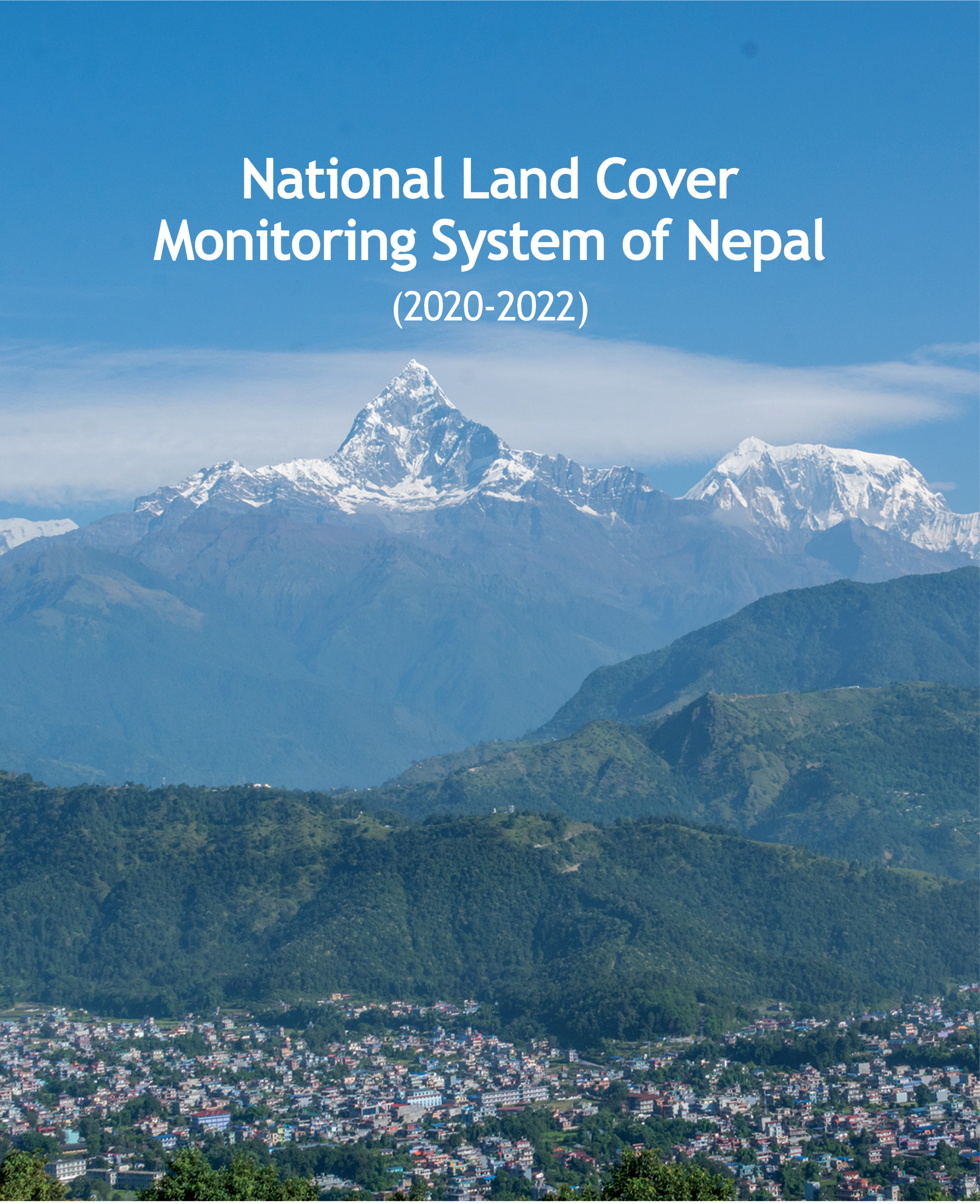
National Land Cover Monitoring System of Nepal

(2020-2022)



Government of Nepal
Ministry of Forests and Environment
Forest Research and Training Centre
2024

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(2020-2022)

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2024

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Front cover: Fishtail Himal in the background, Sarangkot hills and Pokhara Valley *(Photo: ICIMOD)*

Back Cover: Forest and village set up at Salleri, Solukhumbu *(Photo Rajendra KC)*

Date of approval: 2081/08/10 BS
2024/11/25 AD
(Hon Minister level, MoFE)
2081/07/21 BS
2024/11/06 AD
(Survey Committe, Technical Subcommittee)

Citation:

FRTC (2024). National Land Cover Monitoring System of Nepal, 2020-2022. Forest Research and Training Centre (FRTC). Babarmahal, Kathmandu, Nepal.

ISBN: 978-9937-1-7322-3

Published by

Government of Nepal
Ministry of Forests and Environment
Forest Research and Training Centre
Babarmahal, Kathmandu, Nepal
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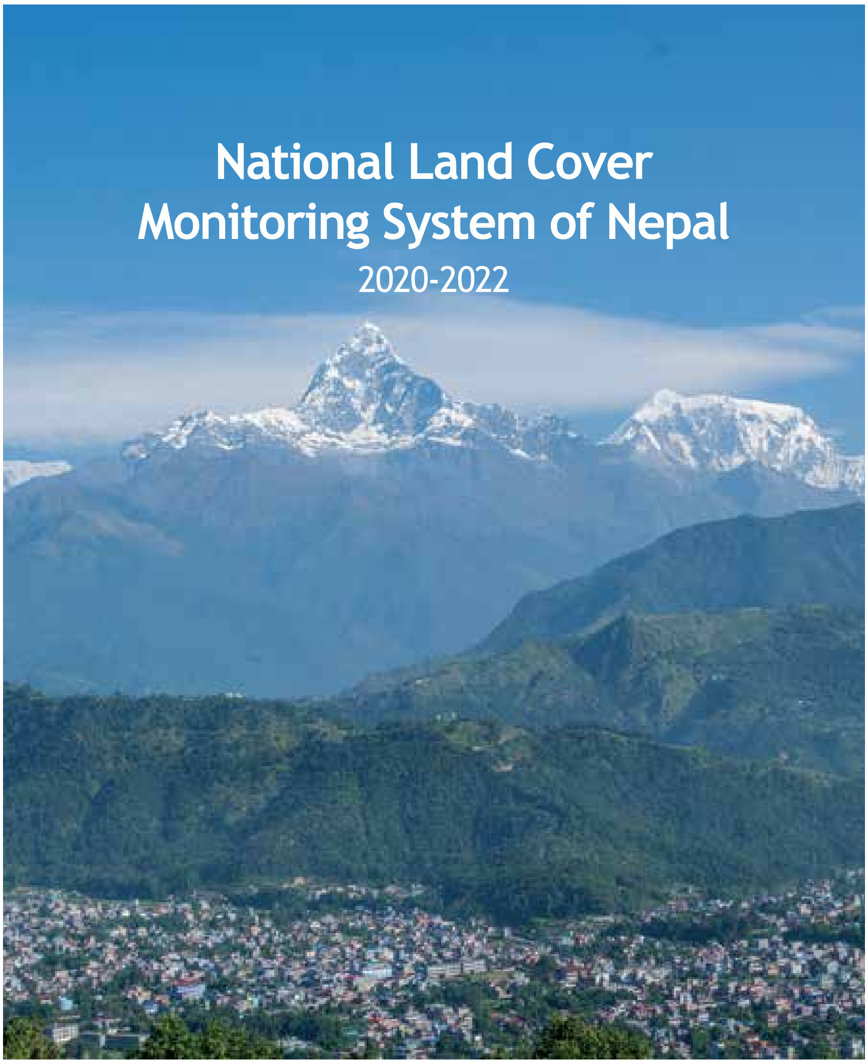
Email: info@frtc.gov.np
Web: http://frtc.gov.np



Government of Nepal
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2024

Government of Nepal
Ministry of Forests and Environment
Singha Durbar, Kathmandu

Message from the Honorable Minister

Forests play a crucial role in supporting livelihoods, maintaining biodiversity, and influencing climate. Effective monitoring of forests and other land cover types is essential for informed decision-making. This report represents a significant advancement in this endeavor. Nepal implemented the National Land Cover Monitoring System (NLCMS) to evaluate changes from 2000 to 2019 and produced first report in 2022.

On behalf of the Government of Nepal, I would like to express my sincere appreciation to the Forest Research and Training Centre (FRTC) for their exemplary efforts in successfully implementing NLCMS of Nepal. I believe Nepal is one of the few pioneer countries in the world that has such a system to produce land cover maps on an annual basis. This achievement is a testament to the dedication and hard work of all those involved. I extend my heartfelt gratitude to all collaborators whose contributions were instrumental in this success.

I am particularly thankful to the International Centre for Integrated Mountain Development (ICIMOD) for their invaluable technical support in developing this critical system. My thanks also go to the Survey Department and Survey Committee,Technical Subcommittee for their thorough and insightful review, feedback, and approval.

The monitoring of land cover changes is of paramount importance for the sustainable management of our natural resources, environmental protection, and ensuring food security. Reliable and consistent land cover data is essential not only for national policy-making but also for fulfilling our international obligations. Recognizing this, the Government of Nepal has prioritized the establishment of a system that meets our specific needs while delivering high-quality, and consistent data.

The NLCMS has already demonstrated its value by producing annual land cover data for Nepal from 2000 to 2019. Now this report on the basis of 2020 to 2022 is proving to be a vital tool for national and international reporting, forest management, reducing greenhouse gas emissions, and planning effective ecosystem management strategies.

I am sure that the Forest Research and Training Centre will keep improving this information, just like they always do, with the help of ICIMOD and our other partners. I ensure you, the Ministry of Forest and Environment is totally committed to making the NLCMS as a key part of our forest planning process, and keeping our forests healthy and growing for the long haul. I hope this data will be a valuable tool for everyone involved in managing our natural resources.

....
Hon. Ain Bahadur Shahi Thakuri
Minister

Government of Nepal

Ministry of Forests and Environment

Singha Durbar, Kathmandu

Message from the Honorable State Minister

Detailed and precise information about forests and other land use systems is crucial for the sustainable management of resources that benefit wider communities and populations. The current National Land Cover Monitoring Report of Nepal offers comprehensive statistics and relevant insights regarding land use changes from 2020 to 2022.

I am pleased to know that the Forest Research and Training Centre (FRTC) has released updated forest cover statistics, along with detailed maps and digital layers. This significant accomplishment underscores FRTC's dedication to sustaining Nepal's National Land Cover Monitoring System (NLCMS) through its own capacity. As a national institution, FRTC's contributions are truly commendable, and I extend my most profound appreciation to the entire team for their unwavering commitment. I would also like to express my sincere gratitude to the collaborators and ICIMOD for their invaluable technical support, which has greatly enhanced the expertise of FRTC's scientists and played a pivotal role in this achievement.

Monitoring land cover, particularly forests, is crucial for managing natural resources, conserving the environment, and ensuring food security. Nepal's forests are vital to local communities and are the part of global biodiversity, contributing climate regulation and carbon sequestration. In this regard, accurate and up-to-date forest mapping is essential. The NLCMS has systematically generated data from 2000 to 2022 and serves as an indispensable tool for national and international initiatives, such as forest conservation actions and combating climate change.

I have profound confidence that, with continued support from ICIMOD and other partners, FRTC will further refine this system to meet the growing needs of sustainable forest management. The Ministry of Forests and Environment is also committed to leveraging the NLCMS to develop and implement forest policies that prioritize sustainability and resilience. This collaborative effort will enhance the effective management of Nepal's forests, ensuring their importance locally and globally.

I extend my heartfelt appreciation and gratitude to the FRTC and ICIMOD for their unwavering support and outstanding collaboration in producing this report at this stage. Special recognition goes to the scientists from both institutions who worked tirelessly with great enthusiasm and dedication, deserving our highest praise.

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Hon. Rupa B.K.
State Minister

Government of Nepal
Ministry of Forests and Environment
Singha Durbar, Kathmandu

Foreword

Changes in land cover come as a result of human activities or natural phenomena; climate change only serves to exacerbate the dynamics in this regard. This report serves to assess how the National Land Cover Monitoring System (NLCMS) incorporates and evaluates remote sensing techniques coupled with data processing analysis for the purpose of Land cover monitoring. Nepal released a report of NLCMS in 2022 which already described the land cover from 2000 to 2019. Now, this report extends the data and maps for 2020, 2021, and 2022. I am extremely proud to have been part of this important project since its early stages of development in Nepal.

The system designed and developed within the National Land Cover Monitoring System is based on consistent satellite imagery resources for the efficient and effective operationalization of annual land cover monitoring. This system will be critical in assisting national and international reporting, such as Nepal's Long-Term Strategy for net-zero emissions and Nationally Determined Contributions (NDC). I am hopeful that NLCMS would also affect our submissions to the System of Environmental Economic Accouting (SEEA) framework and assist in the continued Monitoring & Reporting (MRV) of the REDD process. Moreover, the generated maps will assist in identifying and mapping ecosystems and forest types across the entire country of Nepal.

The flexibility of the NLCMS enables customization for six land cover categories for IPCC reporting, three categories for Global Forest Resources Assessment (GFRA) reporting, and other international reporting requirements as needed. The consistent time series data for two decades will help us understand the changes in different land cover types and conversion trends in the different physiographic regions and at the provincial level. These spatial and temporal patterns will help assess the effectiveness of current and past management policies and practices at the national and provincial levels.

I would like to express my deep appreciation for the dedication of the Forest Research and Training Centre in the development of NLCMS. My sincere thanks to the International Centre for Integrated Mountain Development and all my colleagues for their invaluable support throughout this process. The Ministry of Forests and Environment is confident that NLCMS marks an important step for Nepal with its ability to produce annual land cover maps from 2020 to 2022, which will greatly help meet the country's data needs.

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Deepak Kumar Kharal, Ph.D.
Secretary

Government of Nepal
Ministry of Forests and Environment
Forest Research and Training Centre
Babarmahal, Kathmandu

Acknowledgement

The Forest Research and Training Centre (FRTC) is truly grateful to the International Centre for Integrated Mountain Development (ICIMOD) for their important technical contribution during the creation of Nepal's National Land Cover Monitoring System (NLCMS). This outstanding work was supported by the SERVIR Hindu Kush Himalaya Initiative, which was carried out in collaboration with the National Aeronautics and Space Administration (NASA) and the United States Agency for International Development. Besides that, we are highly grateful to the following co-creator organizations: SilvaCarbon, Global Land Analysis and Discovery (GLAD) group at the University of Maryland, and the US Forest Service for their valuable contributions.

FRTC would like to express our deepest gratitude to various national agencies, including the Ministry of Forests and Environment (MoFE), the Department of Forests and Soil Conservation, the Survey Department, the Department of Agriculture, the National Statistics Office, and the Central Department of Geography for their precious input at the stage of land cover legends finalization as well as for the detailed useful comments on the final land cover maps. My deepest and sincerly appreciation goes to Mr. Prakash Joshi (Director General at Survey Department) and his team. Similarly gratitudes go to the members of Survey Committee,Technical Subcommittee for their important feedback,suggessition and validation of maps. We sincerely extend our gratitude to the MoFE for their support and validation of the NLCMS and its final land cover products.

