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Dynamics of land surface temperature in response to land use land cover change in Phewa watershed, Kaski, Nepal

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KEYWORDS

*Land Use Land Cover Change
Land Surface Temperature
Phewa watershed
Landsat
Supervised*

ABSTRACT

Geospatial tools play an important role in monitoring Land Use Land Cover Change (LULCC) and Land Surface Temperature (LST). This study assessed the extent of LULCC during 1990, 2007 and 2020 using temporal satellite imageries, and estimates LST during the study periods in relation to LULCC and explores various adaptation practices adopted in response to LST change in Phewa watershed. Landsat imageries were used for LULC classification and LST estimation. Purposive household survey (N=150), key informant survey (N=4), focus group discussion (N=4) and direct field observations were carried out to explore various adaptation practices. LULC maps were generated by using supervised classification followed by post classification change detection technique for LULCC analysis. Agricultural land and urban areas were found to have increased by 6.6% and 0.32% respectively while forest area, barren land and water bodies were found to have decreased by 1.88%, 4.41% and 0.63%, respectively, between 1990 and 2007. Forest area, urban areas and barren land had increased by 5.54%, 1.32% and 1.48%, respectively, while agricultural land and water bodies were observed to have decreased by 8.2% and 0.13%, respectively, between 2007 and 2020. The mean LST were 22.59°C, 22.81°C and 24.56°C in March-April and 14.65°C, 14.97°C and 15.27°C in January-December, respectively. Urban areas and water bodies exhibit highest and lowest mean values of LST, respectively, during study periods. LULCC due to urban growth and infrastructural developments had contributed to increase in LST. The highest rank to adaptation practices were for changes in cropping patterns and species, followed by agroforestry, use of improved seeds, shift to other income generation activities, use of more fertilizers, irrigation practices and growing vegetables in poly house which were statistically significant. This study provides scientific insights for policy makers and urban planners in improving urban planning and management.

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Introduction

Land use is the arrangements, activities and inputs that human undertake on a certain land cover type and the observed bio-physical cover on the earth's surface is land cover (FAO 2000). Land use and land cover change (LULCC) is a modification of the Earth's surface mainly due to anthropogenic activities (Roy et al. 2015) and leads to environmental degradation (Hamad et al. 2018). Ecosystem, arable land, biodiversity, water bodies, greenhouse effects, forestry, ambient climate and soil are adversely affected by LULCC (Vittekk et al. 2014). Natural resource management and monitoring of environmental dynamics by assessments of LULCC can contribute to sustainable environmental planning and management (Nayana et al. 2016). Land Surface Temperature (LST) is the skin temperature of surface soil-water content and vegetation cover (Rajendran and Mani 2015); this varies from local to global scale (Li et al. 2013). It is determined by energy fluxes between surface and atmosphere (Voogt and Oke 2003) and this can be applied to climate change modelling and greenhouse effects assessment (Doussset and Gourmelon 2003). It can be used for estimating energy consumption and evaluating heat related risks (Mathew et al. 2016). Evapotranspiration, climate change, hydrological cycle, vegetation monitoring, urban climate and environmental studies are key fields where LST have been widely used (Arnfield 2003). It affects natural and anthropogenic phenomenon (Tran et al. 2017) including agriculture (Smith et al. 2009) and health (Xu et al. 2015). Increase in LST modifies degree of solar radiation's absorption, evaporation rates, desertification, air pollution, albedo, heat storage and wind turbulence (Mallick et al. 2008). Vegetation cover, surface moisture, soil types and topography are the drivers of spatio-temporal LST variation (Osborne and Alvares 2019). LST is one of an important variables which helps in the exchange of earth's surface energy and matter, physical and chemical processes with the atmosphere and is severely affected by LULCC

(Deng et al. 2018). LULCC highly affects LST (Xian and Crane 2005). LST is sensitive to various land surface features and can be used to extract various LULC types' information (Sinha et al. 2015). There is spatial correlation between LST change and LUCCC (Wang et al. 2018) and this can be used for land management and global climate change research. One of the most rapid consequences from the land conversion in an urban area is the development of Urban Heat Island (UHI) which is the variation of LST between the city core area and the peripheral non-urban area (Voogt and Oke 2003). Multi temporal digital satellite imageries help to extract relationship between LST and LULCC which in turn are beneficial for urban land management decision formulation, planning and ecosystem monitoring (Pal and Ziaul 2017).

The analysis of temperature trends for the period 1977 to 1994 reveals a consistent and continuous warming in the period at an annual rate of 0.06°C in Nepal (MOE 2010). The General Circulation Models scenario shows that the mean annual temperature to increase by an average of 1.2°C by 2030, 1.7°C by 2050 and 3°C by 2100 compared to a pre-2000 baseline (MOE 2010). Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages to take advantage of opportunities or to cope with the consequences (IPCC 2001). Adaptation strategies exist across local and global scales, from community level responses through local, national and international government interventions (McGray et al. 2007). Adaptation is important in the climate change issue which helps for assessment of impacts and vulnerabilities and development and evaluation of response options (IPCC 2007) and has become a key aspect of scientific and policy making communities (MOE 2010). The ultimate goal of adaptation is to build long term resilience of communities for sustaining their livelihoods even in extreme shocks and stresses.

There was a drastic change in LULC and various drivers play key role for LULCC in

Phewa watershed (Regmi et al. 2020). Soil erosion, deforestation, unplanned rural road construction and rapid LULCC is mainly degrading Phewa watershed and for sustainable development and management of the watersheds spatial inventories on trends of LULCC are vital (Regmi and Saha 2015). Though LULCC analysis had been done in Phewa watershed for different time periods linking various themes (Bhandari and Darnsawasdi 2014; Paudyal et al. 2017; Regmi and Saha 2015) but the estimation of LST in relation to LULCC is severely lacking in Phewa watershed. So this paper assesses the extent of LULC changes during 1990, 2007 and 2020 using temporal satellite imageries, estimates LST during 1990, 2007 and 2020 in relation to LULCC and explores various adaptation practices adopted in response to LST change in Phewa watershed. Therefore, this paper can help for formulating policies, planning strategies, adaptation plans, information on potential environmental

impacts and effective land management for the sustainability of Phewa watershed.

