# Land Cover Change Before and After the Sendai Framework of Disaster Risk Reduction

**Pragya PANT, Narayan THAPA, Sujan NEPALI, Suman SANJEL, Nepal**

**Key words** Risk management, Land cover change, Sendai Framework, sustainability, climate change.

**SUMMARY**

Land cover practices over the years have induced disasters. Land cover change is crucial for assessing environmental health, particularly as urbanization and climate change increase disaster risks like floods and forest fires. By 2050, 68% of the global population will live in urban areas, intensifying these hazards. Being prepared for disasters and minimizing their impacts is of utmost importance. The Sendai Framework for Disaster Risk Reduction (2015-2030) emphasizes understanding and managing disaster risks, which are often driven by land cover changes.

Advances in geospatial technologies, such as crowd-sourcing, machine learning, and cloud computing, enable more precise land cover monitoring for disaster risk management. Nepal ranked 4th globally for climate-related hazards, faces urgent risks. The government has implemented policies like the Disaster Risk Reduction and Management Act and national disaster risk reduction plans to meet Sendai Framework targets. This study examines land cover practices in Nepal before and after the Sendai Framework to assess progress towards its goals.

This study examines land cover changes in the Sindhupalchowk district of Nepal before and after implementing the Sendai Framework for Disaster Risk Reduction (2015). By analyzing land cover data along with strategies and policies that support this framework, we assess the role of government, stakeholders, and community participation in promoting sustainable land management focus on disaster risk reduction. The findings highlight significant shifts in land cover patterns for different reasons, such as climate hazards, people's willingness to change land cover practices, and the effectiveness of policy measures. This study provides several urgent and important actions that can be guided based on the published documents.

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## 1. INTRODUCTION

Land cover change is a critical indicator of environmental health and sustainability, reflecting the dynamic of interactions between human activities and natural processes. Globally, urbanization is accelerating, with projections indicating that 68% of the world population will reside in urban areas by 2050 (UN Habitat, 2018). This rapid urbanization, coupled with local climate changes, is amplifying the impacts of various hazards, including floods, landslides, forest fires, and Glacier Lake Outburst Floods. These risks are often triggered by land cover changes and, in turn, can further alter land cover.

Achieving the Sustainable Development Goals (SDGs) by 2030 requires effectively addressing these hazards and their magnitudes. In response to these challenges, the Sendai Framework for Disaster Risk Reduction 2015-2030 was developed. This framework emphasizes understanding disaster risk, strengthening disaster risk governance, investing in disaster risk reduction for resilience, and enhancing disaster preparedness for effective response and recovery (United Nation, 2015).

The development of cross-cutting technologies in the field of geospatial has significantly enhanced our ability to monitor land cover change and support decision-making to achieve the target of the Sendai Framework for Disaster Risk Reduction. Innovations in geospatial technologies, such as crowd-sourcing (Shrestha et al., 2023), machine learning techniques (Khanal et al., 2019), cloud computing platforms(Yang et al., 2022) have facilitated the creation of high-resolution datasets. These advancements enable more precise tracking of land cover change, providing critical insights for disaster risk management and sustainable development.

Nepal is a mountainous country, ranked as the 4$^{th}$ most affected globally by climate-related hazards. This alarming ranking underscores the urgent need for action, particularly in Nepal, which is highly vulnerable to natural disasters. The government has developed several plans and policies to guide and achieve the targets of the Sendai Framework for disaster risk reduction. These include the land use policy, the Disaster Risk Reduction and Management Act (Government of Nepal Ministry of Home Affairs, 2019), the national policy for disaster risk reduction (Government of

Nepal Ministry of Home Affairs, 2018), monsoon preparedness and response plan (Government of Nepal Ministry of Home Affairs, 2022).
Thus, this study aims to understand the land cover practices in Nepal before and after the implementation of the Sendai Framework, helping to analyze how close we are to achieving its targets.