In particular, I would like to acknowledge the efforts of the following scientists who have played a decisive role in the successful development of the NLCMS:

Technical Team (GoN): Amul Kumar Acharya, Bimal Kumar Acharya, Sangita Shakya, Apsara Paudel and Kiran Kumar Pokharel.

Technical Team (SERVIR): Bikram Shakya, Birendra Bajracharya, Kabir Uddin, Sajana Maharjan, and Sudip Pradhan.

Data Collection Team: Amul Kumar Acharya, Ananda Khadka, Apsara Paudel, Kabir Uddin, Raja Ram Aryal, Sajana Maharjan and Sangita Shakya.

Field Validation Team: Amul Kumar Acharya, Anand Khadka, Apsara Paudel, Bhisma Ghimire, Bimal Kumar Acharya, Birendra Bajracharya, Kabir Uddin, Sangita Shakya, and Tirtha Raj Baral.

Report Review and Production Team: Amul Kumar Acharya, Ananda Khadka, Bimal Kumar Acharya, Sangita Shakya, Apsara Paudel, Bishnu Prasad Dhakal, Dharma Maharjan, Gauri Shankar Dangol, Kiran Kumar Pokharel, Rabindra Maharjan, Rachana Chettri, Raj Kumar Giri, Raja Ram Aryal and Rajendra KC.

Finally, I would like to thank all contributors who were directly or indirectly involved in developing the NLCMS of Nepal.

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Rajendra KC, Ph.D.
Director General

Acronyms and Abbreviations

BRDF	Bidirectional Reflectance Distribution Function
CBS	Central Bureau of Statistics
CEO	Collect Earth Online
DEM	Digital Elevation Model
EROS	Earth Resources Observing System
ETM	Enhanced Thematic Mapper
FAO	Food and Agriculture Organization of the United Nations
FRA	Forest Resource Assessment
FRTC	Forest Research and Training Centre
GEE	Google Earth Engine
GEOSS	Global Earth Observation System of Systems
GFOI	Global Forest Observations Initiative
GFRA	Global Forest Resource Assessment
GIS	Geographic Information Systems
GLAD	Global Land Analysis and Discovery
HKH	Hindu Kush Himalaya
ICIMOD	International Centre for Integrated Mountain Development
LCC	Lambert Conformal Conic
IPCC	Intergovernmental Panel on Climate Change
LCCS	Land Cover Classification System
LULC	Land Use and Land Cover
MoFE	Ministry of Forests and Environment
MRV	Monitoring, Reporting and Verification
NASA	National Aeronautics and Space Administration
NIR	Near Infra-Red
NOAA	National Oceanic and Atmospheric Administration
NLCMS	National Land Cover Monitoring System
OSM	Open Street Map
OWL	Other Wooded Land
REDD	Reducing Emissions from Deforestation and Forest Degradation
RLCMS	Regional Land Cover Monitoring System
RS	Remote Sensing
SEPAL	System for Earth Observation Data Access, Processing and Analysis for Land Monitoring
SWIR	Short Wave Infra-Red
TDOM:	Temporal Dark Outlier Mask
UMD	University of Maryland
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
USAID	U.S. Agency for International Development
USFS	United States Forest Service
WGS	World Geodetic System
UNFCCC	United Nations Framework Convention on Climate Change

कार्यकारी सारांश

नेपाल सरकार, वन तथा वातावरण मन्त्रालय अन्तर्गतको वन अनुसन्धान तथा प्रशिक्षण केन्द्र तथा अन्तर्राष्ट्रिय एकीकृत पर्वतीय विकास केन्द्र (इसिमोड) को सहकार्यमा SERVIR– HKH द्वारा आफ्नो अध्ययन क्षेत्रमा रहेको भू-क्षेत्र (Land Cover) को अनुगमन गर्न तयार गरिएको विधि र पद्धति अनुशरण गरी नेपालको भू-क्षेत्रको अनुगमन गर्न राष्ट्रिय भू-क्षेत्र अनुगमन प्रणाली (National Land Cover Monitoring System -NLCMS) विकास गरी नेपालको भू-क्षेत्र तथ्याङ्क तथा अनुगमन कार्य गरिदै आएको छ। राष्ट्रिय भू-क्षेत्र अनुगमन प्रणाली तयार गर्दा भू क्षेत्रको वर्गीकरण गर्न विभिन्न क्षेत्रका विज्ञ एवं सरोकारवाला निकायका प्रतिनिधिहरूको सुझाव लिइएको थियो। सरोकारवाला निकायको सुझावका आधारमा देशको कुल क्षेत्रफललाई वन (Forest), कम घनत्व भएको वनवुट्यान क्षेत्र (Other Wooded Land), घाँसे मैदान (Grassland), जल क्षेत्र (Water body), नदी वगर (River bed), कृषि क्षेत्र (Cropland), हिँउले ढाकिएको क्षेत्र (Snow), हिमनदी (Glaciers), खाली जमिन (Bare soil), चट्टान (Bare rock) र निर्मित आवास तथा पूर्वाधारले ढाकिएको क्षेत्र (Built–up) गरी एघार प्रकारको भू क्षेत्रमा वर्गीकरण गरी क्षेत्रफल मापन तथा नक्साङ्कन गरिएको छ ।

आफ्नो आवश्यकता अनुसार दूर संवेदन/भौगोलिक सूचना प्रणाली लगायतको आधुनिक प्रविधिको प्रयोग गरी यस प्रणालीको माध्यमबाट निरन्तर रुपमा भू-क्षेत्रहरूको परिवर्तन मापन गर्न सकिन्छ। वन अनुसन्धान तथा प्रशिक्षण केन्द्रले सन् २००० देखि २०१९ सम्मको भू-क्षेत्रहरू परिवर्तनको प्रतिवेदन सन् २०२२ मा प्रकाशित गरिसकेको छ। यस पछाडिको भू-क्षेत्र परिवर्तनका सन्दर्भमा सन् २०२० देखि २०२२ सम्मको भू-क्षेत्रहरूका तथ्याङ्क र भू-क्षेत्र परिवर्तन विश्लेषणको विस्तृत जानकारी यस प्रतिवेदनले प्रदान गर्दछ। यस प्रतिवेदनले भू-क्षेत्र परिवर्तनलाई सजिलोसँग बुझ्न र तथ्यमा आधारित नीति निर्माणमा सहयोग पुऱ्याउन सकोस् भन्ने मनसायले राष्ट्रियस्तरका साथै प्रादेशिकस्तर र भौगोलिक क्षेत्र अनुसारको तथ्याङ्क उपलब्ध गराउँदछ। यस प्रतिवेदनमा उल्लेखित भू-क्षेत्र परिवर्तनको सामयिक र आवधिक तथ्याङ्कको विवरण राष्ट्रिय र नेपाल पक्षराष्ट्र भएका विभिन्न अन्तर्राष्ट्रिय संघसंस्थाहरूमा नियमितरुपमा विश्वसनीय प्रतिवेदन प्रस्तुत गर्न, व्यवहारिक रणनीतिक योजना निर्माण गर्न, विभिन्न अनुसन्धानका साथै वन र अन्य सम्बन्धित क्षेत्रहरूका विकासका लागि महत्वपूर्ण हुने विश्वास लिइएको छ।

वन अनुसन्धान तथा प्रशिक्षण केन्द्रले सन् २००० देखि २०१९ सम्मको NLCMS प्रतिवेदन तयार गर्न प्रयोग गरिएका विधिहरूलाई नै यसपटक पनि राष्ट्रिय भू-क्षेत्र अनुगमन प्रणाली (NLCMS) प्रतिवेदन तयार गर्न प्रयोग गरिएको छ। यस अध्ययनमा भू-क्षेत्रको नक्साहरु तयार गर्न Landsat-५,७ र ८ भू-उपग्रहबाट लिइएको तस्बिरहरु, Digital Elevation Model (DEM), र संयुक्तराज्य अमेरिकाको मेरिल्याण्ड विश्वविद्यालयको Global Land Analysis Discovery (GLAD) ल्याव द्वारा तयार गरिएको रुख छत्रको उचाई (Tree Canopy Height) र रुख छत्रले ढाकिएको क्षेत्र (Tree Canopy Cover)का तथ्याङ्कहरु प्रयोग गरिएको छ। हिम नदी र हिमताल (Glacier) को लागि इसिमोडबाट उपलब्ध गराइएको तथ्याङ्क प्रयोग भएको छ यसका साथै National Oceanic and Atmospheric Administration (NOAA) को Nighttime light data / Open Street Map(OSM) को निर्मित क्षेत्र (Built–up) को तथ्याङ्कहरु समेत प्रयोग गरिएको छ। सन् २०२०, २०२१ र २०२२ को Land Cover नक्सा तथा प्रतिवेदन तयार गर्दा भू-क्षेत्र को आंकलन गन WGS 1984 मा रहेको Land Cover सम्बन्धी तथ्याङ्कलाई Lambert Conformal Conic (LCC) Projection System मा परिवर्तन गरी नेपालको क्षेत्रफल १,४७,५१६ वर्ग किलोमिटरसँग समायोजन गरी विभिन्न भू-क्षेत्रको क्षेत्रफल आंकलन गरिएको छ।

इसिमोड को SERVIR–HKH पहल अन्तर्गत बिकसित क्षेत्रीय भू-क्षेत्र अनुगमन प्रणाली (RLCMS) मा प्रयोग गरिएको विधिको आधारमा नेपालको भू-क्षेत्र नक्सा (Land cover map) तयार गरिएको थियो। नेपालको भू-क्षेत्र लाई ११ वटा विभिन्न भू-क्षेत्र वर्गहरू

पहिचान गर्नका लागि चित्रको पूर्व-प्रसंस्करण, सहायक भेरिएबलहरूको तयारी, प्राथमिकता उत्पादनका लागि supervised machine learning algorithms बाट primitive generation, temporal smoothing, र assemblage को काम Google Earth Engine (GEE) को कम्प्युटेशनल प्लेटफर्ममा तयार गरिएको छ।

यस प्रतिवेदन अनुसार सन् २०२२ मा नेपालमा ४३.३८% (६३,९९,३४१ हेक्टर) क्षेत्रफल वन रहेको छ जुन यस अगाडि प्रकाशन गरिएको प्रतिवेदन अनुसार सन् २०१९ मा ४१.७१% (६१,५२,८०६ हेक्टर) रहेको थियो। यो सन् २०१९ को तुलनामा १.६७% (२,४६,५३५ हेक्टर) बढोत्तरी भएको छ। सन् २०२२ मा नेपालमा करीब १९% भू-भागमा चट्टान (Bare rock), हिउँ (Snow), हिमनदी (Glaciers),वनवुट्यान (Other Wooded Land [OWL]), नदी बगर (Riverbed), निर्मित क्षेत्र (Built–up Areas), जल क्षेत्र (Water body) र खालीजग्गा (Bare soil) समावेश छ। सन् २०१९ सबैभन्दा बढी (४१.७१%) भू-भाग वनले ढाकिएको थियो भने दोस्रोमा कृषिक्षेत्र (२४.३४%) र तेस्रोमा घाँसे मैदान (१३.२७%) रहेको थियो।

सन् २०२२ मा नेपालको तराईमा सबैभन्दा बढी (६५.४%) भू-भाग कृषिक्षेत्रको रुपमा रहेको छ। यस्तै गरी चुरेक्षेत्र, मध्य पहाड र उच्च पहाडमा सबैभन्दा बढी भू-भाग क्रमशः ७३.६७%, ६४.५४% र ५७.२०% वनक्षेत्रले ओगटेको छ भने उच्च हिमालीक्षेत्रमा सबैभन्दा बढी (४१.५९%) भू-भाग घाँसेमैदानले ओगटेको छ। सन् २०१९ को तुलनामा सन् २०२२ मा घाँसे मैदानहरूको क्षेत्रफल नेपालको सबै भौगोलिक क्षेत्रहरूमा बढेको देखिन्छ। वन क्षेत्र तराई, चुरे र मध्य पहाडी क्षेत्रहरूमा वृद्धि भएको छ। त्यस्तैगरी उक्त अवधिमा वनवुट्यान (OWL) नेपालका सबै भौगोलिक क्षेत्रहरूमा घटेको छ। कृषिभूमि तराई ऽ चुरे, मध्य पहाडका साथै समग्रमा नेपालमा घटेको पाइन्छ। यसको विपरित, निर्मित क्षेत्र (Built–up areas) भने क्रमिक रूपमा सबै क्षेत्रहरूमा बढिरहेको छ।

यस अध्ययनले सन् २०१९को तुलनामा सन् २०२२मा वनक्षेत्र, निर्मित क्षेत्र र घाँसे मैदान क्रमशः १.६७%, २.७०% र १.४४% ले वृद्धि भएको छ भने कृषिक्षेत्र (Cropland), वनवुट्यान (OWL), नदी बगर (River bed), चट्टान (Bare rocks) क्रमशः १.७५ %, ०.९२%, ०.३४% र ०.३९% ले घटेको छ। यस अध्ययनले वनवुट्यान (OWL) र केही कृषिक्षेत्र वनमा रूपान्तरण भएको देखाएको छ। त्यस्तै, कृषिक्षेत्र आवास तथा पूर्वाधार जस्ता निर्मित क्षेत्र (Built up area)मा परिवर्तन भएको छ। यसैगरी उक्त ३ वर्षको अवधिमा चट्टान क्षेत्र मुख्यतया घाँसेमैदानमा परिवर्तन भएको छ। सन् २०१९ देखि २०२२ सम्मको भू-क्षेत्र परिवर्तन सम्बन्धी यस अध्ययनको समग्र शुद्धता ८४.९७% छ र कुल कप्पा तथ्याङ्क ०.७६ रहेको छ। यसैगरी, सन् २०२२ को भूमि क्षेत्र (IPCC वर्गहरू) को समग्र शुद्धता ८९.१३% छ र कुल कप्पा तथ्याङ्क ०.८१ प्रतिशत रहेको छ।

यस अध्ययनबाट प्राप्त नतिजा आगामी दिनमा राष्ट्रिय तथा क्षेत्रीय स्तरको नीति निर्माण, रणनीतिक योजना तर्जुमाका साथै नेपाल पक्ष राष्ट्र भएका सरोकारवाला निकायमा प्रतिवेदन प्रस्तुत गर्नका साथै विभिन्न वन तथा सोसंग सरोकार राख्ने व्यक्ति् तथा संघ संस्थालाई अध्ययन अनुसन्धान गर्न सूचना तथा तथ्याङ्कको लागि सहयोगी हुने विश्वास गरिएको छ।

Executive Summary

The National Land Cover Monitoring System (NLCMS) has been developed to produce annual land cover maps by using consistent and robust remote sensing datasets. This is an operational and flexible system to produce land cover maps.

The Forest Research and Training Centre previously published a report in 2022 detailing land cover changes from 2000 to 2019. This new report offers a comprehensive analysis of land cover statistics and changes from 2020 to 2022, covering national, provincial, and physiographic levels. These types of information are important for national and international reporting, strategic planning, research, and development in forestry and other related sectors.