Materials and Methods

Study Area

Phewa watershed is located in the south-western part of Kaski district of Gandaki Province which lies in the Chitwan Annapurna Landscape area covering both rural and urban area. It extends between 28°11'39" North to 28°17'25" North latitude and 83°47'51" East to 83°59'17" East longitude. It possesses moderate subtropical to the cool temperature type of climate. The lower parts of the watershed have a dominance of Sal (*Shorea robusta*), Katus (*Castanopsis indica*), Chilaune (*Schima wallichii*), Tooni (*Cedrela toona*), Sisoo (*Dalbergia sissoo*), Pipal (*Ficus religiosa*), Simal (*Bombax ceiba*) and Bans (*Dendroclamus strictus*) etc. and in upper parts, Laligurans (*Rhododendron arboreum*),

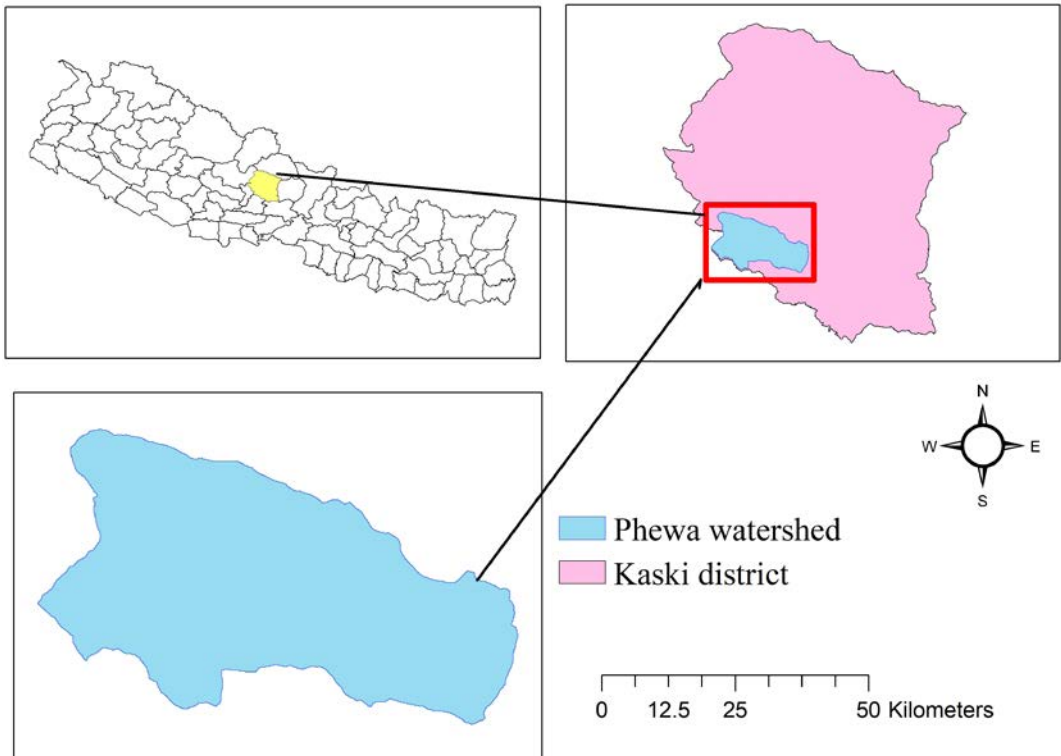


Figure 1: Map of the study area

Salla (*Pinus species*), Bamboo (*Dendrocalamus species*) etc. are the common species (Regmi and Saha 2015). Forest, Agriculture, Bush/Scrub, Waste Land and Built-up Land are the main LULC classes in Phewa watershed. The variation of altitude is from 789-2508.81 m above msl (Regmi and Saha 2015) in the west at Panchase which is biologically rich geographical area and the highest summit of the watershed area.

Data collection

The primary data related to the various adaptation practices adopted in response to LST change were collected through direct field observation, purposive household survey (N=150), key informant interviews (N=4) and focus group discussions (N=4) while the secondary data viz Landsat TM for 1990, Landsat TM for 2007 and Landsat OLI_TIRS for 2020 imageries were freely downloaded from USGS website (earthexplorer.usgs.gov). Aster DEM from USGS website (earthexplorer.usgs.gov) was used for boundary demarcation of the watershed. Temperature data from

1990 to 2020 was collected from nearby meteorological station to estimate the trend and variability of temperature in study area.

Methods

LULC Analysis

Radiometric, Atmospheric and Sun angle corrections of respective Landsat imageries were carried out. LULC maps for change detection analysis were generated using supervised classification with maximum likelihood classifier (Lillesand et al. 2004). Digital supervised classification of Landsat TM for 1990, 2007 and OLI_TIRS for 2020 imageries was analyzed for assessment of LULCC. The LULC classes used for the classification were forest, agricultural land, barren land, water bodies and urban areas (Table 2).

Land Surface Temperature Retrieval for the study time periods (Haylemariyam 2018)

(a) Conversion of pixel values to radiance from metadata of imageries:

For Landsat TM 1990 and 2007 for band 6

Table 1: Data specification of satellite imageries used in LULC classification

Satellite	Sensor ID	Path/row	Total bands	Temporal resolution	Spatial resolution (m)	PAN Band	Date of acquisition
Landsat 5	TM	142/40	1-7	16 days	30.30	Nil	1990-04-16
Landsat 5	TM	142/40	1-7	16 days	30.30	Nil	2007-03-30
Landsat 8	OLI_TIRS	142/40	1-11	16 days	30.30	15:10-8	2020-04-02
Landsat 5	TM	142/40	1-7	16 days	30.30	Nil	1990-01-26
Landsat 5	TM	142/40	1-7	16 days	30.30	Nil	2007-01-25
Landsat 8	OLI_TIRS	142/40	1-11	16 days	30.30	15m,B-8	2020-12-14

Table 2: LULC classes used for classification

S. N.	LULC types	Description
1.	Forest	Shrubs land, trees, grassland bushes.
2.	Agricultural land	Cultivation in sloping mountainous areas in terraced fields In the downstream of study area, mainly variety of paddy is growing and irrigation is good.
3.	Barren land	Sandy areas, Areas exposed after landslides, flash floods and soil erosion. Quality of soil is poor.
4.	Urban areas	Urban and rural human settlement areas.
5.	Water bodies	Lake and rivers with clear water

(spatial resolution 120 m).

$$L\lambda = \left(\frac{L_{\max\lambda} - L_{\min\lambda}}{Q_{\text{calmax}} - Q_{\text{calmin}}} \right) * (Q_{\text{cal}} - Q_{\text{calmin}}) + L_{\min\lambda}$$

Where,

$L\lambda$ = Spectral Radiance at the sensor's aperture in watts/ (meter squared \times ster \times μm)

$L_{\max\lambda}$ = the spectral radiance that is scaled to Q_{CALMAX} in watts/ (meter squared \times ster \times μm) (15.303)

$L_{\min\lambda}$ = the spectral radiance that is scaled to Q_{CALMIN} in watts/ (meter squared \times ster \times μm) (1.238)

Q_{calmax} = the maximum quantized calibrated pixel value (corresponding to $L_{\max\lambda}$) in DN (255)

Q_{calmin} = the minimum quantized calibrated pixel value (corresponding to $L_{\min\lambda}$) in DN (1)

Q_{cal} = the quantized calibrated pixel value in DN

For Landsat OLI_TIRS 2020 for band 10

Band 11 is not recommended for LST retrieval because of larger calibration uncertainty (USGS 2014). The LST estimated from Band 10 (spatial resolution 100 m) (with weaker absorption) has higher accuracy than Band 11 (Yu et al. 2014).

$L\lambda = ML * Q_{\text{cal}} + AL$

$L\lambda$ = TOA spectral radiance (Watts/ ($\text{m}^2 \times \text{srad} \times \mu\text{m}$)),

ML = Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number) (0.0003342)

AL = Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x, where x is the band number) (0.1)

Q_{cal} = Quantized and calibrated standard product pixel values (DN).