## 2. STUDY AREA

Sindhupalchowk district of Nepal is selected for the case study. It spreads from 27˚28' north to 28 ˚13' north latitude and 85˚27' east to 86˚01' east longitude. This district is highly affected by natural disasters like floods, landslides, and earthquakes and has been experiencing drastic changes in land cover (Pariyar, 2022).

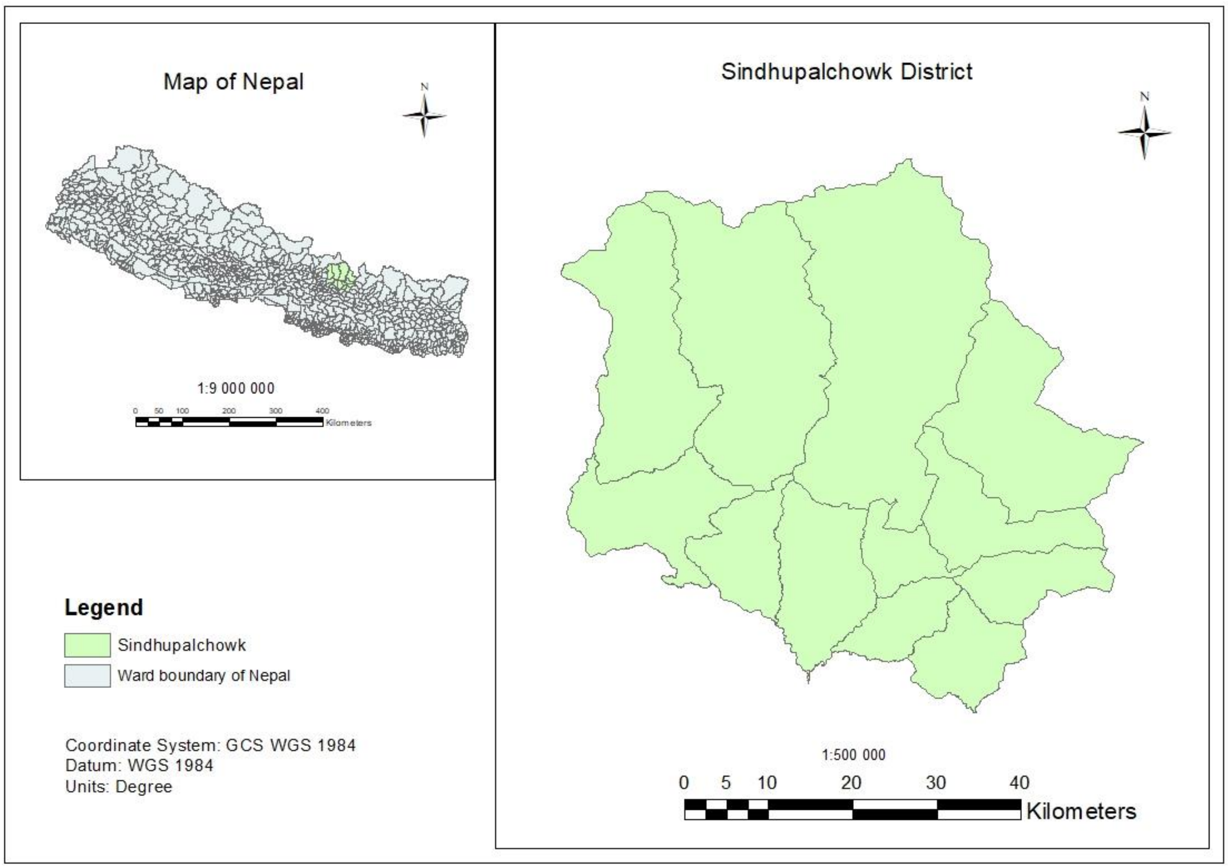


*Figure 1: Location of the study area*

## 3. METHODOLOGY

### 3.1 Data used

The data utilized in this study was developed using the machine learning random forest classified (Uddin et al., 2021), a model widely recognized for its effectiveness in land cover classification (Biau & Scornet, 2016). The ICIMOD land cover dataset is a part of the National Land Cover Monitoring System (NLCMS) of Nepal. The land cover data was developed by using freely available remote-sensing data (Landsat) and cloud-based machine learning architecture on Google Earth Engine (GEE) platform to generate annual land cover maps of 30-meter resolution.