The current NLCMS methodology was applied to produce the NLCMS report of the years 2000 to 2019, published in 2022. Land cover maps have been prepared by using Landsat 5, 7 and 8 images, and other additional layers such as Digital Elevation Model (DEM), tree canopy height, and tree canopy cover data which were provided by the Global Land Analysis and Discovery lab (GLAD) of the University of Maryland (UMD). Similarly, the glaciers and glacial lakes data were generated by ICIMOD and built-up area layers and nighttime light data layers were sourced from Open Street Map (OSM) and National Oceanic and Atmospheric Administration (NOAA) respectively.

The land cover of Nepal was mapped based on the approach and methodology used in the Regional Land Cover Monitoring System (RLCMS) developed under ICIMOD's SERVIR-HKH Initiative and uses a co-development approach with relevant stakeholders. Eleven land cover classes were identified for the country. The steps such as image pre-processing, preparation of covariates, utilization of supervised machine learning algorithms for primitive generation, temporal smoothing, and assemblage were performed on Google Earth Engine (GEE) computational platform.

The total forest area of the country covers 43.38 % (6,399,341 ha) in 2022, whereas, in 2019, it was 41.71% (6,152,806 ha). Approximately 19% of the land cover consists of the bare rock, snow, glaciers, OWL, riverbeds, built-up areas, water bodies, and bare soil, in descending order. In the year 2019, forest was the dominant land cover with 41.71%, followed by cropland (26.44%) and grassland (13.96%). In 2022, forests (43.38%) and OWL (2.70%) together accounted for 46.08% of Nepal's total land area which is a slight increased by 0.75% from 2019.

Province-level land cover statistics from 2019 and 2022 revealed variations in land cover scenarios across provinces. Forest cover dominates in all provinces, with the highest coverage in Bagmati, Lumbini, Sudurpaschim, Koshi, Gandaki, and Karnali at 58.62%, 54.66%, 51.33%, 46.23%, 37.98%, and 27.93%, respectively, except for Madhesh Province, where forest cover is just 25.86% of the total land .

Cropland is dominant in the Terai region, which is 65.40% whereas in Siwalik, Middle Mountain, and High Mountain, forest predominates occupying 73.67%, 64.54%, and 57.20% of the land, respectively. In contrast, grassland dominates in the High Himal covering 41.59 % of total area in 2022 .

Grassland has increased in Terai and High Himal. Forest cover has increased in all geographic regions, while it has slightly decreased by 4,123 ha in the High Himal regions from 2019 to 2022. Additionally, OWL has decreased in all physiographic regions during this period. Cropland has descreased in all physiographic regions except High Mountains and High Himal. Meanwhile, built-up areas have steadily grown across all regions.

The land cover change analysis between 2019 and 2022 showed that forest,built up areas, and grassland increased by 1.67 % , 2.70%, and 1.44% respectively while cropland and OWL decreased by 1.75% and 0.92% respectively. The assessment showed that the part of OWL, and cropland have been converted to the forest. Similarly, some parts of cropland have changed to built-up areas whereas bare rock has mainly changed to grassland from 2019 to 2022. The overall classification accuracy is 84.97% and the overall kappa statistic is 0.76. Also, the overall accuracy of the land cover (IPCC classes) 2022 is 89.13%, and the overall kappa statistic is 0.81.

This latest study on land cover change is expected to serve policy makers and other stakeholders to take evidence based decision about land resource management in Nepal.

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1. Introduction

Land cover maps offer valuable information about the biophysical features on the Earth's surface, serving as a geographic reference for disciplines such as geography, ecology, geology, forestry, land policy, and planning (FAO, 2016). The social, economic, and cultural benefits (Turner et al., 1996), along with ecosystem functions (Defries et al., 2009), are expressed through land use patterns. Land use typically involves the management and modification of the natural environment. The alteration of the earth's surface by anthropogenic activities is usually known as land use and land cover change.

Timely, comprehensive, and precise information on land cover and change dynamics play an indispensable role in policy development, planning, management, and other data-based decisions in most sectors (Lambin et al., 2001; Poortinga et al., 2018; Turner et al., 1995) including forest management.Land cover characterization and mapping are crucial for natural resource planning and management (e.g., development, conservation), environmental modeling, and evaluating ecosystem status and changes, such as logging (Cohen et al., 2010; Jin et al., 2005, Kennedy et al., 2010), glacier retreat (Berthier et al., 2007; Bolch, 2007; Burns et al., 2014; Wei et al., 2014), and urban expansion (Song et al., 20016; Weng et al., 2001; Thomas et al., 2011).

The progress of a country significantly depends on its utilization of modern technology in the monitoring and management of natural resources. Earth observation science and machine learning algorithms are among the most advanced technologies employed for monitoring natural resources and developing management plans. These technologies allow the acquisition of information on various Earth phenomena without direct physical interaction with the ground. Such information is crucial for constructing evidence-based decision-making frameworks regarding the management of natural resources.

Geographic information systems (GIS) and remote sensing have been widely employed and are affordable instruments to track the temporal and geographical dynamics of LULC change worldwide (Huang et al 2021;Lambin et al; Liping et al; 2018). Assessing land cover and considering its dynamics can support sustainable natural resource management, environmental protection, and food security (Andrew et al., 2014; GCOS, 2003; GEOSS, 2005; Herold et al., 2006, 2008; Lambin et al., 2001).

There are several direct and indirect drivers of land use and land cover (LULC) change, such as deforestation, reforestation, infrastructure development, mining, climate change, and migration (Veldkamp and Lambin, 2001). For instance, the conversion of natural ecosystems for agricultural activities has been a major driver of land use and land cover changes (Ramankutty et al., 1999). Continual changes in the way land is used for subsistence and other basic needs are changing land cover (Foley et al., 2005). Thus, land cover change is a dynamic process in which anthropogenic and natural activities (Lambin et al., 2003) influence biophysical processes (Li & Shao, 2014).

The unlimited availability of Earth observation data with global coverage and emerging analytical tools and techniques offers an unprecedented ability to monitor global land cover change scenarios in a cost-effective manner. Advancements in the spatial, temporal, and spectral resolution of satellite data, along with open access, rapid growth in computing power, and cloud-based systems with drastically reduced associated costs over the past decade, have enabled users to process data and develop land cover products efficiently without requiring substantial investments in computing infrastructure (Gorelick et al., 2017; Yang et al., 2017).

1.1 Land cover mapping in Nepal

Nepal has undergone rapid urbanization over the past two decades. Nepal is among the fastest urbanizing countries in the world (UNDESA, 2014). The expansion of infrastructures and superstructures could, therefore, be considered an important element of land cover change in Nepal (Ishtiaque et al., 2017). Historically, factors like grazing, shifting cultivation, illegal/selective logging, flooding, and urbanization have been identified as the main drivers of land cover change in Nepal (Paudel et al., 2016).

Nepal has a long history of preparing a national land cover map, especially a national forest cover map, which provides the fundamental information required for national and international reports. The first attempts at a national level for forest inventory were made between 1963 and 1967 (FRS, 1967). Visual interpretation of aerial photographs taken in 1953–1958 and 1963–1964, mapping, and field inventory were used to create the map during the first national forest inventory. The Land Resource Mapping Project (LRMP) conducted the first comprehensive mapping of the land system in 1986, utilizing aerial photographs from 1978/79 at a scale of 1:50,000 to produce several datasets, including Geology, Land System, Land Use, and Land Potentials (LRMP, 1986). Likewise, a second national forest inventory began in the early 1990s and was completed in 1998, using 1994 as the base year. During this inventory, forest cover was mapped using Landsat satellite images, aerial photographs, and field data. After a prolonged hiatus, the Department of Forest (DoF) of Nepal has generated a forest cover change map for 20 districts in the Terai physiographic region, utilizing Landsat satellite imagery and ground validation (DoF, 2005).

In the continuous effort to advancing the nation's mapping, the Survey Department (SD) of Nepal produced a new series of Topographic Base Maps (TBMs) in 1:25,000 (for Terai and Mid-mountains) and 1:50,000 (for higher Mountains and Himalayas) covering the entire country in paper print between 1992 and 2001 and then converted all these maps into digital form and made them available to users as the National Topographic Database (NTDB). Additionally, the Survey Department generated and published Topographical Base Maps of Nepal between 1992 and 2001 at a scale of 1:25,000 for the Terai and Mid-Mountain and 1:50,000 for the High Mountains and High Himal (Wagle & Acharya, 2020). The International Centre for Integrated Mountain Development (ICIMOD) developed detailed national-level land cover maps from 1990, 2000, and 2010 using Landsat TM satellite imagery at 30 m resolution to study decadal changes (Uddin et al., 2015).

The most recent Forest Resource Assessment (FRA) used high-resolution Rapid Eye imagery (5 m resolution) to produce a comprehensive forest cover map (DFRS, 2015). Recently, Nepal prepared a national forest reference level for REDD implementation using Landsat data from 2000 and 2010 (MoFSC, 2016).

A significant challenge in these mapping efforts is the lack of comparability between different land cover products, mainly due to inconsistencies in input data such as satellite imagery, methodologies, and classification systems used for mapping. As a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), Nepal is required to prepare land use and land cover (LULC) information as per the Intergovernmental Panel on Climate Change (IPCC) guidelines for estimating greenhouse gas emissions and removals (IPCC, 2006). Periodic or annual land cover maps that are comparable, provide essential information about land cover changes. This information is essential for international reporting and to inform land use, forestry, and greenhouse gas mitigation policies at the national, provincial, and local levels. NASA's Landsat-8 Operational Land Imager (OLI) sensor played a key role in generating annual land cover maps using a more advanced methodology and approach. Landsat data, freely accessible since July 1972, enabled detailed visualization of the land.

Nepal released a report of NLCMS in 2022 that describes the land cover from 2000 to 2019, and this report is based on land cover data from 2020 to 2022. Nepal requires a strong land cover monitoring system to meet both national and international data requirements. This effort to produce the second NLCMS aims to meet subnational, national, and international requirements.

1.2 Objectives

The main objective of the National Land Cover Monitoring System is to produce annual land cover maps of Nepal using standardized and consistent satellite data and methodology. The specific objectives are as follows:

a) Estimate the land cover area of the country

b) Develop a land cover change matrix

c) Analyze patterns of land cover changes

2. The NLCMS approach

Nepal released its first national land cover change report in 2022, analyzing changes between 2000 and 2019 using the NLCMS approach. The 2nd national land cover change study also followed the same NLCMS approach which was built on the approach and methodology developed for the Regional Land Cover Mapping System (RLCMS). This system, developed under ICIMOD's SERVIR-HKH Initiative, utilized a co-development process that involved active stakeholder engagement. Engagement activities encompassed subnational and national consultations, online questionnaire surveys, and provincial and national mapping workshops that were conducted during the last decade in the lower Mekong and the Hindu Kush Himalaya (HKH) regions. Incorporating stakeholder suggestions, the RLCMS considered the following design criteria into account to ensure its alignment with regional and national needs:

Flexibility

- The system employs land cover "primitives" or continuous layers of biophysical attributes (e.g., forest cover) that can be swapped for the most state-of-the-art product available at any time.
- The system incorporates land cover typologies according to the country's requirements.

Consistency

- Each country has access to the same set of primitives and assembly systems, with different assembly logic rule sets to accommodate diverse land cover definitions.

Based on remotely sensed data

- The system is data-driven with access to datasets provided by novel cloud computing tools.

Explicit quantification of uncertainty

- Monte-Carlo methods incorporate uncertainty from primitives to provide pixel based estimates of land cover uncertainty.
- Traditional land cover map assessment methods, such as error matrices, are calculated on the final land cover assemblage product.

Capacity building

- The collaborative nature of the system facilitates the exchange of information and technology.
- Free and widely accessible tools and public data are used wherever possible.

The RLCMS is built on the Google Earth Engine (GEE) computational platform. The GEE is an online service that applies cloud computing and storage frameworks to geospatial datasets. The GEE archive holds a vast collection of Earth observation data, allowing scientists to perform calculations on large data series in parallel. The RLCMS was developed based on Landsat images to generate land cover data at 30m spatial resolution, following specific criteria for data selection

- Defining spatial and temporal data requirements
- Data should be freely accessible to ensure sustainability
- Produced consistently to support annual monitoring
- Moderate resolution suitable for national-level assessments
- Availability of historical data for longer-term analysis

Table 1 outlines the available open-source and commercial satellite imageries that are used for classification of land cover. Landsat data were used to generate NLCMS as it requires access to historical data archive

Table 1: Launch and operational phases of different satellite images

	GOES	MODIS	Landsat	Sentinel	SPOT	IKONOS	Planet Labs
Spectral resolution	5	7	9	13	5	4	3
Spatial resolution	4.6 km x 4.2 km	250m–1km	30m	10, 20, 60m	10m, 20m, 1.5 km	1m, 4m	5m
Temporal resolution	Hourly	1-2 days	16 days	5 days	26 days (S1-7), 1day (S4-5)	3-5 days	Daily
Historical archive	1975–present	1999–present	1972–present	2014–present	1986–present	2000–present	2013–present
Access	Free	Free	Free	Free	Charges apply	Charges apply	Charges apply

Technical collaboration

The NLCMS is the customized version of the RLCMS, which was developed collaboratively. The modular design of the RLCMS allows for greater flexibility and broader collaboration. It has been further tailored into the National Land Cover Monitoring System (NLCMS) and implemented in Afghanistan, Bangladesh, Myanmar and Nepal to address specific country needs. SERVIR-Mekong led by the Asian Disaster Preparedness Centre (ADPC), and SERVIR-HKH led by ICIMOD, serve as the regional hubs of SERVIR, working with regional and country partners in the lower Mekong and HKH regions to implement the system. The National Aeronautics and Space Administration (NASA) and United States Forest Service (USFS) provided technical support in developing the algorithms and applying them in Google Earth Engine (GEE). NASA is collaborating with FAO and facilitating the conversion for an online reference data collection system called Collect Earth Online (CEO) to implement the RLCMS framework into its System for Earth Observation Data Access, Processing and Analysis for Land Monitoring (SEPAL). The USAID-funded SilvaCarbon project also assisted in organizing training and workshops. Additionally, further collaboration occurred on individual primitive levels. The University of Maryland collaborated in customizing a tree cover algorithm to produce tree cover and height data.

3. Methodology

The general methodology of the NLCMS involves eight major steps: 1) defining the land cover classification schemes and land cover typology, 2) collecting land cover training samples, 3) selection of Landsat imagery, image correction, preparation of annual composites, 4) selection of additional thematic data, creation of image indices and covariates to make input layers for machine learning, 5) utilization of supervised machine learning algorithms and creation of land cover primitives, primitives evaluation and smoothing, 6) input of annual tree canopy cover and height, 7) construction of customized land cover maps by modifying the assemblage logic using a decision tree, and 8) validation of the land cover maps and assessment of accuracy. A systematic flowchart illustrating the NLCMS development process is shown in Figure 1, with further details provided in the description below.