(b) Conversion of radiance to At-Satellite temperature from metadata of imageries:

$$T = \frac{K2}{\ln\left(\frac{K1}{L\lambda} + 1\right)} - 273.15$$

T = Top of atmosphere brightness temperature in degree ($^{\circ}\text{C}$)

$K2$ = Band specific thermal conversion constant from metadata from metadata ($K2_CONSTANT_BAND_x$, where x is the thermal

band number) (1260.56 for TM sensor and 1321.08 for OLI_TIRS sensor)

$K1$ = Band specific thermal conversion constant from metadata from metadata ($K1_CONSTANT_BAND_x$, where x is the thermal band number) (607.76 for TM sensor and 774.885 for OLI_TIRS sensor)

$L\lambda$ = Spectral radiance in watts/ (meter squared \times ster \times μm).

(c) Normalized difference vegetation index calculation:

For Landsat 5 TM, $\text{NDVI} = (\text{Band4} - \text{Band3}) / (\text{Band4} + \text{Band3})$

Band 4 is Near infrared and Band 3 is Red

For Landsat 8 OLI/TIRS, $\text{NDVI} = (\text{Band 5} - \text{Band 4}) / (\text{Band 5} + \text{Band 4})$

Band 5 is Near infrared and Band 4 is Red

(d) Retrieving of land surface emissivity

$$e = 0.004PV + 0.986$$

Where,

e = Land surface emissivity

PV = Proportion of vegetation

$$PV = ((NDVI - NDVI_{\min}) / (NDVI_{\max} - NDVI_{\min}))^2$$

$NDVI_{\min}$ = minimum value of NDVI

$NDVI_{\max}$ = maximum value of NDVI

(e) Land surface temperature (LST)

$$LST = BT / \left(1 + \frac{\lambda BT}{p} \right) * \ln(e)$$

BT = at satellite temperature

λ = wavelength of emitted radiance for band 6 for Landsat TM 5 (11.45 μm) and band 10 for Landsat OLI_TIRS (10.8 μm)

$p = hc/s$

h = Planck's constant ($6.626 * 10^{-34}$ JS)

s = Boltzmann constant ($1.38 * 10^{-23}$ J/K)

c = Velocity of light ($2.998 * 10^8$ m/s)

$p = 14380$ mK

e = Land surface emissivity

Data Processing and Analysis

LULC classification and LULCC analysis for study periods were performed. Finally,

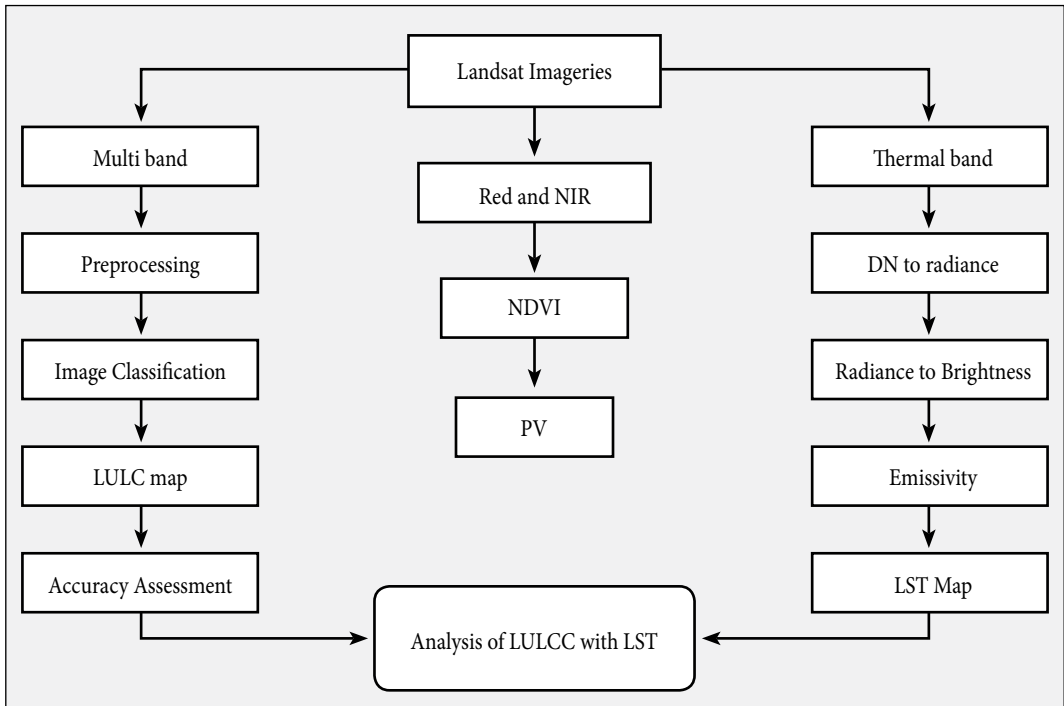


Figure 2: General work flow of methodology

Change/No Change Matrix was computed. LST maps of band 6 for 1990 and 2007 and LST map of band 10 for 2020 were generated with the help of metadata from respective Landsat imageries. Create random points tool was used to lay out random points in the study area. Mean temperature was found for study periods of each LULC classes and LULCC classes in the study area by using create random points maps, LST maps, LULC maps and respective change/no change map. All these analyses were performed in ArcMap 10.3.

Data of temperature from 1990 to 2020 was obtained from Office of Hydrology and Meteorology, Pokhara. The trends of temporal variation of temperature were analyzed using linear regression. The linear trend between time series and temperature data are as given in equation below.

