The Third Pole: Journal of Geography
Vol. 22: 49-60, 2022
DOI: https://doi.org/10.3126/ttp.v22i01.52560

LAND USE AND LAND COVER CHANGE ANALYSIS USING GOOGLE EARTH ENGINE IN MANAMATI WATERSHED OF KATHMANDU DISTRICT, NEPAL

Lalmani Gautam[1], Raju Rai[2]

Abstract

*Understanding the changes in land use and land cover (LULC) is essential in managing and monitoring the resources and planning. This study has analyzed the LULC changes in the years between 1992 and 2017 in Manamati watershed, Kathmandu district. Google Earth Engine Java Script API has been used to prepare LULC database. The supervised classification of a maximum likelihood algorithm is also used to prepare LULC database. The result shows that more than 6% land of the cultivated area has been converted into built-up area from 1992 to 2017, and 2.43 km² area has increased in built-up area. The forest-covered area seems to be constant, and it is not a significant change over the last 25 years. However, proper watershed management practice and land use planning require to control the threats to watershed resources. The results of this study could be a reference to the future planning of watershed resour*ce management.

Keywords: Land use, land cover, google earth engine, likelihood algorithm, watershed management

Introduction

The land cover represents the natural coverage of the earth's surface and land use is the management and modification of it, such as settlement, agriculture, arable fields, pastures and managed woods. Change in land cover includes change in biotic diversity, actual and potential primary production, soil quality, and runoff and sedimentation amounts (Steffen et al, 1992). According to Turner and Skole (1995) 'land cover is the

1 *Gautam is a researcher in Institute of Himalayan Research and Integrated Development, Kathmandu, Institute of Fundamental Research and Studies, Kathmandu*

2 *Rai is a researcher in Institute of Fundamental Research and Studies, Kathmandu, *Correspondence: raju_inner@yahoo.com*

biophysical state of earth surface and instant subsurface'. Land use involves both how the biophysical attributes of land are manipulated and the determined underlying that manipulation- the purpose for which the land is used (Turner et al., 1995). Land use is the intended employment of and management strategy placed on land cover type by the human agent or land managers; the shift in intent and management constitutes land use change (Baulies & Szejwach, 1998).

Since historical times, land use and land cover (LULC) have been changing due to anthropogenic and natural activities (Turner et al., 1994). LULC change due to anthropogenic activities such as urbanization and deforestation is known as a primary cause of changes in the landscape. The total global forest cover (woodland) decreased by 12 million km^2 (19%), grassland and pastures declined by 5.6 million km^2 (8%), whereas the cropland increased by 12 million km^2 (46%) over the last three centuries due to human activities (Richards et al., 1990; Lamichhane, 2008). However, the changes in LULC are found in different pathways with different magnitudes and paces (Khanal and Watanabe, 2006; Paudel et al., 2016). The changes in LULC are dynamic and occur differently when observed at different scales and times (McConnell, 1997; Gautam et al., 2002).

LULC change has several consequences on climate, ecosystems, environment, food security, and human health, and thus a significant impact on local as well as global change (Skole, 1996). It has tremendous implications for sustainable economic and environmental development (Turner, et al., 1995). Such impacts are not only confined to the areas where the change occurs in the mountain but are also easily transmitted and intensified the impacts in lowland areas because of the high gradient of the mountain slopes (Becker & Bugmann, 2001).

The consequence of LULC change is disastrous in the mountain areas like Nepal, where the livelihood of a majority of people is based on national resources. Crop- livestock-forest sectors are traditionally well integrated with the livelihood of Nepal. Small changes in one sector result in a negative impact on the other two sectors. It has been experienced that the balance among these sectors is being lost due to changes in land use and land cover, reducing the productivity of the entire sector's dynamic (Meyar & Turnar II, 1994). Moreover, the vulnerability to normal hazards such as soil erosion, landslide, and floods has also been increasing due to changes in LULC in the country (Sharma et al., 2014). The urban areas of the country are also found at high risk of disasters due to rapid changes in LULC. Rapid urbanization, population growth and migration are found major causes of land cover changes in the Gandaki River Basin (Rai et al., 2020). All these literatures are based on GIS or remote sensing image processing, which is long and manual processing to prepare the LULC database. Instead of manual software-based classification, coding-based image classification through Google Earth Engine (GEE) is a comparatively faster and more effective way to prepare LULC data. In Kathmandu Valley, there are several small watersheds, which are associated with thousands of people, livelihoods, property and disaster management. Still, the study on changes in LULC in the small watershed of the Kathmandu Valley is not carried out. To understand the patterns of LULC change, this study has chosen the Manamati watershed of the Kathamndu district.