*Table 1: Land cover type and description*

| Main Land cover class | Description |
|---|---|
| Waterbody | Rivers are natural flowing water bodies and typically have elongated shapes, lakes, and ponds are potential standing water bodies. |
| Snow and Glacier | This class describes perennial snow(persistence> 9 months per year) and Perennial ice in movement |
| Forest | Land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10% that is predominantly under agriculture or urban land use. |
| Riverbed | A tract of land without vegetation surrounded by the water of an ocean, lake, or stream, it usually includes any accretion in a river course. |
| Built-up area | Built-up areas refer to artificial structures such as towns, villages, industrial areas, airports, etc. |
| Cropland | This category includes arable and tillage land and agroforestry systems where vegetation falls below the thresholds used for the forest land category, consistent with the selection of national definitions. |
| Bare rock | Non-vegetated areas with rock surface. |
| Grassland | Areas covered by herbaceous vegetation with cover ranging from closed to open (15-100%). This category includes rangeland and pasture that is not considered cropland. |

### 3.2 Change detection

Change detection is essential for understanding how the environment and biodiversity evolve due to various factors such as human activities, climate change, and natural disasters. By comparing multiple images or raster datasets, we can identify and analyze these changes. There are different methods to perform change detection: categorical change detection compares different categories like land use or vegetation types: pixel value change detection focuses on changes in pixel values such as temperature or reflectance and time series analysis using methods like LandTrender, which examines changes over extended periods to identify trends and distribution in the landscape. In this study, we use categorical change. This change detection helps to understand the pattern of landcover change before and after the Sendai Framework.

## 4. RESULT

To understand the land cover change before and after the Sendai Framework, we evaluated the change in the area of each land cover type from 2015 to 2000 and 2021 to 2015. For this, we generated maps and graphs based on the land cover change percentage.