$$y = a + bx \text{ (Fig. 6)}$$

Where, y = temperature, x = time (year), “ a ” and “ b ” are constants

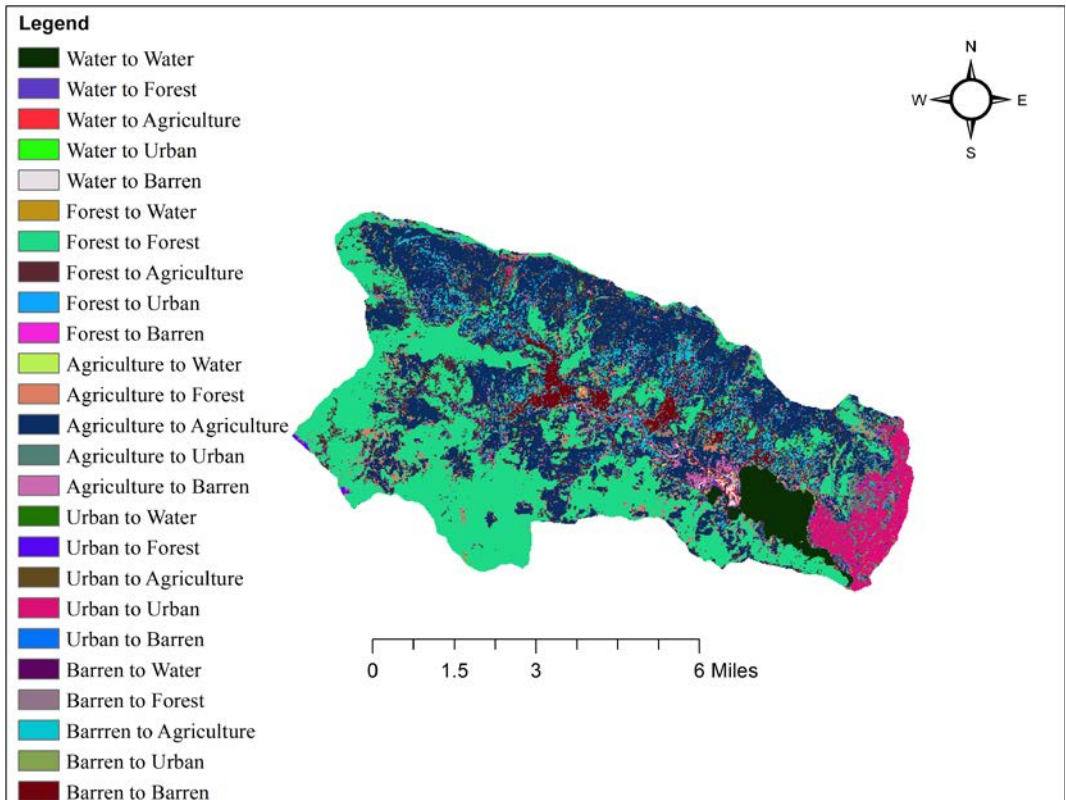
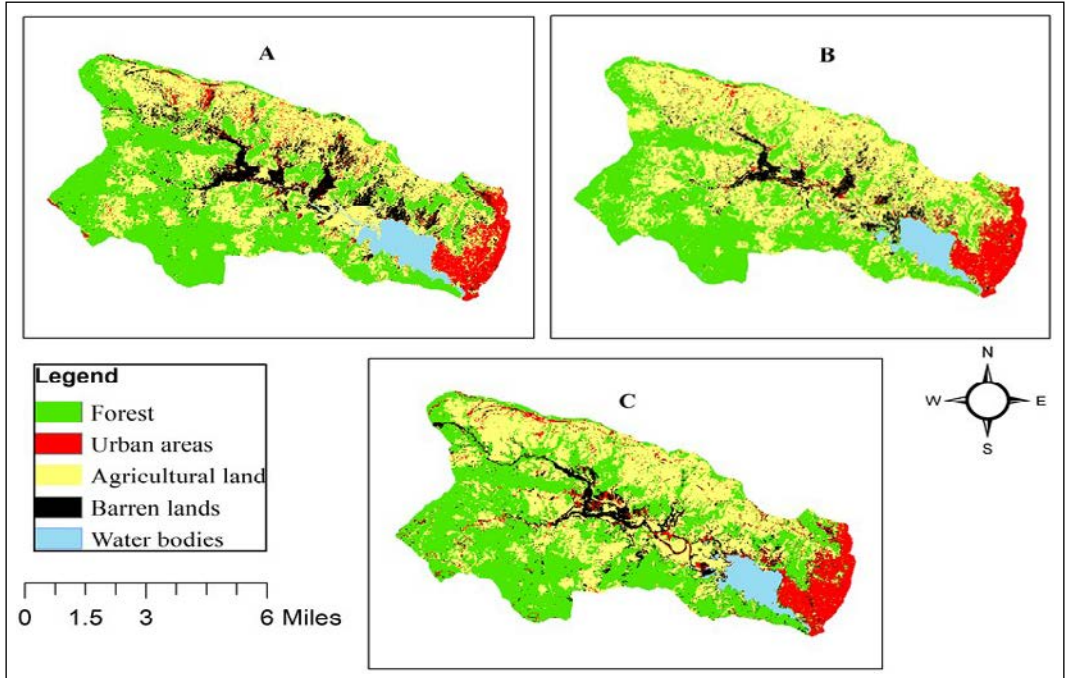
Prioritized responses of respondents on various

adaptation practices adopted in response to LST change in the watershed were analyzed through mean rank and non-parametric Friedman’s rank test in SPSS 23 which was used in (Bhatta et al. 2018) to analyze people’s perception based on rank.

Results

LULC Dynamics of 1990, 2007 and 2020

The LULC maps for study periods is shown in Fig. 3 (A), (B) and (C). There were drastic changes in LULC during these periods in the watershed. In 1990, forest covered 4853.97 ha (40.49%) followed by agricultural land which covered 4579.83 ha (38.20%). Barren land, urban areas and water bodies covered 1236.60 ha (10.31%), 805.77 ha (6.72%) and 513.36 ha (4.28%), respectively. In 2007, agricultural land covered an area of 5371.29 ha (44.80%) followed by forest which covered 4628.97 ha (38.61%). Urban areas, barren land and water bodies covered 843.48 ha (7.04%), 707.76 ha (5.90%) and 438.03 ha (3.65%), respectively. In 2020,



forest covered 5292.99 ha (44.15%) followed by agricultural land which covered 4387.59 ha (36.60%). Urban areas, barren land and water bodies covered 1002.06 ha (8.36%), 884.52 ha (7.38%) and 422.37 ha (3.52%), respectively.

Accuracy Assessment

Altogether 160 ground truth positions were collected with the help of Google Earth image

for 1990 and 2007. Additional GPS points combined with Google Earth image were utilized to collect ground truth positions of classified LULC map for 2020. Confusion matrix was used for accuracy assessment. The overall accuracy of the classified maps was 85.63%, 88.75% and 90.63%, respectively. The Kappa coefficients were 0.81, 0.84 and 0.87, respectively.

Table 3: Change/no change matrix during 1990 and 2007

Years 1990/2007	Forest	Urban areas	Barren land	Water bodies	Agricultural land	Total area in 1990%
Forest	33.60*	0.12	0.12	0.04	6.59	40.49
Urban areas	0.28	4.5*	0.26	0.002	1.68	6.72
Barren land	0.59	0.72	3.30*	0.01	5.71	10.31
Water bodies	0.25	0.05	0.2	3.52*	0.26	4.28
Agricultural aland	3.89	1.64	2.01	0.09	30.56*	38.2
Total area in 2007%	38.61	7.04	5.9	3.65	44.8	100

NOTE: ‘*’ represents the no change in area of specific LULC used.