Methods and materials

Study area

This study has been carried out in the Manamati watershed, which is located in the western part of the Kathmandu district. The geographical location of the watershed is between N 27º 42' 23" to 27º 44' 10" longitudes and E 85º 16' 4" to 85º 14' 4" latitude (Figure 1). Manamati stream starts from Ramkotdanda (Hill) of Kathmandu district and ends at Bishnumati River, and Teku of Kathmandu. After meeting at the Bishnumati River, it immediately meets Bagmati River in Teku. It has a length of about 4.36 kilometers. This watershed covers 10.91 km² of the Kathmandu district.

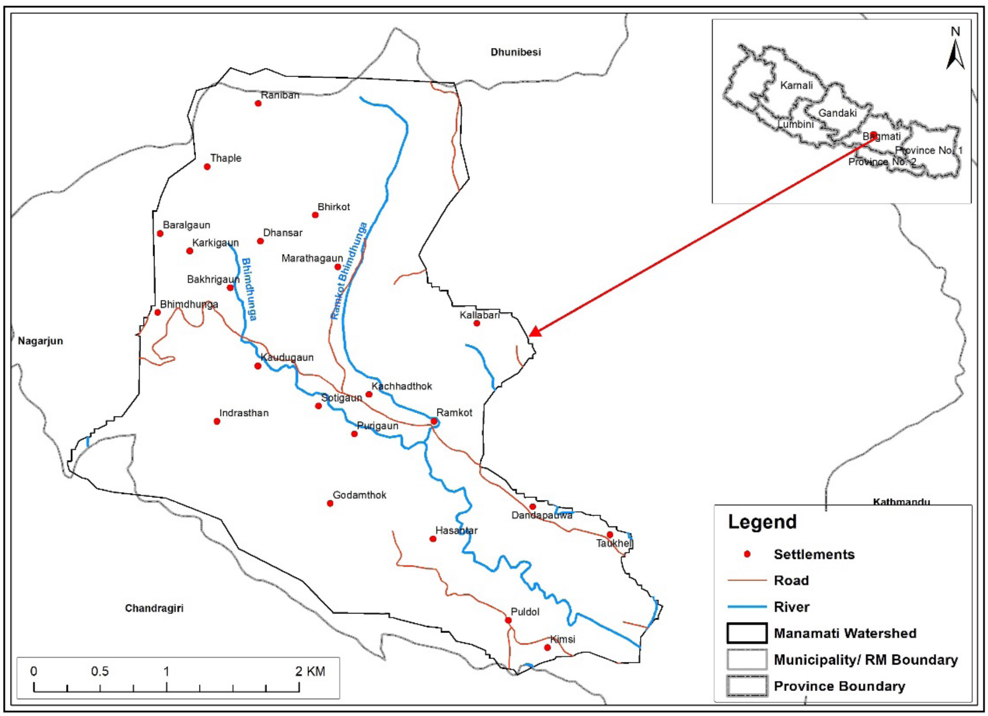

Figure 1: Location of the study area

Data source and image classification

The LULC database has been developed over the recent past 25 years (1992, 2004, and 2017) at 30 m spatial resolution. This study used various images of Landsat- 5-TM, 7-ETM+ and 8-OLI and supervised classification methods in Google Earth Engine (GEE) and then imported them into Arc. GIS were used for analysis and mapping. GEE is an online environmental data-monitoring platform that incorporates data from the National Aeronautics and Space Administration (NASA) as well as the Landsat Program. After the USGS opened access to its records of Landsat imagery in 2008, Google saw an opportunity to use its cloud computing resources to allow records of Landsat imagery to process over its online system. This has enabled users to reduce processing times in analysis of Landsat imagery and make global-scale Landsat projects more feasible (Hansen, et al., 2013). Now, Google Earth Engine is a platform to detect changes, map trends, and quantify changes on the earth's surface by undertaking earth observation (Kumar and Mutanga, 2018). The spatiotemporal scales used for the analysis of agricultural land extent in South Asia (Gumma et al., 2020), land cover change in Singapore (Sidhu et al., 2018), land-use change in the Savannah River Basin (Zurqani et al., 2018), Land Use and Land Cover Dynamics in Central Himalaya Transboundary Landscape (Gu et al., 2021), temporal analysis of NDVI in Chitwan National Park of Nepal (Prasai, 2022), and land cover change in Kaski district of Nepal (Wagle et al., 2020).