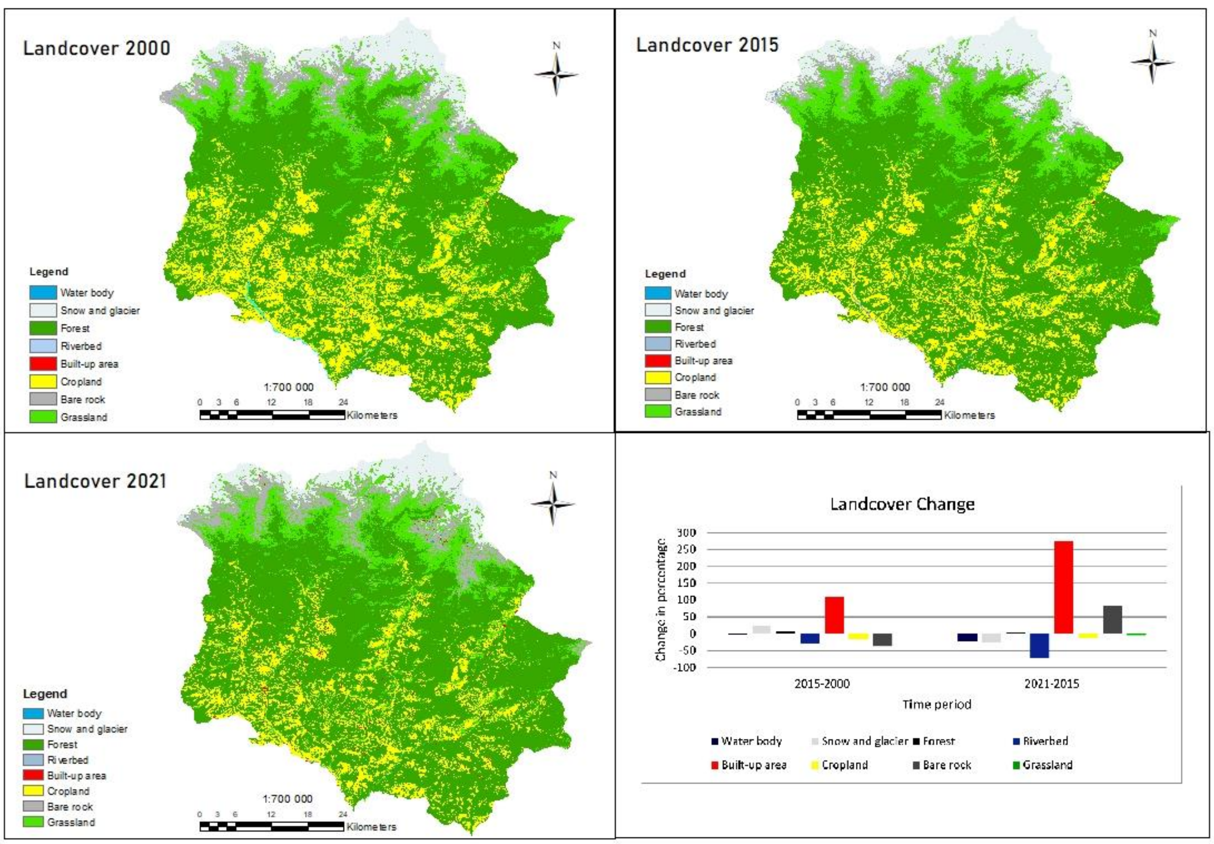


*Figure 2: Land cover at different years and change*

The result of the analysis is shown in

Table 2 and For the years between 2000 and 2021, water bodies decreased from 2.14 to 1.63 sq. km and cropland decreased from 425.22 to 316.11 sq. For this period, water bodies have dropped from 2.14 in 2000 to 1.63 in 2021. Snow and glaciers went up first from 151.05 square km as reported in the year 2000 to 185.48 km in 2015 with a decline from the year 2021 to 139.32 square km. During 2000-20015, bare rock bare rock declined and rose again in 2021. Forest areas expanded during these years, while riverbeds sharply declined. The built-up area increased by almost three times while the grassland slightly decreased.

Table 3, it shows a significant increase in built-up area that is increasing by double in the time frame, a steady increase in forest cover, and a decline in water bodies, snow and glaciers, cropland, and grassland.

*Table 2: Land cover change in area(sq.km) over the years 2000,2015, and 2021*

| Landcover (sq. km) area / Year | Water body | Snow and glacier | Forest | Riverbed | Built-up area | Cropland | Bare rock | Grassland |
|---|---|---|---|---|---|---|---|---|
| 2000 | 2.14 | 151.05 | 1250.96 | 3.99 | 1.02 | 425.22 | 130.82 | 318.14 |
| 2015 | 2.1 | 185.48 | 1335.54 | 2.84 | 2.12 | 356.7 | 82.67 | 315.9 |
| 2021 | 1.63 | 139.32 | 1363.32 | 0.85 | 7.97 | 316.11 | 151.56 | 302.59 |

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*Table 3: Percentage of change in land cover area before and after 2015*

| Change (%) / Time period | Water body | Snow and glacier | Forest | Riverbed | Built-up area | Cropland | Bare rock | Grassland |
|---|---|---|---|---|---|---|---|---|
| 2015-2000 | -1.87 | 22.79 | 6.76 | -28.82 | 107.84 | -16.11 | -36.81 | -0.71 |
| 2021-2015 | -22.38 | -24.89 | 2.08 | -70.07 | 275.94 | -11.38 | 83.33 | -4.22 |

The most significant change is in the built-up area, which increased by 107.84% from 2000 to 2015, and by a remarkable 275.94% from 2015 to 2021, indicating rapid urbanization over the two decades. Water bodies and Riverbeds declined, particularly between 2015 and 2021, with water bodies decreasing by 22.38% and riverbeds by 70.07%. The snow and glacier cover increased by 22.79%, followed by a decline of 24.89% in the 2015-2021 period, potentially indicating climate-related changes. Consistent decline in cropland area over both periods, reflecting possible land-use changes, such as urban encroachment or environmental factors. The bare rock increased by 83.33% from 2015 to 2021 contrasts with the previous decline, indicating possible land degradation or other environmental shifts.