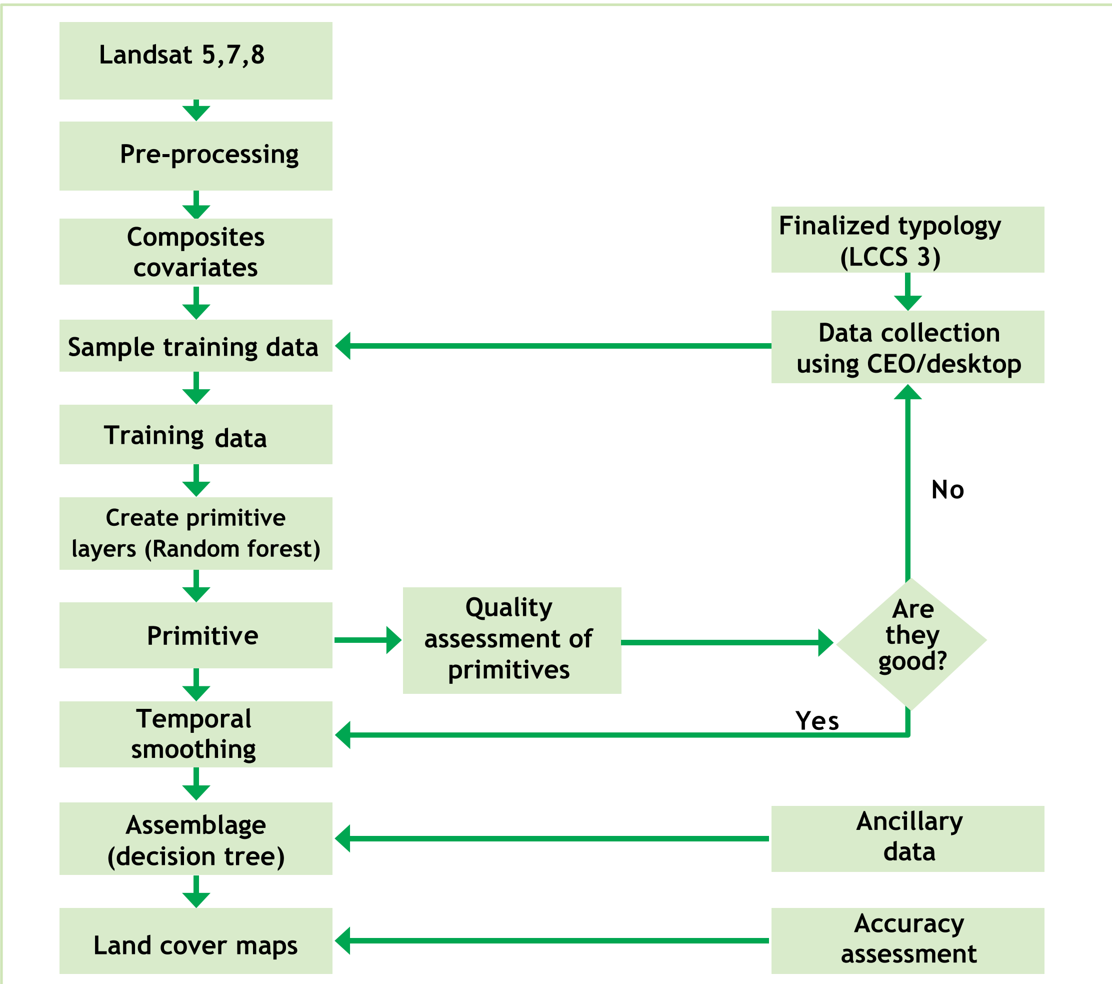


Figure 1: Flowchart of the overall applied methods in preparing NLCMS

3.1 Establish land cover typology

The first step in creating land cover maps is to establish the typology. The NLCMS requires well-defined and comprehensive land cover typologies, which are essential for determining how maps are assembled and for gathering reference data. A classification system, or typology, must be clear, precise, and based on objective standards (Bajracharya et al., 2010). A workshop was organized by the FRTC to establish the typology of the NLCMS in Nepal, bringing together participants from several departments, including the Ministry of Forests and Environment, Department of Agriculture, Department of Forest and Soil Conservation, National Statistics Office, and the Central Department of Geography and Survey Department (Figure 2). The workshop resulted in an agreement on 11 land cover categories for Nepal: forest, cropland, built-up area, glacier, snow, water body, riverbed, bare soil, bare rock, grassland, and other wooded land. However, Nepal is also required to report to the Intergovernmental Panel on Climate Change (IPCC) with six land use classes for REDD and Global Forest Resource Assessment (GFRA), making these typologies ideal for accurately representing the country's current land cover in the comprehensive maps. The Land Cover Classification System (LCCS) Software version 3, developed by the FAO, was used to define each of these classes. A detailed list of land cover categories and their definitions is provided in Table 2.

Table 2: Land cover classes and definition

NLCMS Land cover Value	Main land cover class	Description	IPCC land cover class	IPCC Value
4	Forest	Land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10%, or trees able to reach these thresholds in-situ. It does not include land that is predominantly under agricultural or urban land use.	Forest Land	1
11	Other wooded land (OWL)	Land not classified as forest spanning more than 0.5 ha, having at least 20 m width and a tree canopy cover of trees between 5% and 10%. or The canopy cover of trees less than 5% but the combined cover of shrubs, bushes and trees more than 10%; includes areas of shrubs and bushes where no trees are present.	Forest Land	1
10	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.	Grassland	3
7	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.	Cropland	2
6	Built-up area	Built-up areas refer to artificial structures such as towns, villages, industrial areas, airports, etc.	Settlements	5

NLCMS Land cover Value	Main land cover class	Description	IPCC land cover class	IPCC Value
1	Water body	Rivers are natural flowing water bodies and typically have elongated shapes. Lakes and ponds are perennial standing water bodies.	Wetlands	4
5	Riverbed	A tract of land without vegetation surrounded by the waters of rivers, stream & lakes it usually includes any accretion in a river course.	Wetlands	4
8	Bare soil	A soil surface devoid of any plant material.	Other	6
9	Bare rock	Non-vegetated areas with a rock surface.	Other	6
3	Snow	This class describes perennial snow (persistence > 9 months per year).	Other	6
2	Glacier	Perennial ice in movement.	Other	6

Grassland inside Shuklaphanta National Park *(Photo by Rajendra KC)*

Figure 2: Workshop on National Land Cover Classification System for Nepal *(Photo: FRTC)*

3.2 Collecting land cover training samples

Quality-assured reference data is key for the development of the NLCMS and assessment of the results. A total of 46,000 reference samples were collected and some data were collected from the 2 x 2 km grid spread over the entire country and additional data were collected purporsively as shown in Figure 3 using Collect Earth desktop software. The quality of those points was rechecked thoroughly using high-resolution satellite imageries, and differential indices of vegetation, water and snow. Thereafter, those points that were not considered quality reference points for the particular land cover typology assigned previously were removed. Additional reference data were collected from high-resolution satellite images using the Collect Earth Online (CEO platform). These data were divided into two lots: i) primitive generation and ii) accuracy assessment of final land cover maps to produce a confusion/error matrix.

3.3 Image preprocessing and preparation of covariates

Landsat 5, 7 and 8 images were used for land cover classification. Various preprocessing steps such as cloud masking, shadow masking, bidirectional reflectance distribution function (BRDF), and topographic correction were performed to reduce distortion effects (Young et al., 2017). Pixels with cloud and cloud shadows were removed in cloud and shadow masking respectively. Clouds were masked using a pixel-qa band and the Google cloud Score algorithm. Google's cloud Score algorithm uses the spectral and thermal properties of clouds to identify and remove pixels with cloud cover from the imagery. The algorithm identifies pixels that are bright and cold and then compares them to the spectral properties of snow. The snow score was also calculated using the Normalized Difference Snow Index (NDSI) to prevent snow from being masked. The algorithm calculates scaled cloud scores for the blue, all visible, near-infrared, and shortwave infrared bands and then takes the minimum. The algorithm was described by Chastain et al. (2019).

To remove cloud shadows, Temporal Dark Outlier Mask (TDOM) algorithm (Housman et al., in review), was applied which detects pixels that are dark in the infrared bands but not consistently dark across past or future observations. This is achieved by identifying statistical outliers based on the sum of the infrared bands. Subsequently, dark pixels were identified by using the combined values of the infrared bands (NIR, SWIR1, and SWIR2). The pixel quality attributes generated from the CFMask, C code based on the Function of Mask (Fmask) algorithm (pixel-qa band) were also used for shadow masking. The nadir view angles of the Landsat satellites cause directional reflection on the surface, which can be described by the BRDF (Lucht et al., 2000 ; Roy et al., 2016, 2017). BRDF correction involves correcting differences in illumination between images.This was necessary to improve image quality. Topographic correction for Landsat images is necessary for study areas that exhibit mountainous topographic characteristics such as slope and aspect, as they can cause variations in spectral radiance within a particular land cover (Vanonckelen et al., 2013; Moreira et al., 2014).

The Modified Sun-Canopy-Sensor Topographic Correction method was followed, as explained by Soenen et al. (2005). This algorithm uses a modified Sun-Canopy-Sensor (SCS) model to account for diffuse radiation. After preprocessing, composites for every year (2020–2022) were prepared by consolidating all available images for each year into a single image (Figure 4). Every single image (composite) represented a particular year and was used to prepare the land cover map for that year. Each pixel value of the composite is a medoid, the observed value closest to the median. Each composite consists of 24 bands. It includes Landsat bands such as red, green, blue, NIR, SWIR1 and SWIR2, the percentile of these bands, percentile of indices such as NDVI, snow index, and urban index. A composite for 2012 was not prepared due to Landsat -7 ETM+ SLC (Scan Line Corrector) of images (Chen et al., 2011).

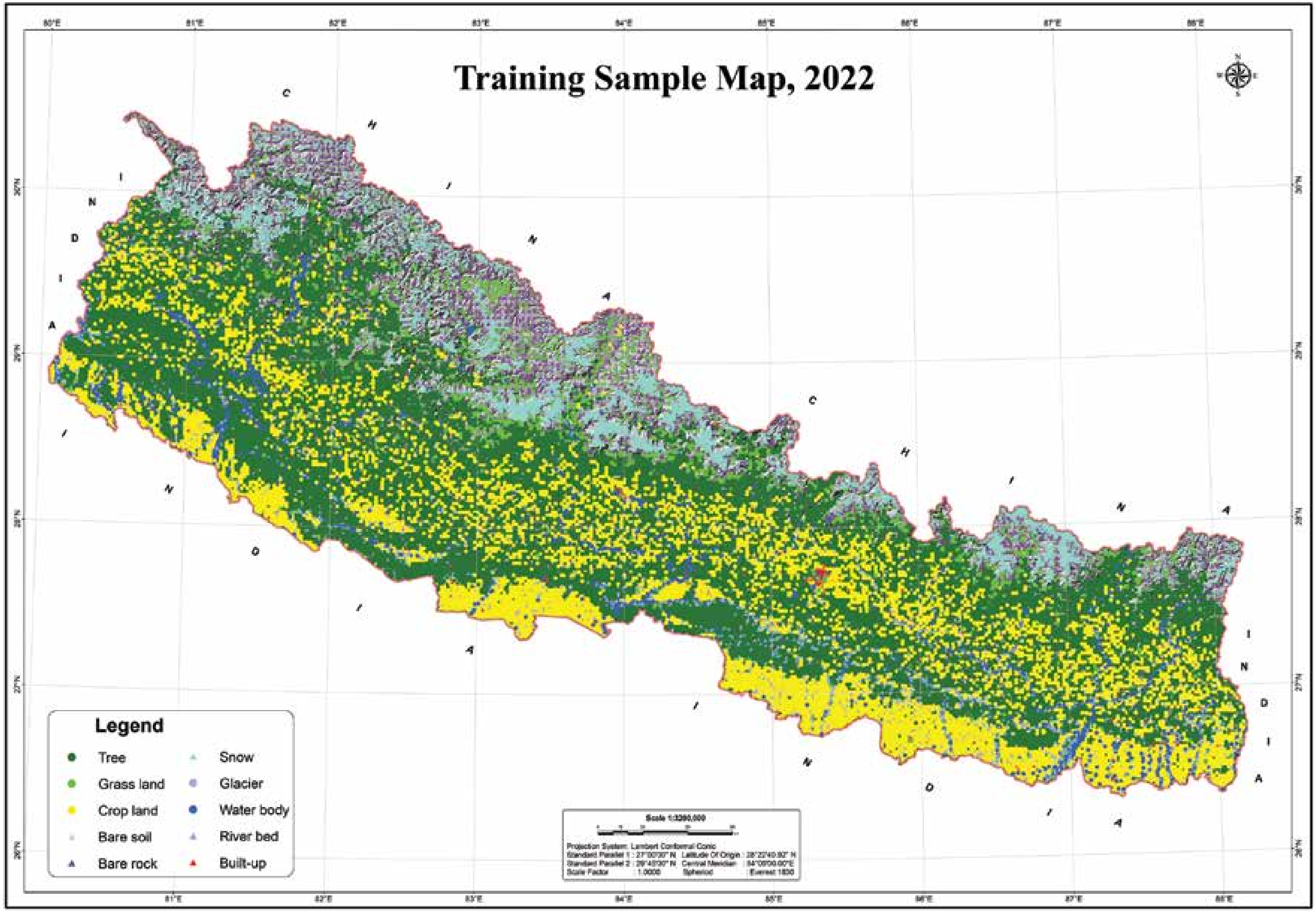


Figure 3: Distribution of Land cover training samples across the Nepal.

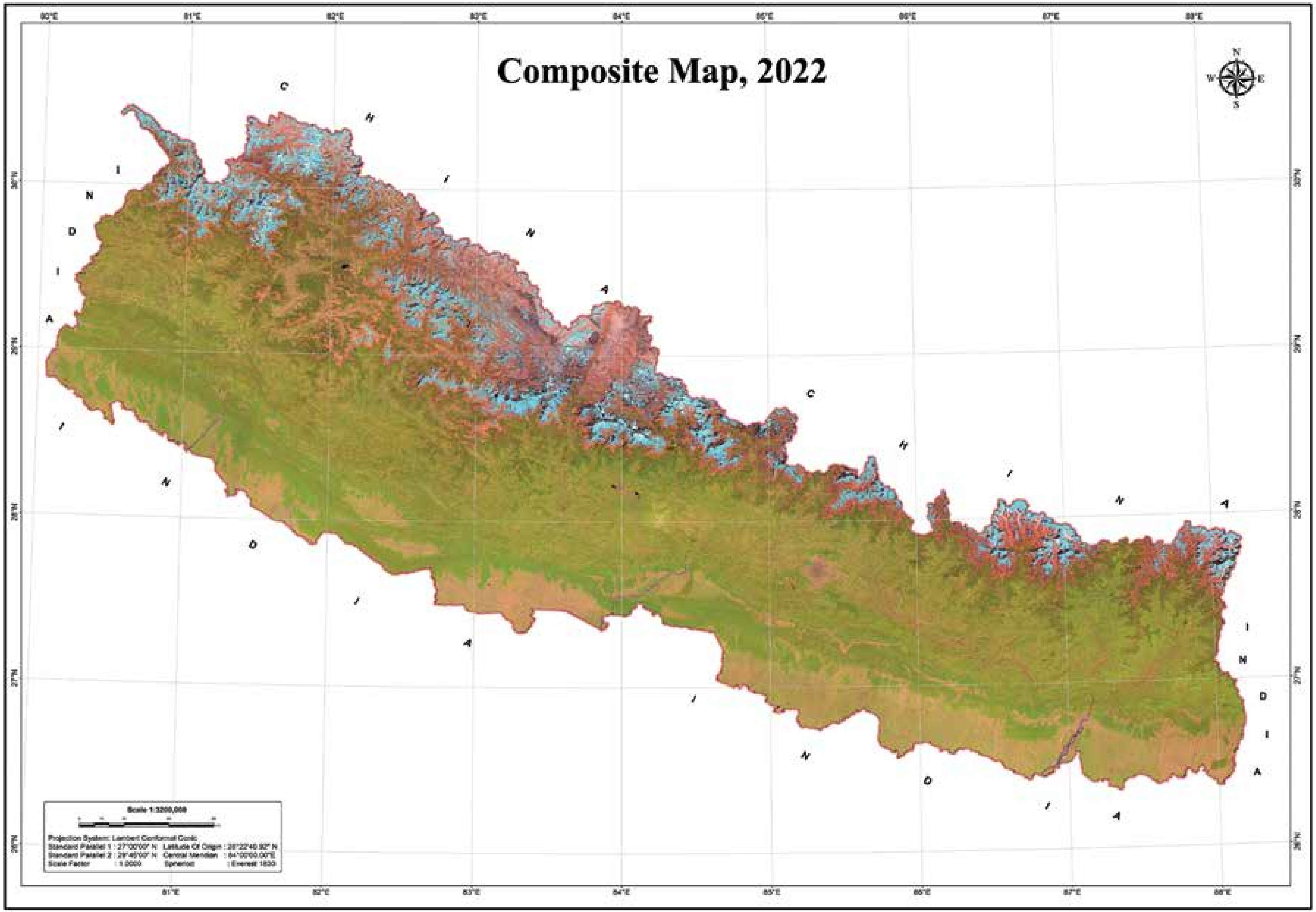


Figure 4: A true color composite of the Landsat image used for the land cover analysis, green color represents forest, cyan color indicates snow area

3.4 Primitive generation and smoothing

Primitives are building blocks for generating land cover maps (Saah et al., 2020). They are mappable biophysical elements that can be used alone or in combination to define a class. It is a probability layer, which means each pixel of the layer represents the probability of particular biophysical features. This approach has made the system highly flexible as land cover classification can be done based on the adopted definition of the classes, which might vary with multiple stakeholders.