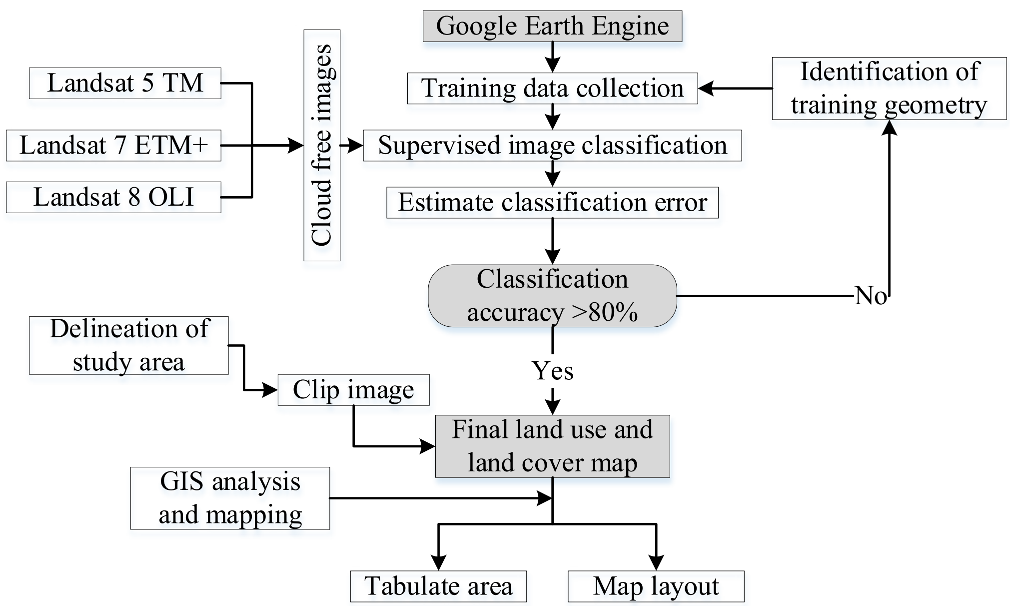

Figure 2: Overall workflow of the study

The methodology for this study is outlined in the workflow diagram in Figure 2. Google Earth Engine JavaScript API can be used to programmatically access and analyze vast amounts of geospatial data. This study also classified into five major LULC classes based on the national level land cover classification: forest, cultivation land, built-up, shrub, water bodies, and others.

Image Processing

This study has proceeded from the preprocessing of satellite images in the first. It is especially used for critical detection of change assumes that the spectral properties of non-changed areas are stable, and inadequate pre-processing can increase error by causing a false change in spectral space (Lu & Weng, 2007).

This study also carried out radiometric corrections, cloud, and shadow masking in the preprocessing steps. The data preparation step includes the creation of image composites in the Second. It is relevant to particular geographic regions, such as persistence of cloud cover, topography, the dynamism of landscape processes, phenology, and Landsat data. They are important considerations for applying a compositing approach. Pixel□based image compositing of Landsat data has emerged from a unique confluence of scientific and operational developments, predicated by free and open access to the Landsat archive and supported by computing and data storage capacity to fully automate radiometric and geometric pre-processing and create increasingly robust standardized image products (White, et al., 2014; Cohen, Yang, & Kennedy, 2010). After preprocessing, the training samples or Region of interest (ROI) were given for each LULC by visually observed satellite image. In total, 40 to 60 samples were given as ROI for each land cover type.

