation (1990). The FAO Penman-Monteith equation was used to calculate reference evapotranspiration ( $ET_2$ ), effective rainwater was estimated using WECS guideline no. 1 of 1998, and the cropping system in the command area demand was used to calculate crop water requirements. The irrigation water requirement of the Phewa Irrigation System, with a cultivable command area of 126.8 ha, 97.2 ha, and 88.6 ha and a gross cropped area of 177 ha, 135.6 ha, and 123.6 ha (cropping intensity 140%) respectively during the years 2025, 2032, and 2042,

shows seasonal variations driven by crop type and growth stage.

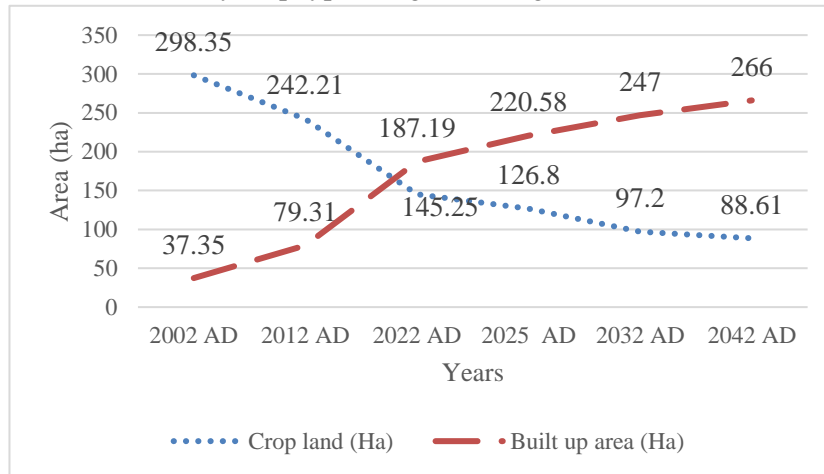


Fig. 11: Graph of cropland and built-up area

Monsoon paddy, cultivated in two varieties-monsoon Paddy 1 (39.4% area) and monsoon paddy 2 (47.3% area)-dominates irrigation demand from June to November, with peak requirements reaching 4.84 L/s in early November for MP2. Winter crops, including wheat (11.8%), potato (5.7%), oilseed (4.7%), maize (20.1%), and winter vegetables (5.36%), contribute to irrigation needs primarily between November and March, with maize demand peaking in April-May. Summer vegetables (5.36%) add to the demand between July and September. The total diversion requirement (intake water requirement) during the peak period is 1296.66 lps, 993.96 lps, and 906.22 lps, respectively, for the years 2025, 2032, and 2042. And, water requirement fluctuates seasonally, with the highest peak in early November and significant secondary peaks in early June, highlighting the need for efficient scheduling and water allocation to meet both monsoon and winter crop demands without stressing available water resources.

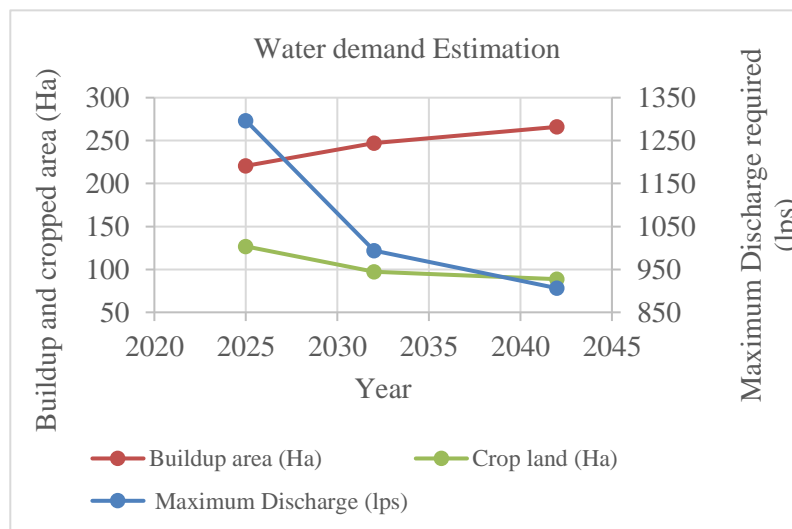


Fig. 12: Graph of Water demand estimation

Table 4: Predicted Land Use Land Cover and its Changes from 2022 to 2042

LULC CLASS	2022	%	2032	%	2042	%	Net change		Change %		Rate of change Ha/year	
	(Ha)		(Ha)		(Ha)		2022-2032	2032-2042	2022-2032	2032-2042	2022-2032	2032-2042
<b>Barren land</b>	6.84	1.83	12.67	3.40	8.87	2.38	5.83	-3.80	1.56	-1.02	0.156	-0.085
<b>Built-up Area</b>	196.62	52.65	247.1	66.23	266.15	71.35	50.48	19.05	13.58	5.11	1.358	0.426
<b>Crop Land</b>	146.16	39.14	97.2	26.05	88.62	23.76	-48.96	-8.58	-13.08	-2.30	-1.308	-0.191
<b>Forest Area</b>	16.38	4.39	10.21	2.74	1.90	0.51	-6.17	-8.31	-1.65	-2.23	-0.165	-0.186
<b>Waterbodies</b>	7.47	2.00	5.91	1.58	7.50	2.01	-1.56	1.59	-0.42	0.43	-0.042	0.036

Table 5: Land Use Land Cover, and its Changes from 2002 to 2022

LULC Class	2002	%	2012	%	2022	%	Net change		Change %		Rate of change Ha/year	
	(Ha)		(Ha)		(Ha)		2002-2012	2012-2022	2002-2012	2012-2022	2002-2012	2012-2022
<b>Barren land</b>	19.44	5.21	36.9242	9.90	19.2937	5.17	17.4842	-17.63	4.69	-4.72	0.469	-0.394
<b>Built-up Area</b>	37.35	10.00	79.4072	21.28	187.192	50.18	42.0572	107.78	11.28	28.90	1.128	2.408
<b>Crop Land</b>	298.35	79.89	243.157	65.17	145.256	38.94	-55.193	-97.90	-14.71	-26.24	-1.471	-2.186
<b>Forest Area</b>	17.73	4.75	6.11745	1.64	16.8301	4.51	-11.61255	10.71	-3.11	2.87	-0.311	0.239
<b>Waterbodies</b>	0.18	0.05	7.93601	2.13	4.4246	1.19	7.75601	-3.51	2.08	-0.94	0.208	-0.078

#### 4. Conclusion and Recommendations

The LULC analysis of the Phewa irrigation command area shows a clear decline in cropland and rapid growth of built-up areas between 2002 and 2025 and predicts the same trend up to the year 2042. This trend indicates rapid urban expansion at the expense of agricultural land.

Based on the area of crop land on the classified LULC map of 2025 and the present cropping pattern in the command area of the Phewa irrigation system, the total diversion requirement (intake water requirement) during the peak period is 1296.66 lps. Further, the predicted irrigation water requirement for the years 2032 and 2042 are 993.96 lps and 906.22 lps, respectively.

As the Phewa irrigation command area shows a clear decline in cropland and rapid growth of built-up areas, resulting in the decreasing trends of the water demands, the use of the water source from Phewa lake is a crucial issue, so further study incorporating the land use policy and the multi-use of the water in different scenarios will help to integrate water resource management.

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#### Conflicts of Interest

The authors declare no conflict of interest.

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