Since there are 76 covariates, it is important to understand which covariates contribute to better separating particular primitives from others. Temporal Smoothing Algorithms proposed by Khanal et al. (2020) were implemented in RStudio Software (R Core Team, 2020) to prioritize covariates for generating each primitive layer (Saah et al., 2020). The order of covariates was different for each primitive. Using this information and a Random Forest classifier, primitives were generated. Initially, nine primitives were generated through this process. They were bare rock, bare soil, built-up area, cropland, tree, water, snow, grassland, and riverbed.

3.4.1 Temporal smoothing

Land cover data is sometimes inconsistent when compared across different years due to noise and misclassification in data for some years. A temporal smoothing technique was used to reduce these noises and make the data temporally consistent. Temporal smoothing was applied for some primitives such as tree, built up area, riverbed, and grassland (Figure 5). A Fourier Smoothing algorithm was used in this process (Khanal et al., 2020).

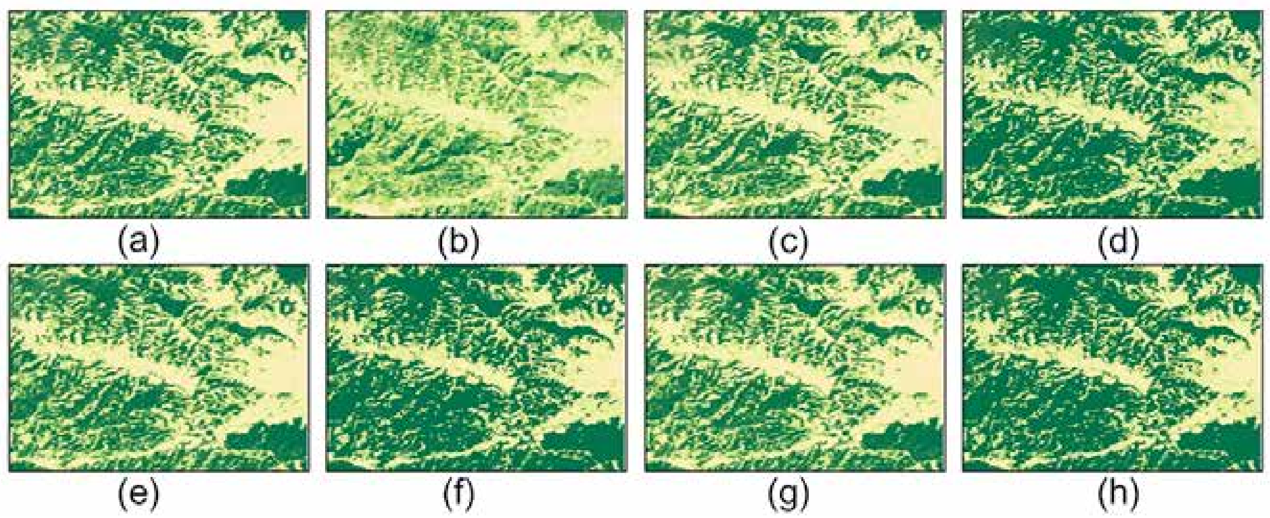


Figure 5: Demonstration of forest (green) and other land cover (yellow) from 2019 to 2021 in the middle part of the study region (a–d) display un-smoothened results for 2019, 2020, 2021, and 2022 respectively. In the same way, (e–h) show smoothened results for 2019, 2020, 2021, and 2022 respectively. A considerable improvement can be seen in 2020. These are the final results generated from the best primitive set, i.e., picking the best primitives after applying different algorithms on each primitive.

3.5 Input of annual tree cover height from UMD GLAD

Global Land Analysis and Discovery Lab (GLAD) at the University of Maryland has been developing tree canopy cover and height at a global scale. GLAD global initiation and algorithm were customized and improved through collaboration between SERVIR to produce annual dynamics of woody vegetation structure and primary forest extent. The products were consistent at the regional level and provided at a spatial resolution appropriate for the national analysis. For the NLCMS, we used the tree canopy cover and tree cover height data developed by Potapov et al. 2020 as inputs for land cover mapping. The tree canopy height represents the median height of the top of the tree canopy above the ground. The map value represents canopy height in metres for each year. The regional tree cover and height model were calibrated using tropical airborne lidar data and applied annually.

3.6 Land cover assemblage

All the generated primitives and other additional layers such as DEM, tree canopy height, and tree canopy cover provided by Global Land Analysis and Discovery (GLAD) and the University of Maryland (UMD), glacier and glacial lake data generated by ICIMOD, built-up layers of the open street map (OSM), and night light were also used as external primitives in the assemblage. During the assemblage, a decision tree classifier was used to classify each pixel and produce the land cover map. The primitive and assemblage processes are shown in Figure 6. In the assemblage, land cover classes are classified in the following order;

(i) Water body	(ii) Glacier	(iii) Snow
(iv) Forest	(v) River bed	(vi) Built-up
(vii) Crop land	(viii) Bare soil	(ix) Bare rock
(x) Grassland	(xi) Other wooded land	

Cropland adjoining forest areas at Sandhikharka Municipality, Arghakhanchi *(Photo by Rajendra KC)*

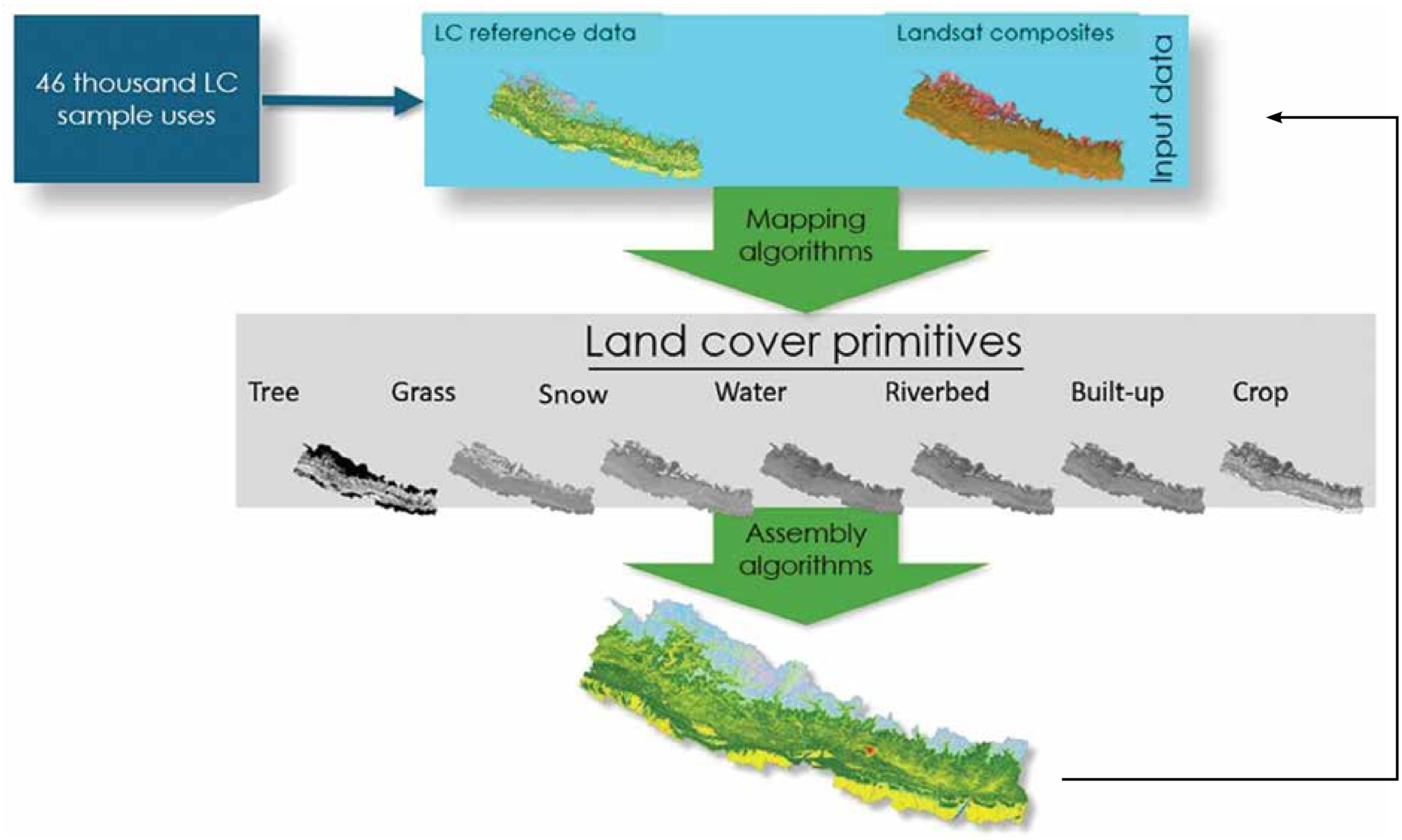


Figure 6: Fundamental steps used for land cover mapping of Nepal

3.7 Accuracy assessment

The accuracy assessment process in remote sensing-based land cover classification is defined as the evaluation of the agreement between reference samples and the classified image. A classification error occurs when a pixel or feature is incorrectly categorized. Accuracy assessment can be conducted using qualitative methods, such as visual interpretation, or through quantitative methods that rely on statistical analysis. The error matrix method is frequently utilized for quantitative accuracy assessments. This statistical approach involves comparing the classification results with a set of reference data.

The accuracy assessment used land cover data from the most recent year, 2022 for the land cover map of Nepal and for validation, independent reference data (4452 points) were collected from various sources. A total of 321 points were obtained in the field using cellphone applications, which also allowed for the collection of geotagged photos in offline mode (Figure 7). The validation points and photos were uploaded directly to the server without manual input. Additionally, 1700 permanent sample plots from FRTC's Forest Resource Assessment were incorporated, along with another 2431 points collected using the latest version of CEO. Figure 8 illustrates the spatial distribution of points used for the validation assessment across the country.

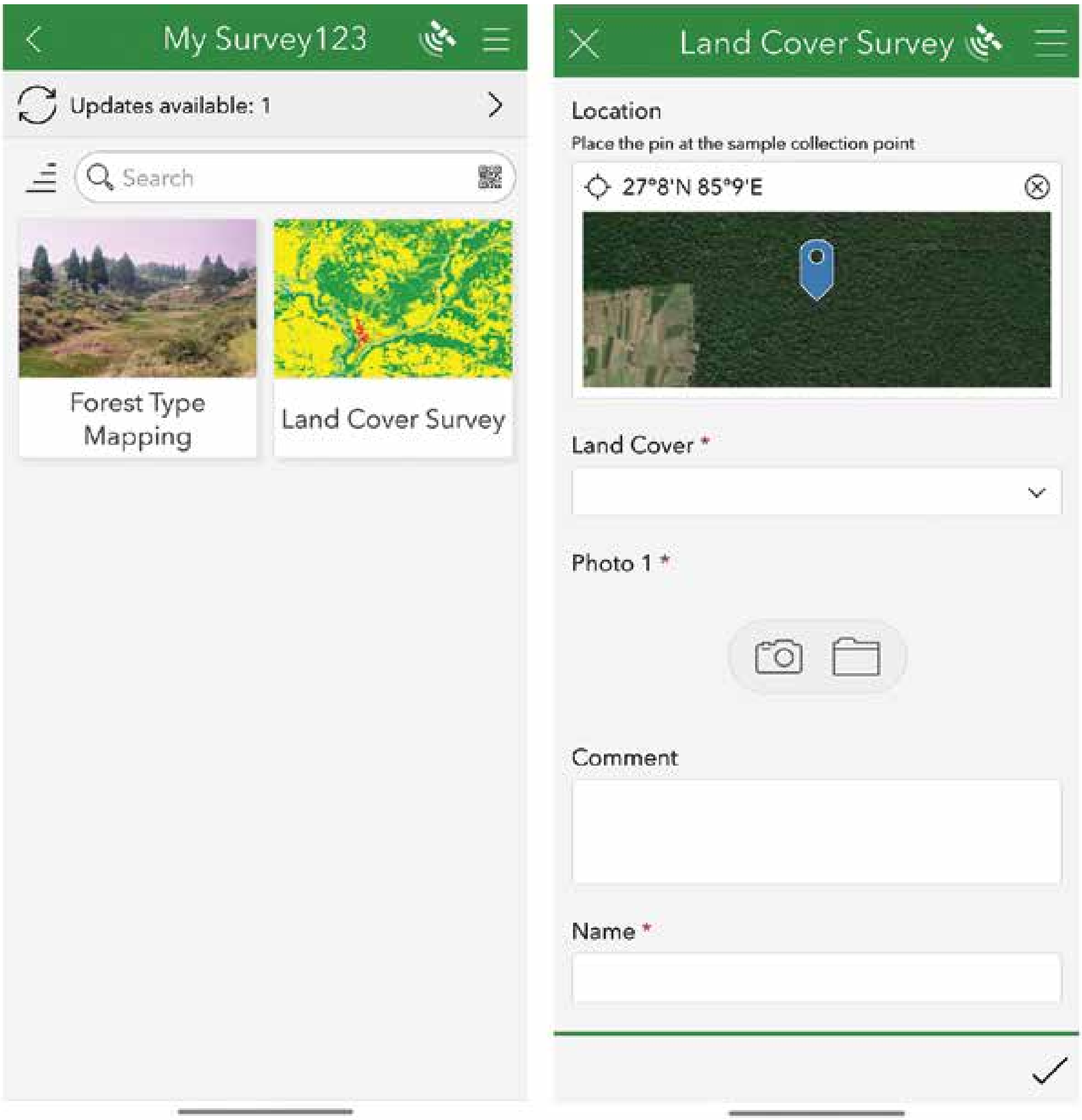


Figure 7: Mobile application used for field-based validation of land cover analysis

3.8 Projection system

Primarily, the output of NLCMS is in the World Geodetic System (WGS, 1984). The data from WGS 1984 were transformed into National Geodetic Datum (Nepal Datum) using seven parameters (Table 3) suggested by Manandhar (2015).