Accuracy Assessment

Accuracy assessment has been done to evaluate classification performance and usefulness of image classification. Accuracy assessment in terms of class-specific producers and user's accuracy, overall accuracy, and Kappa coefficient has subsequently computed after generating confusion matrix. The producer's accuracy relates to the probability that a reference sample has correctly mapped and measures the errors of omission.

***Producer accuracy*:** This is the measure that indicates the probability that the classifier has labeled an image pixel into class A given that the reference class is A. It is calculated using Equation 1.

$$\text{PA} = \frac{\text{Number of correctely classified pixels in each category}}{\textit{Total number of reference pixel in that cetogory (the column total)}} \times 100$$

Where;
PA = Producer accuracy

User accuracy: This measures the probability that a pixel is a class A given that the classifier has labeled the pixel into class A. It is calculated using flowing Equation 2.

$$\text{User accuracy} = \frac{\text{Number of correctely classified pixels in each category}}{\textit{Total number of reference pixel in that cetogory (the row total)}} \times 100$$

Overall accuracy**:** This is calculated by summing the number of pixels correctly classified, divided by the total number of pixels in that land-cover class. It is calculated using flowing Equation 3.

$$\text{Overall accuracy} = \frac{\text{Total number of classified pixels (diagonals)}}{\textit{Total number of referenc epixel}} \times 100$$

Kappa coefficient**:** The Kappa Coefficient (K) measures the agreement between the classification results with that of the reference pixels. Perfectly agreed to indicate that the kappa coefficient tends to one or is very close to one. It is calculated using flowing Equation 4.

$$K = \frac{(Ts \times Tcs) - \sum(\text{Column total} \times \text{Row total})}{Ts^2 - \sum(\text{Column total} \times \text{Row total})} \times 100$$

Where;
Ts = total sample
Tcs = total number of corrected sample

Results and discussion

Status of LULC from 1992-2017

This study reveals that the largest land cover is dominated by the forest. The spatial distribution of the forest is confined to the northern and southwestern parts of the study area. It is followed by the cultivated land in the southeastern and central part, and the southeastern part is predominated by the built-up area of the watershed. The results indicate that the forest cover was 50.97% in 1992, and it was increased by about 1% area during the last 25 years. Conversely, the cultivated area was shrinking from 32.63% to 26.4% during the same period (Table 1 and Figure 3).

Table 1: LULC change (1992-2017)

LULC types	Area (km^2)					
	1992	%	2004	%	2017	%
Forest	5.56	50.97	5.85	53.62	5.6	51.33
Cultivation land	3.56	32.63	2.97	27.22	2.88	26.4
Built-up	0.45	4.12	1.17	10.72	1.8	16.5
Water body	0.05	0.45	0.06	0.55	0.05	0.45
Shrub and other	1.29	11.83	0.86	7.89	0.58	5.32
Total	10.91	100	10.91	100	10.91	100