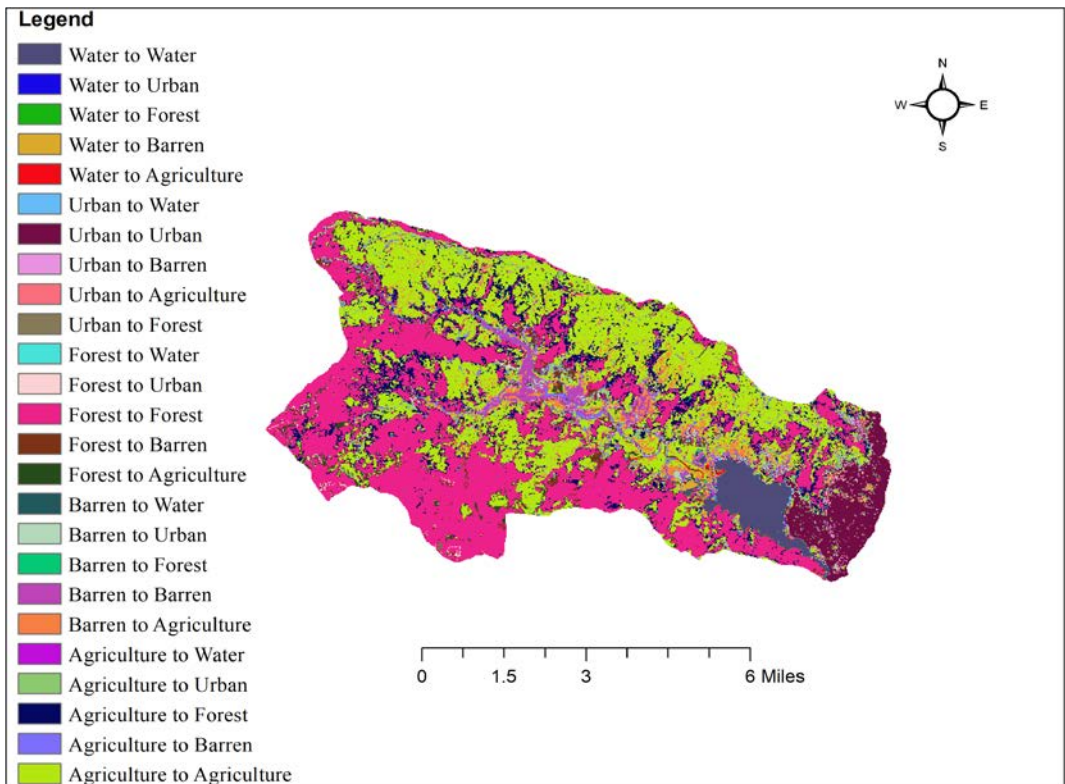


Figure 5: Change/No change map during 2007 to 2020

As shown in change/no change map for 1990-2007 is shown in (Fig. 4) land use was changed from forest to agricultural land by 6.59%, barren land to agricultural land by 5.71%, agricultural land to forest by 3.89%, urban areas to agricultural land by 1.68% and water bodies to agricultural land by 0.26% (Table 3).

The change/no change map for 2007-2020 (Fig. 5) shows that the land use was changed from agricultural land to forest by 9.77%, forest area to agricultural land by 2.52%, barren land to agricultural land by 3.27%, urban areas to agricultural land by 0.93% and water bodies to barren land by 0.15% (Table 4).

Temperature variability from meteorological station

The meteorological data showed variability in the temperature trend (Fig. 6) and is in increasing trend for both maximum and minimum temperature in average annually.

Analysis of LST

The LST map extracted from the thermal infrared band of Landsat data for March and April in 1990, 2007 and 2020 is shown in Fig. 7. The details of LST information are shown in Table 5.

Table 4: Change/no change matrix during 2007 and 2020

Years 2007/2020	Forest	Urban areas	Barren land	Water bodies	Agricultural land	Total area in 2007%
Forest	33.68*	0.61	1.8	0.1	5.59	38.61
Urban areas	0.37	5.20*	0.52	0.02	0.93	7.04
Barren land	0.24	0.42	1.93*	0.04	3.27	5.9
Water bodies	0.08	0.02	0.15	3.30*	0.1	3.65
Agricultural land	9.77	2.11	2.97	0.07	29.88*	44.8
Total area in 2020%	44.15	8.36	7.38	3.52	36.6	100

NOTE: ‘*’ represents the no change in area of specific LULC used.