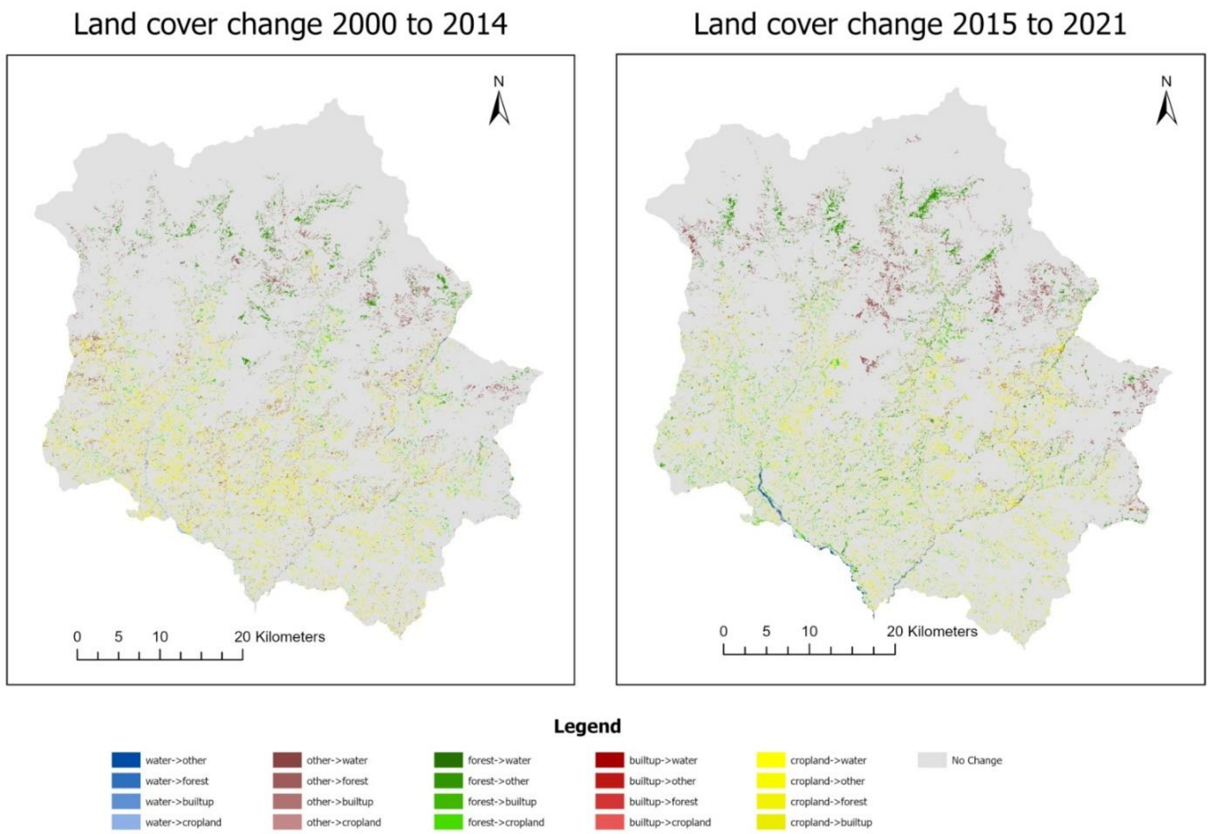


*Figure 3: Land cover change with respect to the Sendai framework*

The land cover change analysis reveals a significant change in built-up areas, forest areas, cropland, and other areas including bare soils and bare rock classes. The majority of the area, however, remains unchanged. This change is visualized in figure1. The most notable change after the implementation of the Sendai framework was observed near the river basin, primarily due to the 2021 flood. The red areas near the water bodies indicate urbanization before the flood which was later transformed into water bodies due to the flood. Similarly, the yellow areas representing cropland show expansion in certain regions, but some of these areas were converted to other land cover types due to the flood. The green areas indicated an increase in forest cover, but some forest regions near the river basin were also affected by floods leading to changes in land cover. These findings highlight the inability to create resilient infrastructure and present an opportunity for further modeling and analysis to improve disaster resilience strategies.