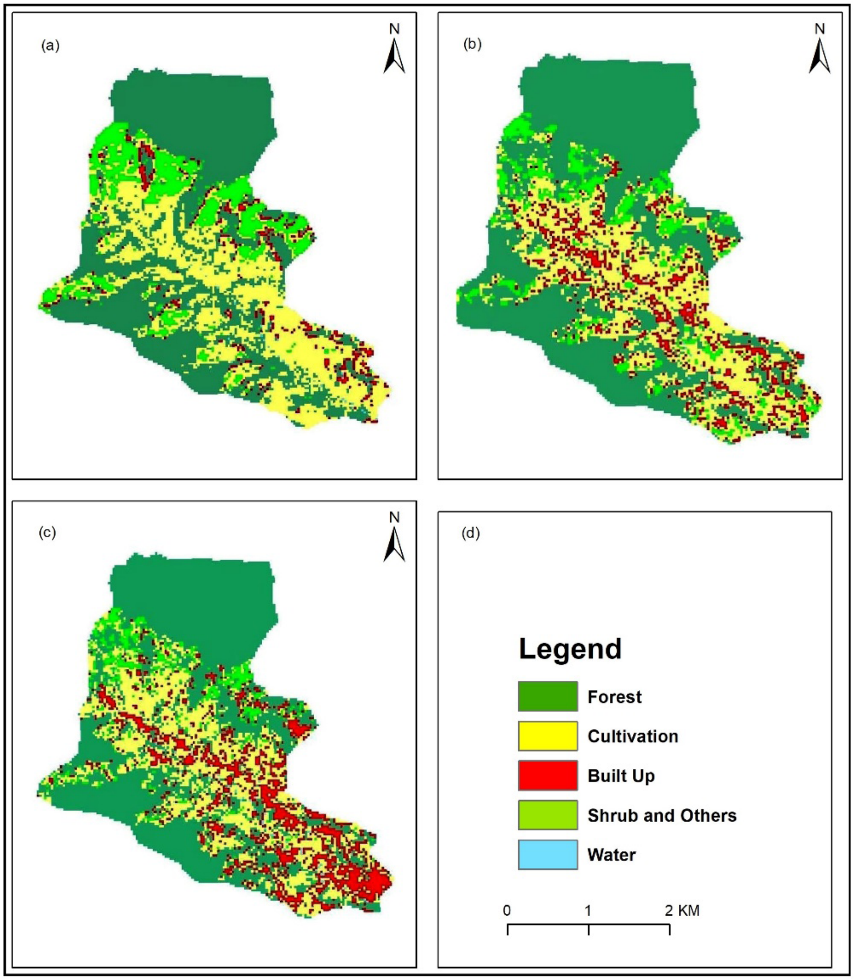

Figure 3: Status of LULC in Manamati watershed; (a) 1992, (b) 2004 and (c) 2017

Changes in LULC

Forest Cover

The forest cover of the study area in 1992 was 5.56 km^2 which decreased to 5.60 km^2 in 2017 (Table 1 and Figure 3). Overall, the forest cover has positive change. However, various studies showed that forest cover had increased from 9.79 km^2 to 14.73 km^2 between 1989 to 2016 in the Kathmandu Valley (Ishtiaque et al., 2017), and it also increased from 931 ha to 1442 ha in Chandragiri municipality of Kathmandu district at the same time (Joshi et al., 2021). From 1989 to 2016, the forest cover increased from 9.79% to 14.73% in the Kathmandu Valley (Ishtiaque et al., 2017) and increased by 6.31% between 2010 to 2018 (Lamichhane and Shakya, 2021). However, the forest cover in the Bagmati watershed decreased by 6.23 km^2 converting into a built-up area from 2010 to 2018 (Pokhrel, 2018). The decreasing trends of forest cover in the Bagmati River Basin have been revealed by the study of Rijal et al. (2021) from 1988 to 2018. About 71 km^2 decreased due to built-up area. The forest cover decreased by 17.27 km^2 in the Kathmandu district between 1990 and 2010 (Wang et al., 2020) and it was 23.08% to 19.43% from 1967 to 2000 (Thapa and Murayama, 2009).

Cultivated Land

The cultivated land is the second-highest coverage of the study area. The result indicates that it is in a decreasing trend. It is mainly due to population growth, urbanization, and use of secondary and tertiary activities. The results show that the cultivated land was 32.63% (3.56 km^2) in 1992 and it was 27.22 and 26.4% in 2004 and 2017 respectively (Table 1 and Figure 3). The decreasing trends of cultivated land also revealed in various studies in Chandragiri municipality (495 ha lost between 1996 and 2017) and Bagmati watershed (29 km^2) has supported the finding of this study (Joshi et al., 2021; Pokhrel, 2018).