Table 3: Transformation parameters for WGS84 to National Geodetic Datum (Nepal Datum)

Name	Value
X Axis Translation (meters)	124.3813
Y Axis Translation (meters)	-521.6700
Z Axis Translation (meters)	-764.5137
X Axis Rotation (seconds)	-17.1488
Y Axis Rotation (seconds)	8.11536
Z Axis Rotation (seconds)	-11.1842
Scale Difference (ppm)	2.1105

Further, transformed data (Nepal Datum) is converted into Lambert Conformal Conic (LCC) Projection System where following parameters shown in Table 4 were adopted.

Table 4 : Projection parameters for Lambert Conformal Conic (LCC) System

Parameter	Value
False Easting	500000
False Northing	500000
Central Meridian	84°00'00"E
Standard Parallel 1	27°00'00"N
Standard Parallel 2	29.75°00'00"N
Scale Factor	1.0
Latitude of Origin	28°22'40.92" N

Meanwhile, land cover statistics at the national, provincial and physiographic levels are calculated using the Lambert Conformal Conic (LCC) projection system. After projected into LCC system, land cover statistics of NLCMS 2024 (2020-2022) have been adjusted to total area of Nepal (147,516 sq.km). Additionally, the land cover statistics of NLCMS 2022 (2000-2019) have also been readjusted to the total area of the country.

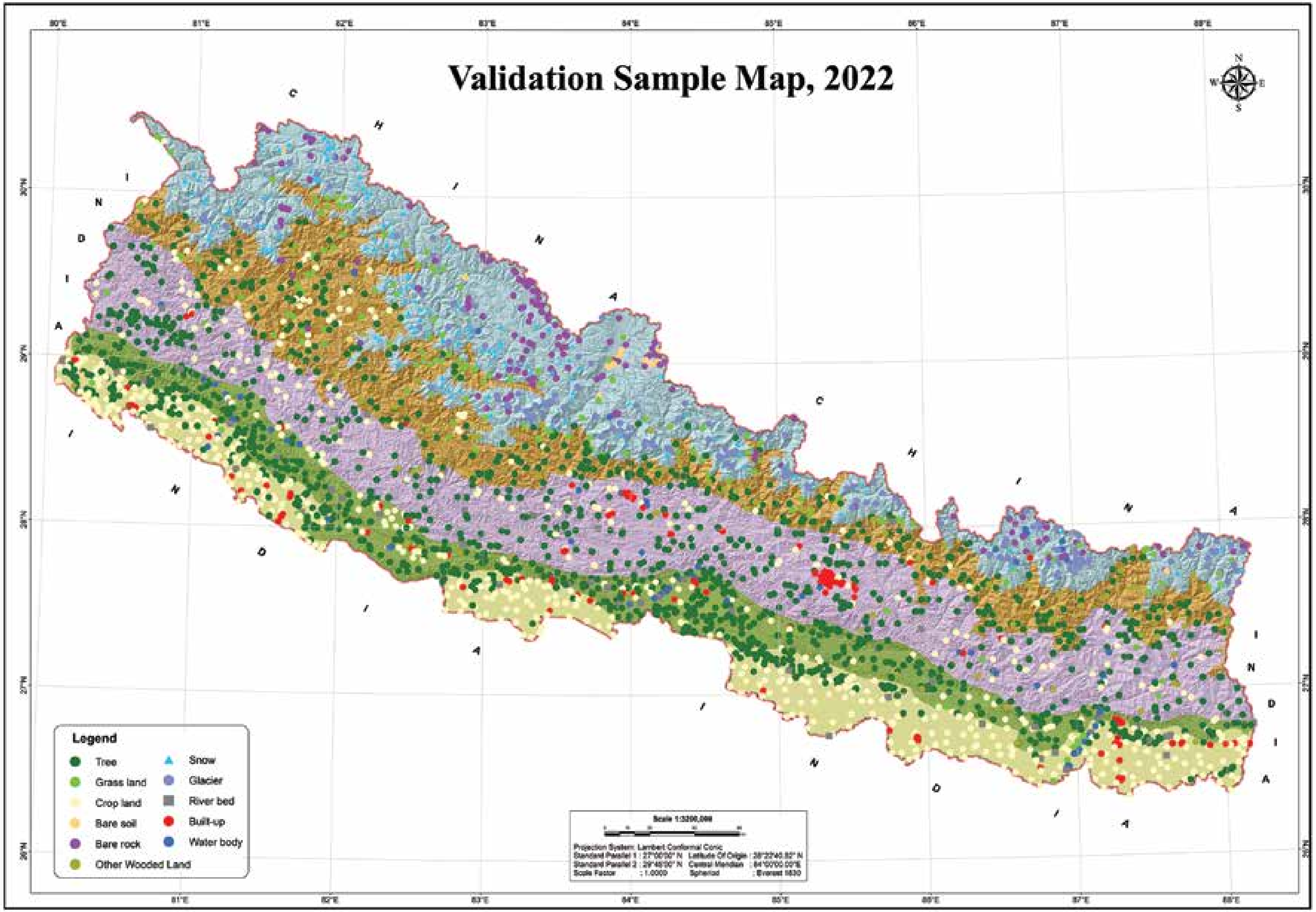


Figure 8: Spatial distribution of validation points used for land cover assessment in Nepal

4. Results and discussion

4.1 National land cover

Land cover area statistics from the land cover map of 2019 - 2022 are presented in Annex 1. The land cover area for the year 2022 is given in Figure 9. In 2022, forest cover is the dominant land cover with 43.38%, followed by cropland with 22.59%, grassland with 14.71%, and other wooded land with 2.70%. Remaining around 19% land cover is occupied by bare rock, snow, glacier, OWL, riverbed, built-up, water body, and bare soil in descending order. Forest (43.38%) and OWL (2.70%) together covered 46.08 % of total land area in 2022. The land cover maps from 2020, 2021 and 2022 are shown in Annex-4.

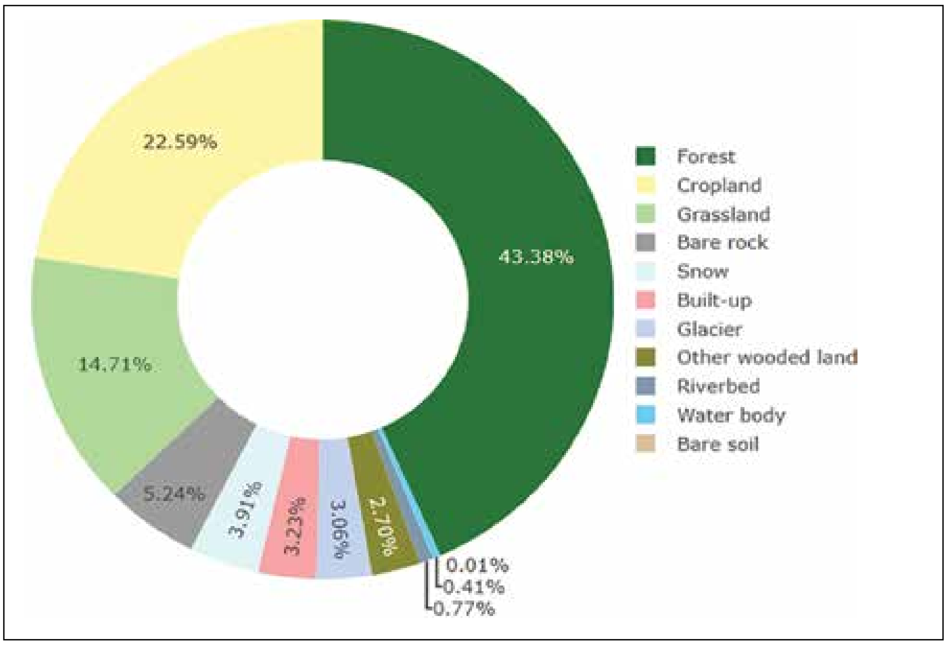


Figure 9: Land cover area of Nepal in 2022 AD

(Note: Land cover areas adjusted to the total area of Nepal (147,516 sq km) after using the Lambert Conformal Conic (LCC) map projection.)

4.2 Land cover at the province level

Land cover statistics at the provincial level for the years 2000, 2019, 2020, 2021 and 2022 are given in the Annex 2, which reveals the variations in land cover across different provinces of 2022. Forests are the most dominant land cover in the Bagmati, Lumbini, Sudurpaschim, Koshi, Gandaki, and Karnali provinces, while cropland is predominant in Madhesh. The land cover proportions in all seven provinces are illustrated in Figure 10 (a-g) and 11.

4.2.1 Koshi Province

Most of the land is covered by forests, accounting for 46.23%, followed by cropland, which covers 24.66%. Grassland is another significant land cover type in Koshi Province, ranking just after cropland as shown in (Figure 10 (a)).

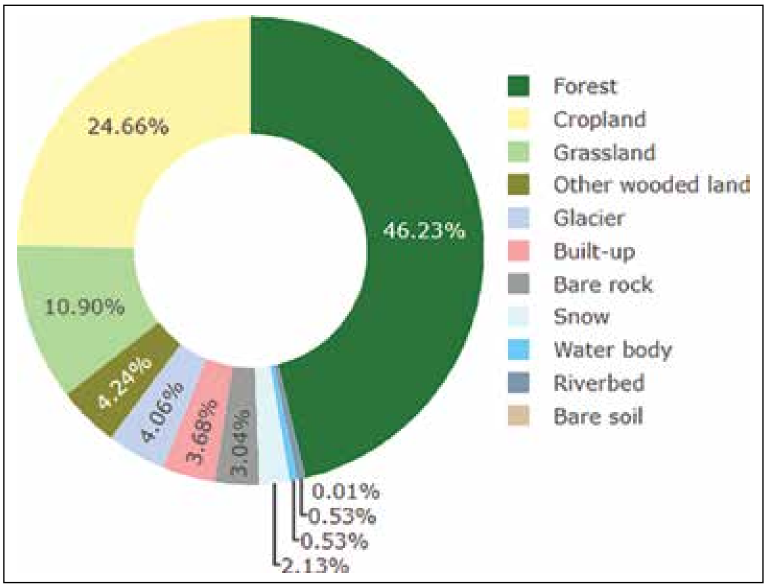


Figure 10 (a): Land cover area of Koshi province in 2022

4.2.2 Madhesh Province

Highest proportion land in Madhesh province is covered with cropland, accounting for 59.10% of the total land area of the province, followed by forest, which covers 25.86% of land. The third most dominant category of the province is built-up area, which covers 5.99% of the total provincial land coverage (Figure 10 (b)).

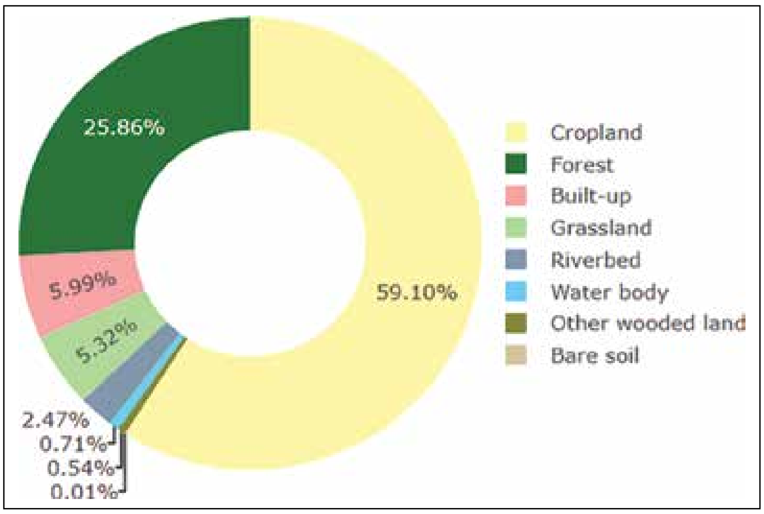


Figure 10 (b): Land cover area of Madhesh province in 2022

4.2.3 Bagmati Province

Most of the land is covered by forest covering 58.62 % followed by crop land having 18.96 %. Grassland is also the major land cover after cropland in Bagmati province. (Figure 10 (c)).

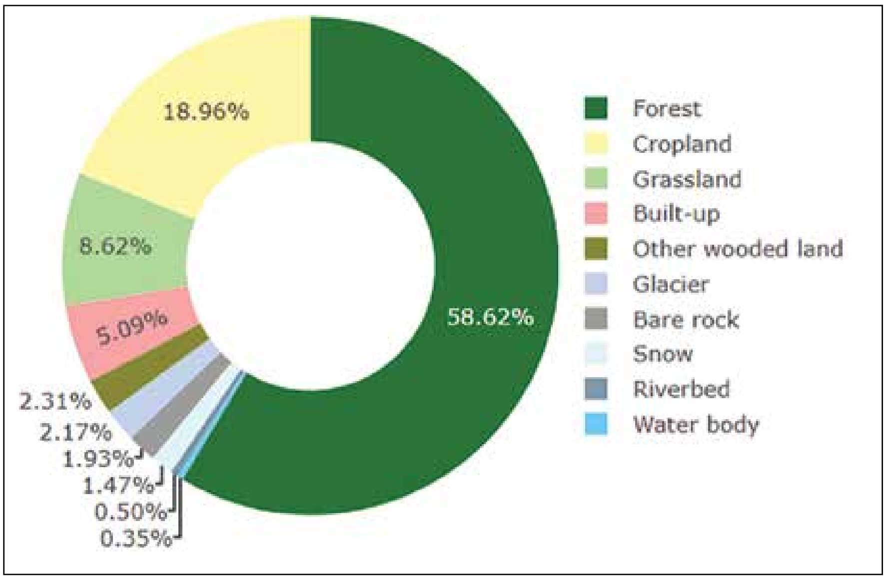


Figure 10 (c): Land cover area of Bagmati province in 2022

4.2.4 Gandaki Province

Highest proportion of land is covered by forest, covering 37.98 % followed by grassland, having 22.01%. Crop land is also a major land cover after grassland in Gandaki province (Figure 10 (d)).