## 5. DISCUSSION

Land cover change is a significant factor in understanding and managing disaster risk, particularly in the hilly region of Nepal where flash floods and landslides are the major incidents to disturb the practice of human beings on land. Utilizing 30-meter resolution satellite imagery, this study examines land cover changes from 2000, 2015, and 2021, revealing critical insights. A major disaster in 2021 underscored the vulnerability of the region with the area being highly prone to such events (Thapa & Prasai, 2022).

There is an increase in forest cover with a 6.76% increase in 2015 to a 2.08% increase in 2021, although there is a decrease in land cover change percentage, this change seems to be aligning with the targets of the Sendai framework. This change may be due to the presence of National parks and tourist attraction sites which are being protected by the government and the local community. There is an increasing area of bare rock resulting from activities like landslides and floods after 2015. This has also been triggered by the Gorkha Earthquake in 2015.

Despite various government frameworks for disaster risk reduction, these often fail to consider the local people's willingness to live near riverbeds, increasing the vulnerability. The conversion of agricultural land to built-up areas and riverbeds highlights the urgent need for effective land use planning. Human activities such as hill cutting for road construction and developing road networks close to rivers, significantly contribute to land cover changes, exacerbating the risk of landslides and infrastructure failure. Multi-criteria analysis has proven effective in planning these changes, helping to mitigate the impacts of multiple cascading, and amplifying hazards. The rapid conversion of forest area to other land uses further amplifies disaster risks, as forest plays a crucial role in stabilizing soil and preventing landslides(Sahin et al., 2020). Effective disaster risk reduction requires comprehensive frameworks that address multiple hazards and involve community participation, reflecting local preferences and behaviors to provide safer living alternatives.

The channeling of rivers and the construction of infrastructure close to riverbanks have also been significant issues. These activities not only alter the natural flow of rivers but also increase the risk of flooding and erosion. This was reflected by conversations with other land cover classes to built-up area to water bodies and river belt. This shows a strict rule of no-service rule is required to reduce the willingness of people to river. The land near the river bank which was classified as other land in 2000 was converted to the built-up area in 2014. This change was conceded with the implementation of the Sendai framework in 2015. However, by 2021, a natural disaster had further transformed this built-up area into a water body and riverbed class. This sequence of events highlights the lack of proper implementation of this framework at the local level. In the context of Nepal, the policy on land use rights might be a major cause of this type of sequential change.

Nepal's land use policies and land rights have historically allowed individuals significant freedom to develop their land according to their preferences. The National Land Use Policy 2015 aimed to address issues related to land use, including the protection of agricultural land and the management of land resources to ensure food security and sustainable development (Ministry of Land Management Cooperatives, 2015). The National Land Policy 2019 further emphasized securing land tenures and land ownership, protecting land rights, and rehabilitating landless individuals, squatters, and informal tenure holders(Ministry of Land Management, 2019). The policy aimed to provide equitable access to land for all, including women, and vulnerable groups and to ensure tenure security for landless peasants for farming. Despite these efforts, the policy also allowed for significant individual discretion in land development, which can lead to unplanned and potentially hazardous land use changes.

The scientific methodology is required to guide Nepal's land use policies to balance development with sustainability and the Sendai Framework for disaster risk reduction, in collaboration with local stakeholders. The major concern should be to address the willingness of people to develop their land, often driven by immediate economic needs and urbanization pressures. By integrating scientific methodologies and community involvement, policies can be more effectively tailored to mitigate the impact of land cover changes and ensure the resilience of cropland and other critical land uses in disaster-prone areas.