The remote sensing analysis also revealed that the cultivated land decreased from 32.9% to 31.6% between 1988 and 2018 in Bagmati River Basin (Rijal et al., 2021). A historical study has found that in 1989 the agricultural land was 80.54% which decreased to 63.87% in 2009 and 55.30% in 2016 in Kathmandu Valley. Mainly the agricultural land was converted into a built-up area of 89 km^2 between 1989 and 2016. Another study has also revealed that the cultivated land decreased by 6.51% from 2010 to 2018 in Kathmandu Valley (Lamichhane and Shakya, 2021). Overall, in Nepal, the agricultural land has decreased by 2858.87 km^2 between 1990 and 2010 (Uddin et al., 2018).

Built-up Area

The built-up area is an increasing trend in many developing countries like Nepal. The result shows that the built-up area increased from 0.45 km^2 to 1.8 km^2 between 1992 and 2017 in the study area (Table 1). In Kathmandu Valley, the population was 202609 in 1961 with a 12% population growth rate, which increased by 1084443 population with a 499% growth rate (Haack and Rafter, 2006). A historical study found that the built-up area increased from 657 ha to 819 ha between 1996 and 2017 in the Chandragiri municipality of Kathmandu district (Joshi et al., 2021). Likewise, built-up areas in Kathmandu Valley also found an increasing trend. In 1967, the built-up area was only 2010 ha, which increased to 3362, 6313, and 9717 ha in 1978, 1991, and 2000, respectively (Thapa and Murayama, 2009).

The preliminary report of the national population census of 2021 also reported that the total household of the country has increased by 24.57% between 2011 to 2021 (CBS, 2021). The built-up area in the Kathmandu Valley increased from 40.53 km^2 to 144.35 km^2 between 1988 and 2016. Mainly the built-up area transformed from agricultural land in the Kathmandu Valley (Rimal et al., 2018). From 1989 to 2016 the built-up area increased from 5.10% to 26.06% in the Kathmandu Valley (Ishtiaque et al., 2017). The built-up area increased by 4.96% with the loss of agricultural land between 2010 and 2018 in the Kathmandu Valley (Lamichhane and Shakya, 2021). Similar to the existing studies, overall, the built-up area has increased by 1.35 km^2 in the study area.

Water Bodies, Shrubs, and Other Lands

Water bodies, shrubs, and other land cover only a small portion, and they are on decreasing trend in the study area. This study results that water bodies were only 0.05 km^2 in 1992, which was 0.02 km^2 in 2017 (Table 1). Mainly, the water bodies were converted to forest and cultivation land in the study area. Shrub and other lands also decreased from 1.29 km^2 to 0.58 km^2 over the past 25 years, which also converted to forest, cultivation, and built-up in the study area. The water bodies also decreased in Kathmandu Valley. From 1989 to 2016, water bodies decreased from 0.19% to 0.17% in the Kathmandu Valley; mainly, it was converted to agricultural land and urban areas in the Valley (Ishtiaque et al., 2017). The land cover also decreased from 1.9% to 1.3% from 1988 to 2018 in Bagmati River Basin (Rijal et al., 2021).

Conclusion

This study has analyzed the land use, land cover change in the Manamati watershed of Kathmandu district using Google Earth Engine over the recent past 25 years. During this time, the built-up area significantly increased with human population. Due to the continuous urbanization process, land use, land cover has rapidly changed; mainly, urbanization takes place in the cultivation of land, which has an imbalance in the biological and social environment. The encroachment of the riverbank and poor drainage system is likely to be creating worsening inundation and damage to property in the study area as well as Kathmandu Valley. This information may be a supporting tool for policy formation, planning, and natural resource management of the Kathmandu Valley.

References

Baulies, X. & Szejwach, G. (1998). *LUCC data requirements workshop: Survey of needs, gaps and priorities on data for land-use/land-cover change research*. Spain: Institute Cartografic de Catalunya.

Becker, A. & Bugmann, H. eds. (2001). Global change and mountain regions: The mountain research initiative*. The IGBP Report Series to the Global Change News Letter*. Stockholm: Royal Swedish Academy of Sciences,

Central Bureau of Statistics [CBS]. (2021). *Preliminary report of national population census of 2021*. Kathmandu: Author.