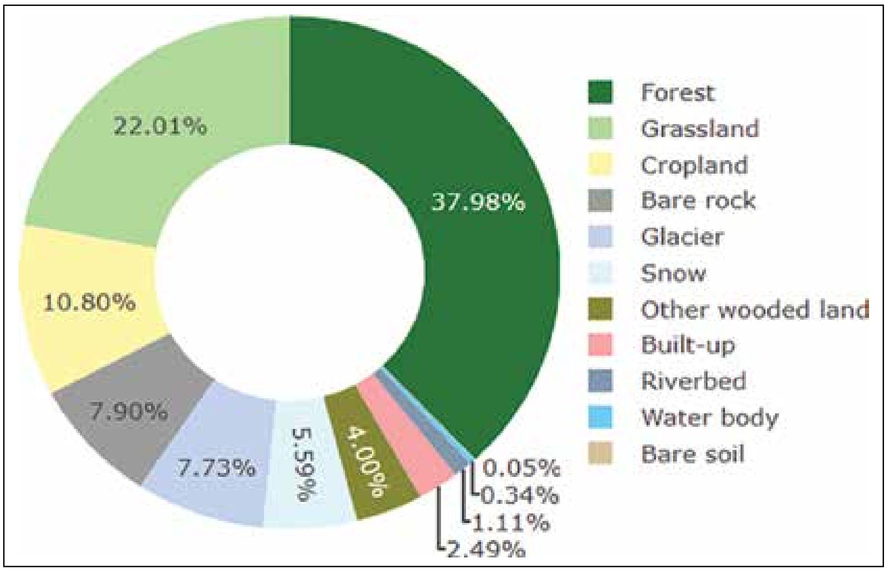


Figure 10 (d): Land cover area of Gandaki province in 2022

4.2.5 Lumbini Province

Highest proportion of land is covered by forests, accounting for 54.66%, followed by cropland at 32.02%. Grassland is also a major land cover after cropland in Lumbini province. Other 8 categories of land use consist of nearly 8.51% of land area of the province (Figure 10 (e)).

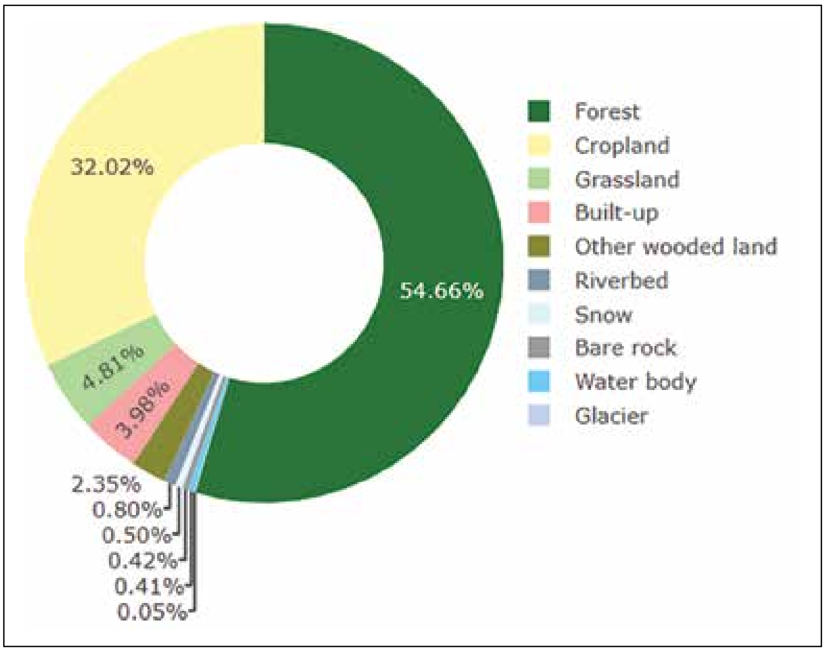


Figure 10 (e): Land cover area of Lumbini province in 2022

4.2.6 Karnali Province

The highest proportion of land in Karnali Province is covered by forests, which make up 27.93%, followed closely by the grasslands at 27.21%. Following forests and grasslands, cropland is the next dominant land cover in the province. Similarly the bare rock occupies the significant portion of land cover in this province (Figure 10 (f)).

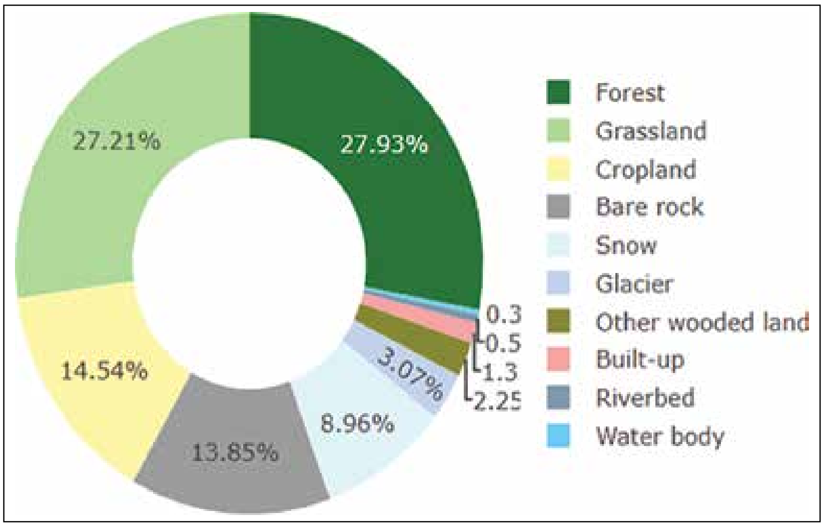


Figure 10 (f): Land cover area of Karnali province in 2022

4.2.7 Sudurpaschim Province

Highest proportion of land in this province is covered by forest covering 51.33% followed by cropland having 22.31%. Grassland is also a major land cover after cropland in Sudurpaschim province (Figure 10(g)).

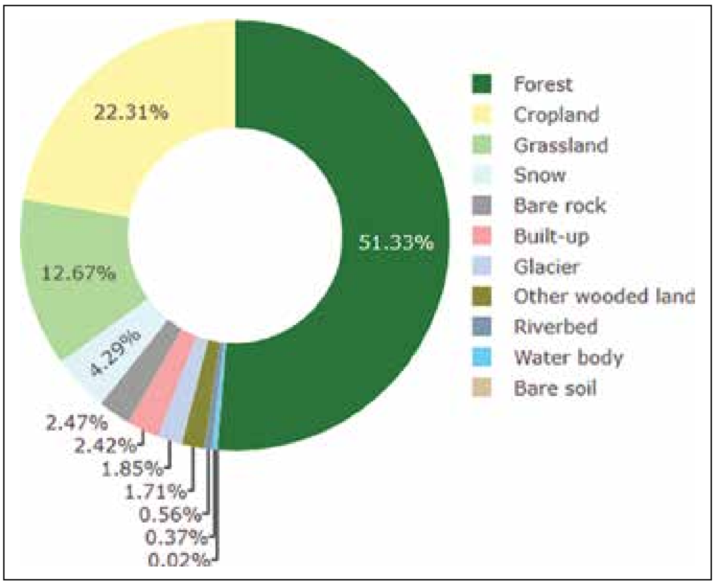


Figure 10 (g): Land cover area of Sudurpaschim province in 2022

All eleven catagories of land use accross all seven provinces could be compared from the Figure 11

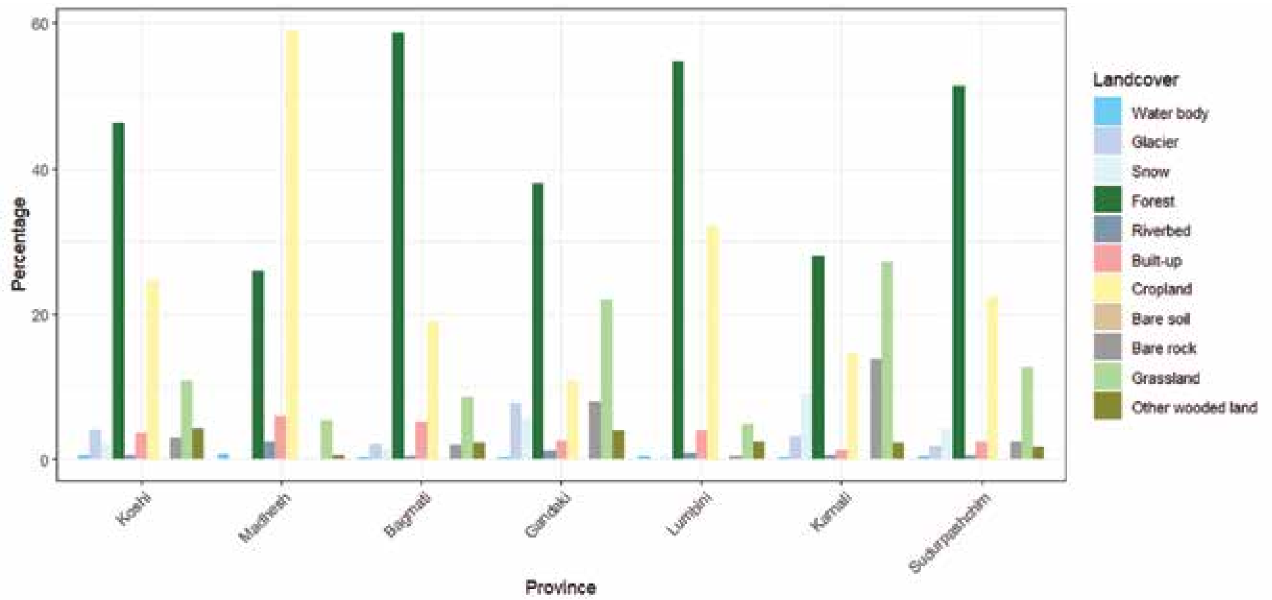
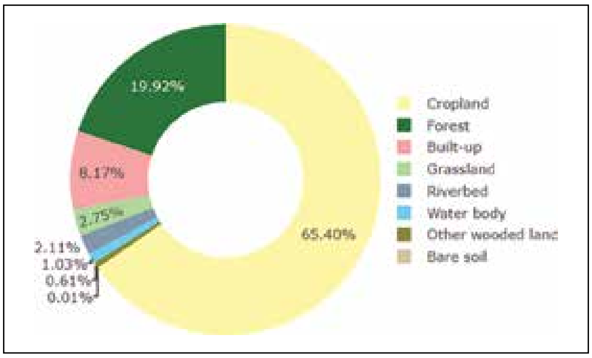


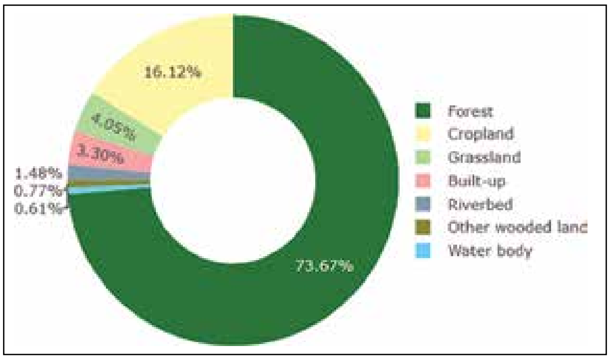
Figure 11: Bar graphs showing 11 categories of land cover in seven provinces

4.3 Land cover at physiographic regions

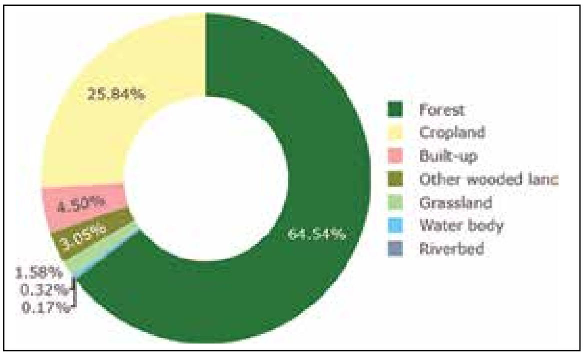
Land cover statistics for various physiographic regions are provided in Annex 3. In the Terai region cropland is dominant land cover which is 65.40% whereas in Siwalik, Middle Mountain and High Mountain, forest predominates occupying 73.67%, 64.54%, and 57.20% of the land respectively. In contrast, grassland dominates in the High Himal covering 41.59 % in 2022 Figure 12 (a-e). In the pie chart, we have represented land cover classes with values more than 0.01 % among the 11 land cover categories. Notably the Terai region is absent of bare rock, snow, and glaciers, and the Chure region also lacks snow and glaciers. While in the Middle Mountain areas, bare soil, snow, glaciers, and bare rock are also uncommon. Additionally, bare soil cover is minimal in the High Mountain regions. However, the High Himal uniquely encompasses all 11 land classes identified by the NLCMS.



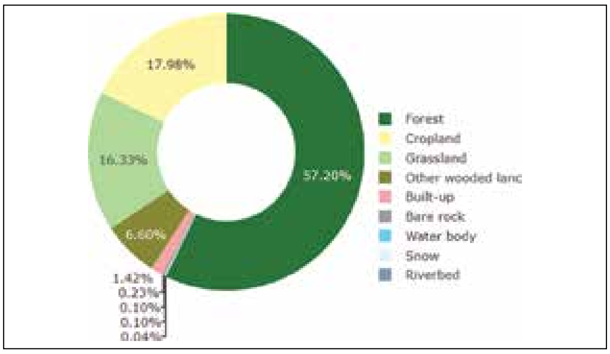
a) Terai



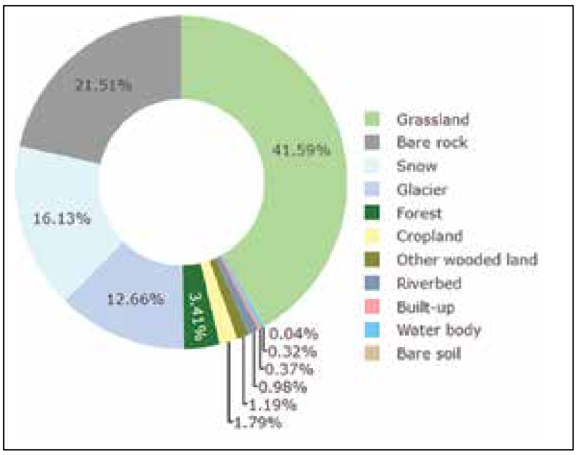
b) Chure



c) Middle Mountain



d) High Mountain



e) High Himal

Figure 12 (a-e): Land cover at physiographic regions

4.4 Forest (including OWL) changes between 2019 and 2022

The distribution of forests, including OWL, among Nepal's seven provinces is uneven. Koshi Province holds the largest share of the country's total forests at 19.28%, followed by Bagmati (18.12%), Lumbini (16.05%), Sudurpaschim (15.66%), Karnali (13.72%), and Gandaki (13.48%). In contrast, Madhesh Province had the smallest forest area, comprising just 3.69% of the total across all provinces in 2022. Forest cover has slightly increased in Koshi, Madhesh, Lumbini, and Sudurpaschim provinces, while it has slightly decreased in Bagmati, Gandaki, and Karnali provinces (Figure 13 & Annex 2).