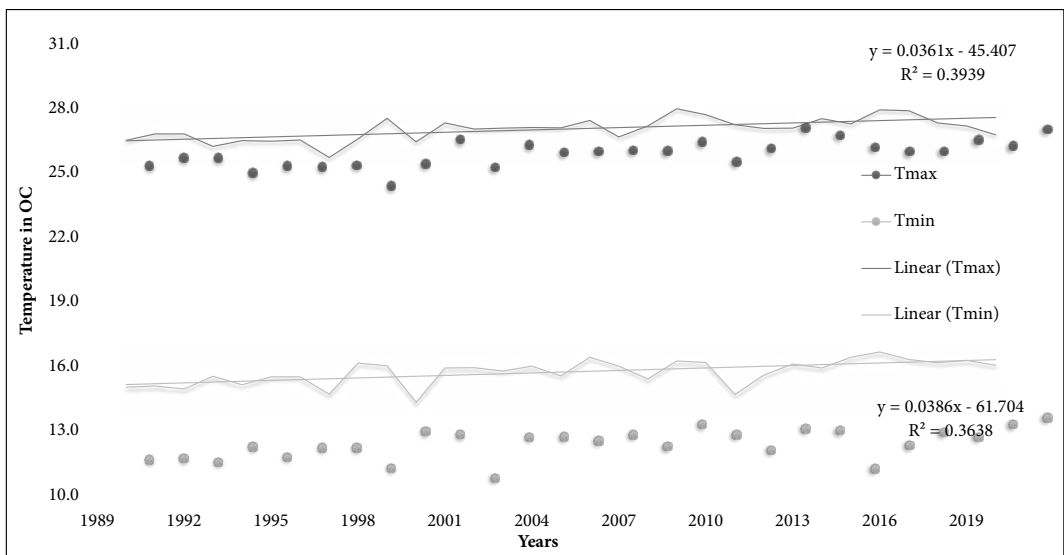


Figure 6: Average annual maximum and minimum temperature trend

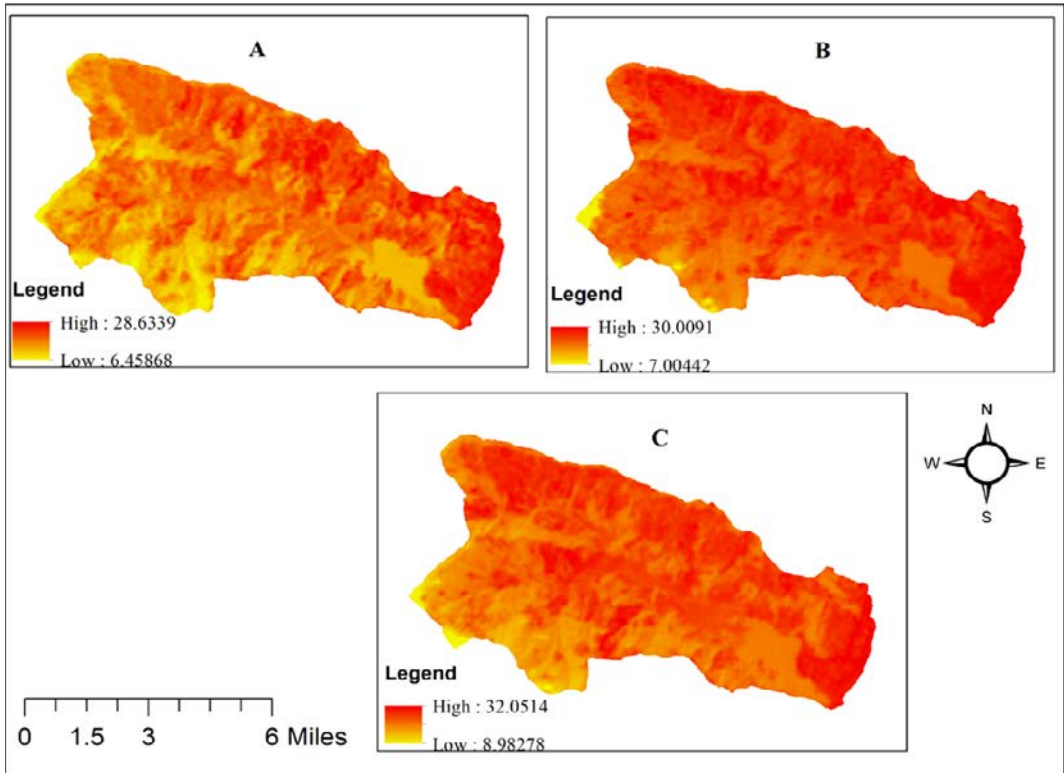


Figure 7: LST map for (A) 1990, (B) 2007 and (C) 2020

The LST map extracted from the thermal infrared band of Landsat data for January and December in 1990, 2007 and 2020 is shown in Fig. 8. The details of LST information are shown in Table 5.

As shown in Table 5, the mean LST values fluctuate between 1990, 2007 and 2020 for March-April and January-December. The mean LST increased by 0.22°C from 1990 to 2007 and by 1.75°C from 2007 and 2020 in March-April. During 30 years from 1990 to 2020 mean LST was increased by 1.97°C.

The mean LST increased by 0.35°C from 1990 to 2007 and by 0.30°C from 2007 and 2020 in January-December. During 30 years from 1990 to 2020 mean LST was increased by 0.62°C. There was overall increasing trend of mean LST for March-April and January-December for study periods in Phewa watershed.

From the analysis of this study, the relationship between LULC and LST we observed that the mean LST of urban areas was highest and water bodies was lowest than other LULC classes over the study periods for March-April and January-December. The details of mean LST in LULC classes for March-April and January-December is shown in (Table 6).

LST change in different detected LULCC categories

The analysis of change/no change map and respective LST maps for March-April and January-December was conducted. The results shows that if one LULC class is changed to urban areas there will be more temperature in that newly grown land than if LULC class is changed to forest areas. The details of newly grown land with respective mean LST information for study periods in March-April and January-December is shown below (Table 7).

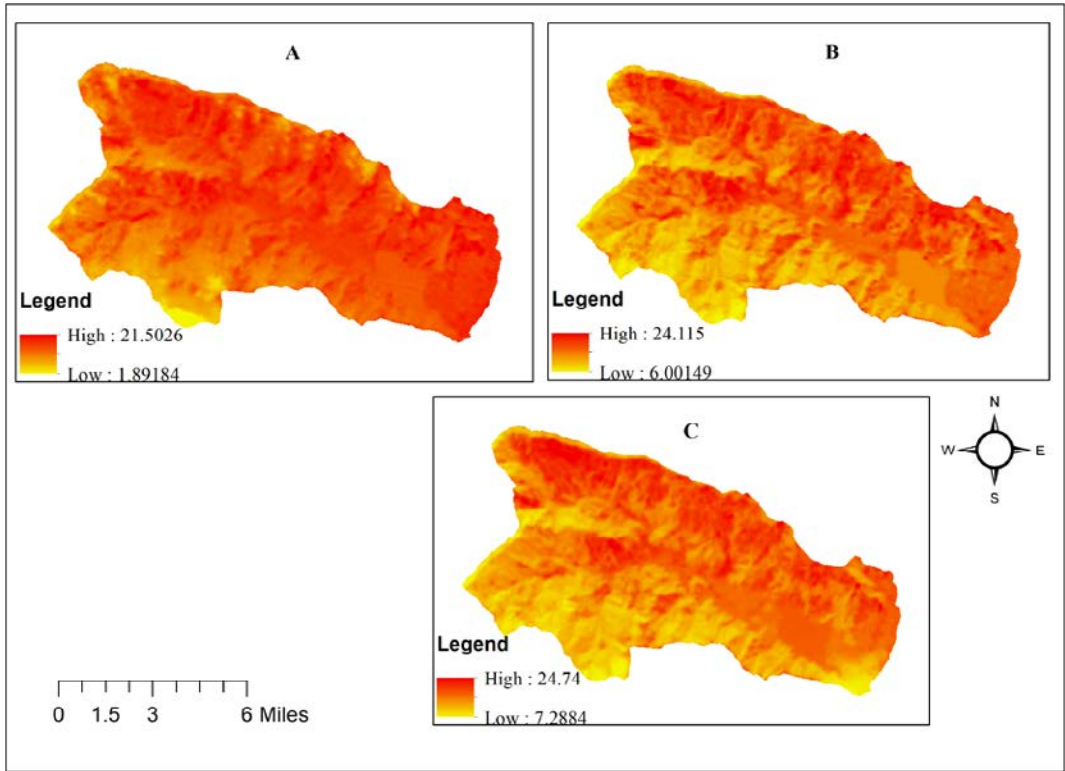


Figure 8: LST map for (A) 1990, (B) 2007 and (C) 2020

Variation of mean LST with reference to altitudinal range for March-April and January-December in Phewa watershed

From Aster DEM, extract by mask was tool was used to extract area of interest. The highest elevation of Phewa watershed was 2418.1 m and lowest elevation was 759.156 m with a mean elevation as 1203.65 m (Fig. 9A).

Three altitudinal zone as Tropical zone (below 1000 m), Subtropical zone (1000-2000 m) and Temperate zone (above 2000 m) (Fig. 9B). The

mean LST was found to be increased in study periods in all altitudinal zone (Table 8).