## 6. CONCLUSION

The study of land cover changes before and after the implementation of the Sendai Framework for Disaster Risk Reduction highlights significant environmental and socio-economic dynamics. Despite various policies aimed at mitigating disaster risk, challenges persist, such as the local population's preferences for living near riverbeds, and the rapid conversion of agricultural and forest lands to built-up areas and back to other land cover classes. These changes increase the vulnerability to floods, landslides, and other hazards, underscoring the need for comprehensive land use planning and community-inclusive approaches. To achieve the Sendai Framework's target, it is crucial to integrate scientific methodologies with local stakeholder involvement, balancing development with sustainability and ensuring the resilience of critical land uses in disaster-prone areas.

## REFERENCES


Biau, G., & Scornet, E. (2016). A random forest guided tour. *Test*, *25*(2), 197–227. https://doi.org/10.1007/S11749-016-0481-7/METRICS

Government of Nepal Ministry of Home Affairs. (2018). *National Policy for Disaster Risk Reduction*.

Government of Nepal Ministry of Home Affairs. (2019). *Disaster Risk Reduction and Management Act, 2074 And Disaster Risk Reduction and Management Rules, 2076 (2019)*.

Government of Nepal Ministry of Home Affairs. (2022). *Monsoon Preparedness & Response Plan-2077 Part 1 Monsoon Preparedness and Response Plan* (Vol. 2077, Issue Part 1).

Khanal, N., Uddin, K., Matin, M. A., & Tenneson, K. (2019). Automatic detection of spatiotemporal urban expansion patterns by fusing OSM and Landsat data in Kathmandu. *Remote Sensing*, *11*(19). https://doi.org/10.3390/rs11192296

Ministry of Land Management, C. and P. A. (2019). *National Land Policy 2019*.

Ministry of Land Management Cooperatives, and P. A. (2015). *National Land use policy 2015*.

Sahin, E. K., Colkesen, I., & Kavzoglu, T. (2020). A comparative assessment of canonical correlation forest, random forest, rotation forest and logistic regression methods for landslide susceptibility mapping. *Geocarto International*, *35*(4), 341–363. https://doi.org/10.1080/10106049.2018.1516248

Shrestha, R., Thapa, N., & Shrestha, R. (2023). Urban Health Transdisciplinary Forum. : *: Urban Health Transdisciplinary Forum. Bochum, 15.02.2023. Düsseldorf: German Medical Science GMS Publishing House*. https://doi.org/10.3205/23uhtf15

Thapa, N., & Prasai, R. (2022). Impacts of floods in land use land cover change:- A case study of Indrawati and Melamchi river, Melamchi and Indrawati municipality, Nepal. *SSRN Electronic Journal*. https://doi.org/10.2139/SSRN.4104357

Uddin, K., Matin, M. A., Khanal, N., Maharjan, S., Bajracharya, B., Tenneson, K., Poortinga, A., Quyen, N. H., Aryal, R. R., Saah, D., Lee Ellenburg, W., Potapov, P., Flores-Anderson, A., Chishtie, F., Aung, K. S., Mayer, T., Pradhan, S., & Markert, A. (2021). Regional Land Cover Monitoring System for Hindu Kush Himalaya. In *Earth Observation Science and Applications for Risk Reduction and Enhanced Resilience in Hindu Kush Himalaya Region* (pp. 103–125). Springer International Publishing. https://doi.org/10.1007/978-3-030-73569-2_6

UN Habitat. (2018). *68% of the world population projected to live in urban areas by 2050, says UN | UN DESA | United Nations Department of Economic and Social Affairs*. https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

United Nation. (2015). *Sendai Framework for Disaster Risk Reduction 2015 - 2030*.

Yang, L., Driscol, J., Sarigai, S., Wu, Q., Chen, H., & Lippitt, C. D. (2022). Google Earth Engine and Artificial Intelligence (AI): A Comprehensive Review. *Remote Sensing 2022, Vol. 14, Page 3253*, *14*(14), 3253. https://doi.org/10.3390/RS14143253

## BIOGRAPHICAL NOTES

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