Cohen, W. & Goward, S. (2004).Landsat's role in ecological applications of remote sensing. *BioScience*, 54 (6); 535–545.

Gautam, A. P., Webb E. L. & Eiumnoh A. (2002). GIS assessment of land use/land cover changes associated with community forestry implementation in the middle hills of Nepal. *Mountain Research and Development*, 22 (1), 63-69.

Gu, C., Zhang, Y., Liu, L., Li, L., Li, S., Zhang, B., Cui, B. & Rai, M. K. (2021). Qualifying land use and land cover dynamics and their impacts on ecosystem service in central himalaya transboundary landscape based on google earth engine. *Land* 10, 173. https://doi.org/10.3390/land10020173

Gumma, M. K., Thenkabail, P. S., Teluguntla, P. G., Oliphant, A., Xiong, J., Giri, C., Pyla, V., Dixit, S. & Whitbread, A. M. (2020). Agricultural cropland extent and areas of South Asia derived using landsat satellite 30 m time-series big-data using random forest machine learning algorithms on the Google Earth Engine cloud. *GIScience Remote Sensing*, 57, 302-322.

Haack, B. N. & Rafter, A. (2006). Urban growth analysis and modeling in the Kathmandu Valley, Nepal. *Habitat International 30, 1056-1065.*

Hansen, M., Potapov, P., Moore, R., Hancher, M., Stehman, S., Goetz, T. & Loveland, A. (2013). *High-resolution global maps of 21st-century forest cover change*. Retrieved from http://earthenginepartners.appspot.com/science-2013-global- forest.

Ishtiaque, A., Shrestha, M. & Chhetri, N. (2017). Rapid urban growth in the Kathmandu Valley, Nepal: Monitoring land use land cover dynamics of a Himalayan city with Landsat imageries. *Environments* 4, 1-16.

Joshi, S., Rai, N., Sharma, R. & Baral, N. (2021). Land use/land cover (LULC) change in suburb of central Himalayas: A study from Chandragiri, Kathmandu. *Journal of Forest Environmental Science an Indian Journal*, 37, 44-51.

Khanal, N. R. & Watanabe, T. (2006). Abandonment of agricultural land and its consequences: A case study in the Sikles area, Gandaki basin, Nepal Himalaya. *Mountain Research and Development,* 26, 32-40.

Kumar, L. & Mutanga, O. (2018). Google Earth Engine applications since inception: Usage, trends, and potential. *Remote Sensing.* 10, 1509.

Lamichhane, B. R. (2008). *Dynamic and driving forces of land use/forest cover changes and indicators of climate change in Mountain sub-watershed of Gorkha*. Nepal: Dissertation in Institute of Forestry.

Lamichhane, S. & Shakya, N. M. (2021). Land use land cover (LULC) change projection in Kathmandu valley using the clue-s model. *Journal of Advanced College of Engineering Management Research*, 6, 221-233.

Lu, D. & Weng, Q. (2007). A survey of image classification methods and techniques for improving classification performance. *International Journal of Remote Sensing*, 823-870.

McConnell, W. (1997). How and why people and institutions matter beyond economy: People and trees in Madagascar. *International Geosphere-Biosphere Programme*, 20-22.

Meyar, W. B. & Turnar II, B. L. (1994). *Modeling land use and cover as part of global environmental change.* USA: George Perkins Marsh Institute, Clark University, Worcester, MA 01610, 45-64.

Paudel, B., Gao, J., Zhang, Y., Wu, X., Li, S. & Yan, J. (2016). Changes in cropland status and their driving factors in the Koshi River basin of the Central Himalayas, Nepal. *Sustainability,* 8, 1-17.

Pokhrel, B. K. (2018). Impact of land use change on flow and sediment yields in the Khokana outlet of the Bagmati River, Kathmandu, Nepal. *Hydrology,* 2018, *5*(2), 22; https://doi.org/10.3390/hydrology5020022

Prasai, R. (2022). Using Google Earth Engine for the complete pipeline of temporal analysis of NDVI in Chitwan National Park of Nepal. *Research Square,* 1, 1-13.