Socio-economic characteristics of respondents

Among the surveyed 150 households, female represented 53.30% and male 46.70%. Old (above 50) age category represented 66.70% followed by adult (36-49) 21.30% and young (18-35) 12%. Brahmin/Chettri was dominant ethnicity with 76.70%, followed by Janajati 15.30% and Dalit by 8%. In education status of the respondents,

Table 5: Statistics of LST for study periods

Years	Months	Minimum LST °C	Maximum LST °C	Mean LST °C
1990	April	6.45	28.63	22.59
1990	January	1.81	21.5	14.65
2007	March	7.01	30.01	22.81
2007	January	6.01	24.11	14.97
2020	April	8.98	32.05	24.56
2020	December	7.28	24.74	15.27

Table 6: Mean LST of each LULC classes in study periods for March-April and January-December

Years	LULC Classes	Mean LST °C in March-April	Mean LST °C in Jan-Dec
1990	Forest	20.78	15.38
	Agricultural land	23.71	16.62
	Urban areas	25.3	17.85
	Water bodies	20.17	14.7
	Barren land	23.49	16.32
2007	Forest	21.03	15.98
	Agricultural land	24.9	17.95
	Urban areas	25.86	18.02
	Water bodies	20.87	14.91
	Barren land	24.27	16.97
2020	Forest	23.3	16.42
	Agricultural land	25.7	18.07
	Urban areas	28.83	18.74
	Water bodies	21.18	16.38
	Barren land	24.86	17.76

Table 7: Mean LST 0C in various transformed LULC classes in March-April and January-December:

Newly grown land	March-April			January-December		
	1990	2007	2020	1990	2007	2020
Water bodies to Forest	21.52	22.42	22.81	13.61	14.36	15.11
Water bodies to Agricultural land	22.29	23.68	24.11	15.17	15.79	16.09
Forest to Agricultural land	23.52	23.70	23.93	14.24	15.11	15.54
Forest to Barren land	21.25	22.18	23.15	12.36	14.39	14.41
Agricultural land to Forest	22.21	23.24	24.82	14.22	15.21	15.87
Agricultural land to Urban areas	24.22	25.68	26.11	16.38	17.10	18.24
Agricultural land to Barren land	23.92	24.43	25.74	16.13	16.58	17.01
Urban areas to Forest	22.87	24.54	25.07	15.36	16.92	18.36
Urban areas to Agricultural land	24.68	24.79	25.67	15.67	16.86	17.67
Urban areas to Barren land	22.87	24.97	25.76	15.28	16.10	17.07
Barren land to Forest	22.08	22.90	23.24	14.08	15.01	15.60
Barren land to Agricultural land	23.93	24.30	26.07	16.31	17.34	17.70
Barren land to Urban areas	23.95	24.49	26.09	16.15	17.06	17.41

illiterate was dominant by 66.70%. Within the literate category of 33.30%, secondary education (9-12) represented 16.70% followed by primary education (1-8) 11.30% and Bachelor level by 5.30%. Agricultural occupation was dominant among the respondents which represented 71.30%, followed by business 11.30%, wage

labor 6.70%, abroad 4.70%, study 3.30% and government/private service by 2.70%.

The Table 9 deals with various adaptation practices in response to LST change in Phewa watershed felt by the respondents. The highest rank to adaptation practices was for change

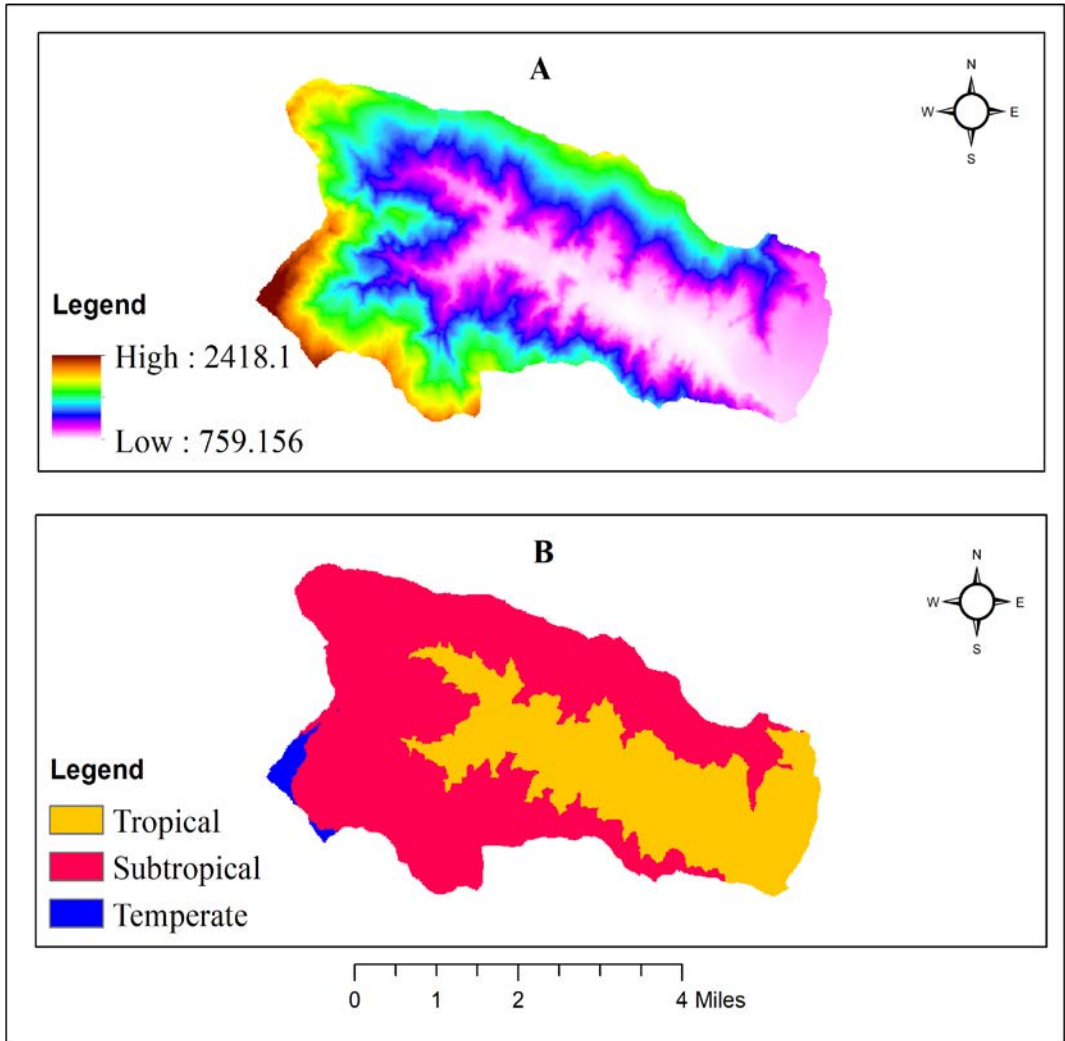


Figure 9: DEM of Phewa watershed (A) and (B) Different altitudinal zone

Table 8: Mean LST in different altitudinal range for March-April and January-December

Years	Months	Means LST °C in tropical zone	Means LST °C in sub-tropical zone	Means LST °C in temperature zone
1990	April	24.02°C	22.08°C	13.19°C
1990	January	15.39°C	13.89°C	9.6°C
2007	March	24.51°C	23.35°C	14.13°C
2007	January	15.75°C	14.74°C	10.45°C
2020	April	25.64°C	24.43°C	18.17°C
2020	December	17.46°C	16.71°C	12.3°C

Table 9: Friedman test on rank to various adaptation practices in response to LST change

Number of respondents n=150 with df=6		
Adaptation practices	Mean Rank	Friedman Chi square value (p value)
Change in cropping patterns and species	3.61 (1)	
Improved/Hybrid seeds	3.72 (3)	
Agroforestry	3.62 (2)	
Shift to other Income Generation activities	3.96 (4)	27.646(0.000)*
Use of more fertilizers/Pesticides	4.19 (5)	
Irrigation Practices	4.30 (6)	
Growing vegetables in poly house	4.60 (7)	

*Extremely significant (p<0.01)

in cropping patterns and species followed by agroforestry, use of improved seeds, shift to other income generation activities, use of more fertilizers, irrigation practices and growing vegetables in poly house. Non parametric Friedman rank test showed that different respondents ranked the adaptation practices in response to LST change differently which is statistically extremely significant ($\chi^2=27.646$, $p<0.01$) in Phewa watershed.