Rai, R., Yili, Z., Paudel, B., Khanal, N. R. & Acharya, B. K. (2020). Satellite image-based monitoring of urban land use change and assessing the driving factors in Pokhara and Bharatpur metropolitan cities, Gandaki basin, Nepal. *Journal of Resources Ecology and Society,* 11, 87-99.

Richards, J. F., Turners, W. C., Clark, R. W., Kates, J. F., Richards, J. T. & Mayer, W. B. (1990). *The earth as transformed by human action*. Cambridge: Cambridge University Press.

Rijal, S., Rimal, B., Acharya, R. P. & Stork, N. E. (2021). Land use/land cover change and ecosystem services in the Bagmati River Basin, Nepal. *Environmental Monitoring Assessment*, 193, 1-17.

Rimal, B., Zhang, L., Keshtkar, H., Haack, B. N., Rijal, S. & Zhang, P. (2018). Land use/land cover dynamics and modeling of urban land expansion by the integration of cellular automata and Markov chain. *ISPRS International Journal of Geo-Information,* 7, 1-21.

Sharma, S., Pandey, S., Pathak, D. & Sijapati-Basnett, B. (2014). *State of migration in Nepal*. Kathmandu: Centre for the Study of Labour and Mobility.

Sidhu, N., Pebesma, E. & Câmara, G. (2018). Using Google Earth Engine to detect land cover change: Singapore as a use case. *European Journal of Remote Sensing*, 51, 486-500.

Skole, D. (1996). Land use and land cover change: An Analysis. *International Geosphere-Biosphere Programme,* 4-7.

Steffen, W. L., Walker, B. H., Ingram, J. S. & Koch, G. W. (1992). Global Change and Terrestrial Ecosystem: The Operational Plan. *International Geosphere-Biosphere Programme*, 93.

Thapa, R. B. and Murayama, Y. (2008). *Spatial structure of land use dynamics in Kathmandu Valley*. University of Tsukuba, Japan: The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences.

Thapa, R. B. & Murayama, Y. (2009). Examining spatiotemporal urbanization patterns in Kathmandu Valley, Nepal: Remote sensing and spatial metrics approaches. *Remote Sensing*, 1, 534-556.

Turner, B., William, B. & Skole, D. L. (1994). *Global land use/land cover changes: Towards an integrated study.* Royal Swedish Academy of Sciences: Allen Press.

Turner, B. L., Skole, D., Sanderson, S., Fisher, G., Fresco, L. & Leemans, R. (1995). *Land- use and land-cover change science/research plan*. Stockholm and Geneva: International Geosphere-Biosphere Programme and Human Dimension of Global Environmental Change Programme.

Uddin, K., Abdul Matin, M. & Maharjan, S. (2018). Assessment of land cover change and its impact on changes in soil erosion risk in Nepal. *Sustainability*, 10, 4715.

Wagle, N., Acharya, T. D., Kolluru, V., Huang, H. & Lee, D. H. (2020). Multi-temporal land cover change mapping using google earth engine and ensemble learning methods. *Applied Sciences*, 10, 8083. doi:10.3390/app10228083

Wang, S. W., Gebru, B. M., Lamchin, M., Kayastha, R. B. and Lee, W.-K. (2020). Land use and land cover change detection and prediction in the Kathmandu District of Nepal using remote sensing and GIS. *Sustainability* 12, 3925.

White, J., Wulder, M., Hobart, G., Luther, J., Hermosilla, T., Griffiths, P. & Guindon, L. (2014). Pixel-based image compositing for large-area dense time series applications and science. *Canadian Journal of Remote Sensing*, 192-204

Zurqani, H. A., Post, C. J., Mikhailova, E. A., Schlautman, M. A. & Sharp, J. L. (2018). Geospatial analysis of land use change in the Savannah River Basin using Google Earth Engine. International Journal of Applied Earth Observation Geo-information, 69, 175-185.