Discussion

LULC dynamics in Phewa watershed

Regmi and Saha (2015) have found that dense forests have decreased during the study periods 2000, 2005 and 2010 and the prediction of 2015 and 2020. They have also observed that medium to fairly dense forests and open forests have increased during these study periods and predicted periods. The increase in forest area has been aided by the proper management of the forest through introduction of community forest programs, Forest Act and Forest Regulation in the middle mountains (Niraula et al. 2013), reduction in the dependency of the fuelwood (Pandey et al. 2016), decreasing dependency on forest for manure and grass and use of alternative sources of energy such as Liquid Petroleum Gas, solar energy and electricity (Balla et al. 2014). Expansion of private forests in the

abandoned cultivated land (KC et al. 2017) has increased forest area. Population growth and expansion of municipal boundaries are the primary factors for the rapid increase of built-up areas (Rai et al. 2020). Rapid urbanization occurs due to drivers like economic opportunities, population growth, migration, public service accessibility, globalization, tourism, plans and policies, land market and political factors (Rimal et al. 2015). Adhikari et al. (2016) revealed that there is a decrease in cultivated land with the increase of settlement due to increase of urban expansion and development. There is increasing migration trend of youth to towns and cities due to lack of employment opportunities and political stability which ultimately led abandonment of cultivated land in mid hill of Nepal (KC et al. 2017). Increased costs of production (Jaquet et al. 2016) have created a favorable environment for the natural appearance of vegetation in abandoned agricultural land. There is decreasing trend in agricultural land in Phewa watershed (MOFE 2018; Regmi and Saha 2015). Multiple hazards such as avalanches, debris flow, soil erosion and sinkholes due to unpredicted precipitation finally contribute to increase in barren area (Jaquet et al. 2015). Increasing abandonment of agricultural land has raised vulnerability towards various geomorphic changes leading towards the formation of barren land (Khanal and Watanabe 2006). Haphazard

rural road constructions and developmental activities accelerate soil erosion which facilitates the transport of sand and gravel into the lake (MOFE 2018; Regmi and Saha 2015). Heyojoo and Takhachhe (2014) have explained that sediment deposition in the lake is induced by human activities like haphazard road construction and unsuitable land use practices in both upstream and downstream areas in the watershed.

LST analysis of each class in Phewa watershed

The urban temperatures have 2-5°C higher than those in rural surroundings (Ackerman 1985). Urban areas exhibit high mean LST than other LULC classes (Nzoiwu et al. 2017). Urban areas add more roads, buildings, industries and population so temperatures in downstream areas become much higher than temperatures in rural surroundings resulting Urban Heat Island (UHI) phenomenon (Voogt 2004). Increase in impermeable hard and dark surfaces such as stone, metal, asphalt and concrete building materials increase LST by low reflection and high absorption of solar radiation (Buyadi et al. 2013) and do not allow moisture seepage into the soil (Deng et al. 2018). Urban areas suggests greater construction of building areas which hinders heat dissipation by wind resulting in high LST (Mushore et al. 2017). Green spaces can reduce UHI intensity (Guha et al. 2018). Vegetation cools temperature mainly through shading and evapotranspiration processes which absorbs heat energy and releases water vapor and thus reducing the temperature (Zhang et al. 2014). Water bodies can reduce UHI intensity (Guha et al. 2018). The temperature of water bodies is usually lower than other kinds of land uses (Zhang and Huang 2015). Water bodies contribute to mitigate high temperature and enhancement of the cooling effects (Rasul et al. 2017) and helps to control LST (Chen and Zhang 2017). Agricultural land consists of sparse vegetation and exposed bare soil which is less effective in

mitigating urban warming effect than forest (Estoque et al. 2017). Mushore et al. (2017) found that cultivated land act as a heat source as they absorb and release large amounts of heat due to negligible evaporation. Du et al. (2009) found that higher temperature is found on barren land because it comprised of areas where ongoing development was taking place and they had no vegetation cover. Open barren land has low evapotranspiration as compared to vegetated land (Sinha et al. 2015).

Adaptation practices in response to LST change

Soil and water management, adjustments to the timing of farm operations and crop and varietal adjustment by farming households are the major adaptation strategies at local level (Dahal et al. 2018). Karki et al. (2020) revealed that adaptation strategies include crop and varietal adjustments, fertilizer management, farm operations time management, adoption of technologies, diversification of income sources and agriculture practices, soil and water management, migration, access to financial resources and risk reduction measures. Efficient water technology, use of farmland in cash crops, vegetables and fruit production, growing vegetables in poly houses, livelihood diversification, changing cropping patterns and species, compost making and farm yard manure improvement are major adaptation practices in response to climate change (Adhikari et al. 2018).

Conclusion

LST in relation to LULC dynamics and associated adaptation practices in response to LST change in Phewa watershed of western Nepal was analyzed based on geospatial tools and social survey techniques. Use of temporal satellite data are very useful, time saving and cost effective for the preparation of LULC maps, change analysis and LST assessment. There was a drastic change in LULC in Phewa watershed during the study periods. Agricultural land and urban areas were found to have increased

by 6.6% and 0.32% respectively while forest area, barren land and water bodies were found to have decreased by 1.88%, 4.41% and 0.63%, respectively between 1990 and 2007. Forest area, urban areas and barren land had increased by 5.54%, 1.32% and 1.48%, respectively while agricultural land and water bodies were observed to have decreased by 8.2% and 0.13%, respectively, between 2007 and 2020. The analysis of change process using Landsat imageries showed compromise among various LULC classes. The mean LST was in increasing trend during study periods for March-April and January-December. The highest and lowest mean LST was found for urban areas and water bodies during study periods for March-April and January-December. LULCC due to rapid urbanization was considered the major contributor to urban climatic warming which created the major spatiotemporal variation in LST particularly due to urban growth, construction of new built up and pollution expansion that could be attributed to settlement expansion resulting in a large amount of waste heat in turn affecting the surface energy budget. There is overall increasing trend of mean LST in tropical zone, sub-tropical and temperate zone during study periods for March-April and January-December. The highest rank

to adaptation practices was for change in cropping patterns and species followed by agroforestry, use of improved seeds, shift to other income generation activities, use of more fertilizers, irrigation practices and growing vegetables in poly house which was statistically significant. The above findings recommend the establishment of measures that can mitigate strong effect of increasing LST and may help in promulgating sustainable urban land use policies for avoiding the effect of urban heat island. So, this study provides scientific insights for policy makers and urban planners in improving urban planning and management.

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