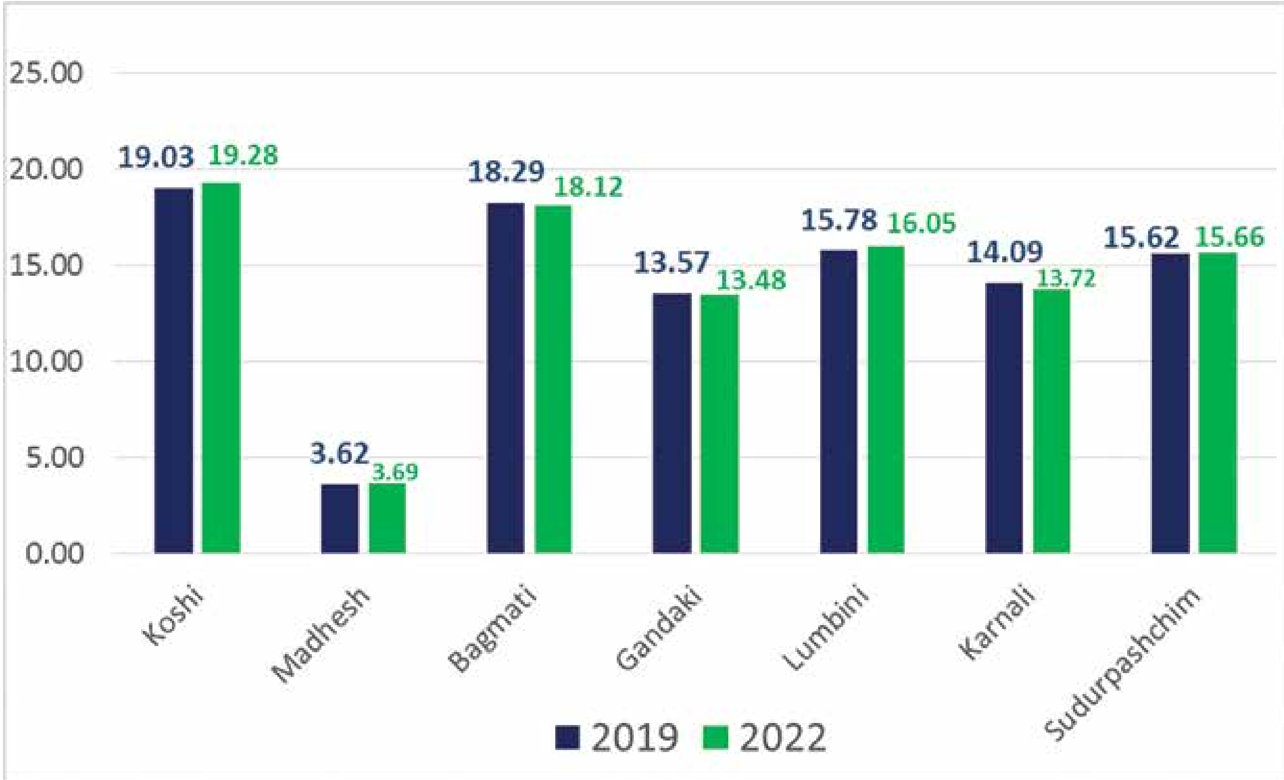


Figure 13: Forest (including OWL) changes between 2019 and 2022

4.5 Land cover change analysis

Nepal's land cover is undergoing minimal conversion across all 11 land cover classes in general as shown in Table 3. Overall, the forest area has increased from 2019 to 2022, while the areas of bare rock, cropland, and other wooded land have decreased. Built-up areas and grassland have also increased during this period. The change analysis of land cover data between 2019 and 2022 revealed that forests, built-up areas, and grasslands increased by 1.67%, 2.70%, and 1.44%, respectively. In contrast, cropland, other wooded land, and bare rock decreased by 1.75%, 0.92%, and 0.39%, respectively (Table 5).

The assessment indicated that other wooded land (OWL), and some cropland have been converted to forest areas. Similarly, portions of cropland have been transformed into built-up areas, while bare rock has primarily changed to grassland from 2019 to 2022. The area classified as snow has been fluctuating, likely due to changes in annual precipitation patterns and warming across the country. Variations in areas classified as snow lead to corresponding fluctuations in bare rock and grassland coverage, as these land types are typically concealed under snow. When snow cover recedes, these areas become exposed, resulting in noticeable shifts in their reported extent. A change matrix was generated (Table 6) using land cover data from 2019 and 2022.

Table 5: Land cover changes in percentage between 2019 and 2022

Land Cover	2019 (%)*	2022 (%)	Changes (%)
Water body	0.49	0.41	-0.08
Glacier	3.04	3.06	+0.02
Snow	6.23	3.91	-2.32
Forest	41.71	43.38	+1.67
River bed	1.11	0.77	-0.34
Built-up	0.53	3.23	+2.70
Crop land	24.34	22.59	-1.75
Bare soil	0.03	0.01	-0.02
Bare rock	5.63	5.24	-0.39
Grassland	13.27	14.71	+1.44
Other wooded land	3.62	2.70	-0.92

**Land Cover area is adjusted to Nepal's total area (147,516 sq km) so the statistics are slightly different from the NLCMS report, 2022.*

Figure 14 shows the distribution of forest cover change to other categories and vice versa. From these maps, it is apparent that in the eastern Terai, forest area has been converted to other land cover types in the Middle Mountain region, other land cover types have been converted to forest area. Figure 15 showing NLCMS web based GeoApps. GeoApps is an interactive, web-based tool designed to provide easy access to land cover data and statistics for a wide range of users. These applications offer access to land cover maps, enabling users to visualize, analyze and download data at national and sub-national scales. Figure 16 includes a number of examples of high-resolution satellite image windows that are chosen randomly over few areas and show their land cover change, with particular emphasis to the increase in Nepal forest cover. These satellite windows depict the transformation in forest areas, highlighting patches where vegetation has become denser over time. Other land use and land cover changes can be seen as, such as conversion of agricultural land, urbanized expansion, water bodies flow alterations etc. and it also illustrates a contrast between previous and current land uses.

Table 6: Land cover changes between 2019 and 2022

2019 (ha)	2022 (ha)											
	Land cover	Water body	Glacier	Snow	Forest	River bed	Built-up	Cropland	Bare soil	Bare rock	Grassland	OWL	Total
	Water body	45,665	1	44	604	7,742	452	4,063	333	89	12,749	83	71,825
	Glacier	2	448,464	98	0	0	1	0	0	70	130	0	448,765
	Snow	1,021	174,1	382,359	472	247	603	1,917	33	209,937	320,493	549	919,372
	Forest	657	0	5	5,764,789	179	39,016	131,657	0	1	107,303	10,9197	6,152,803
	River bed	7,997	0	22	2,811	63,053	2,181	56,439	189	13	30,411	871	163,986
	Built-up	403	0	282	39	2,389	74,128	356	2	55	499	2	78,155
	Crop land	2,991	0	0	338,791	7,162	34,6869	2,851,255	14	0	21,229	22,187	3,590,498
	Bare soil	29	0	54	5	228	14	74	770	298	2,533	5	4,011
	Bare rock	175	114	138,865	266	4,629	999	7,147	165	399,825	278,123	388	830,694
	Grassland	1,226	383	55,459	94,335	28,375	9,426	247,084	379	162,048	1,314,069	44,685	1,957,468
	OWL	68	0	37	197,231	23	2,191	32,578	0	28	81,916	219,950	534,023
	Total	60,233	45,0703	577,225	6,399,344	114,027	475,878	3,332,570	1,886	772,363	2,169,454	397,917	14,751,600

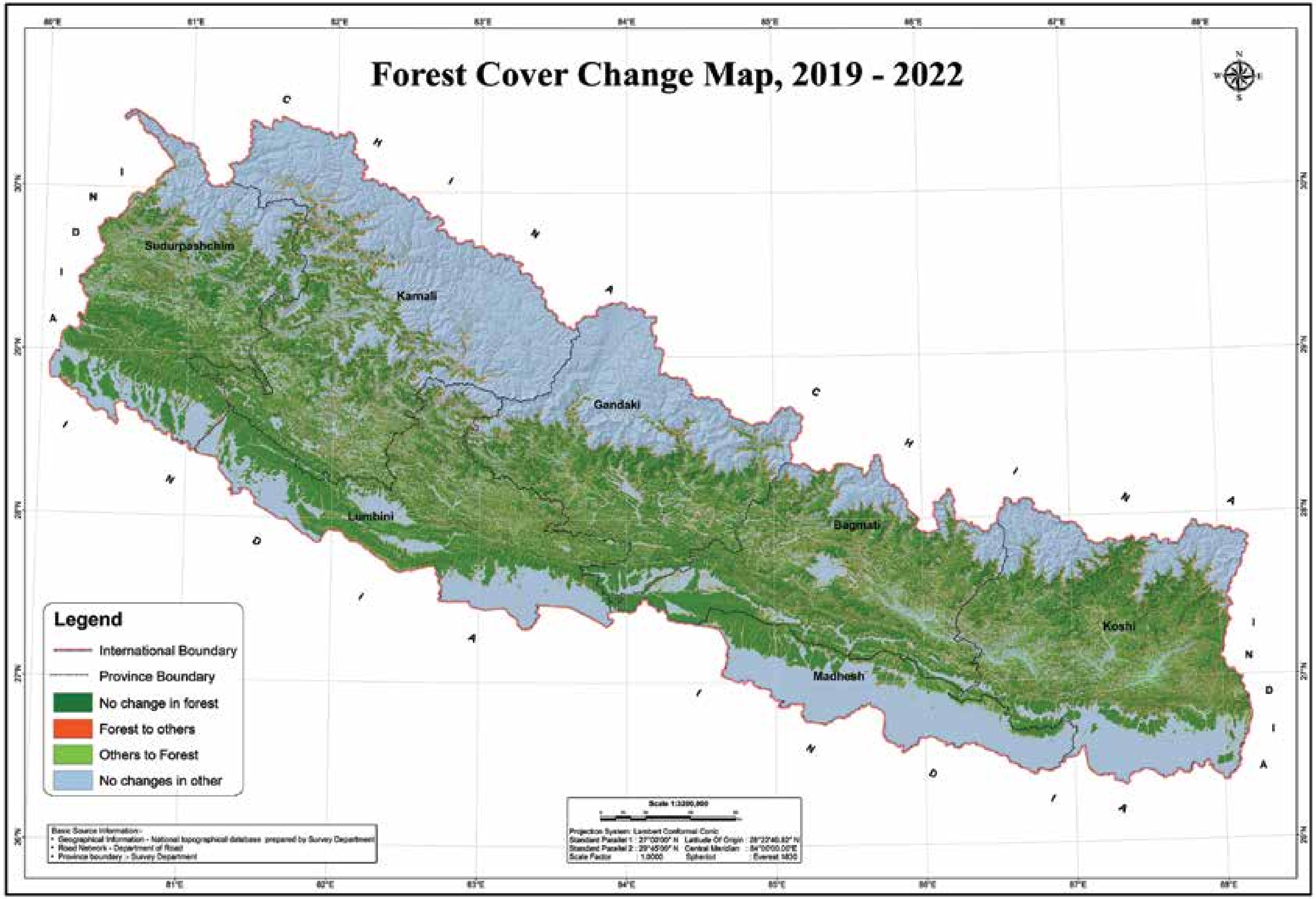


Figure 14: Spatial distribution of changes in forest area between 2019 and 2022

Note: This change map is derived after reclassifying the land cover of 2019 and 2022 into forest and other land only. Change matrices are only four classes (forest remains forest, forest changes into other land, other land changes into forest and other land remains other land).

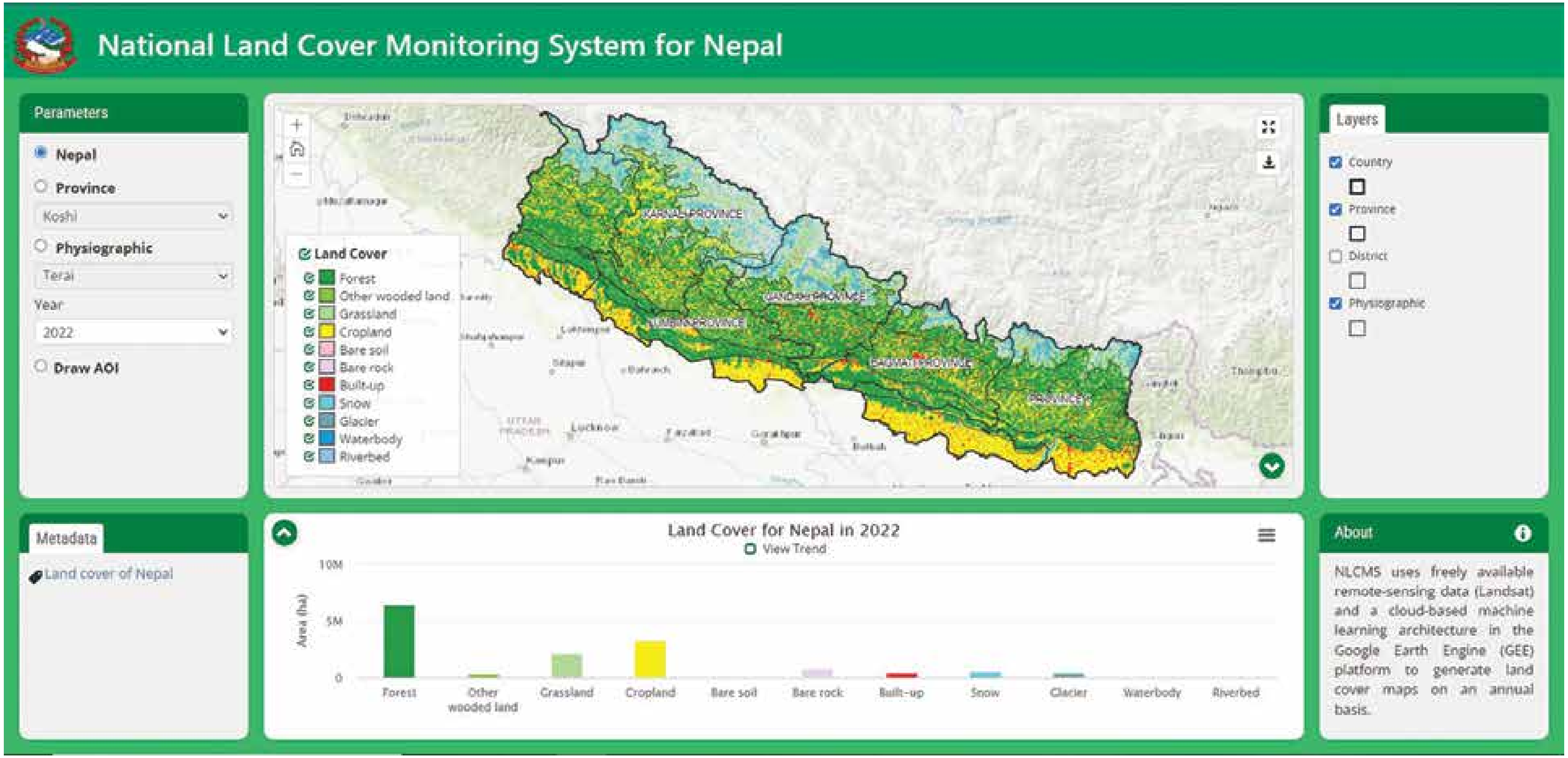


Figure 15: The National Land Cover Monitoring System of Nepal – a web-based application provides land cover information at the national and provincial levels for 2000–2022. Users can also access land cover statistics for different physiographic regions in Nepal or specify a defined area of interest

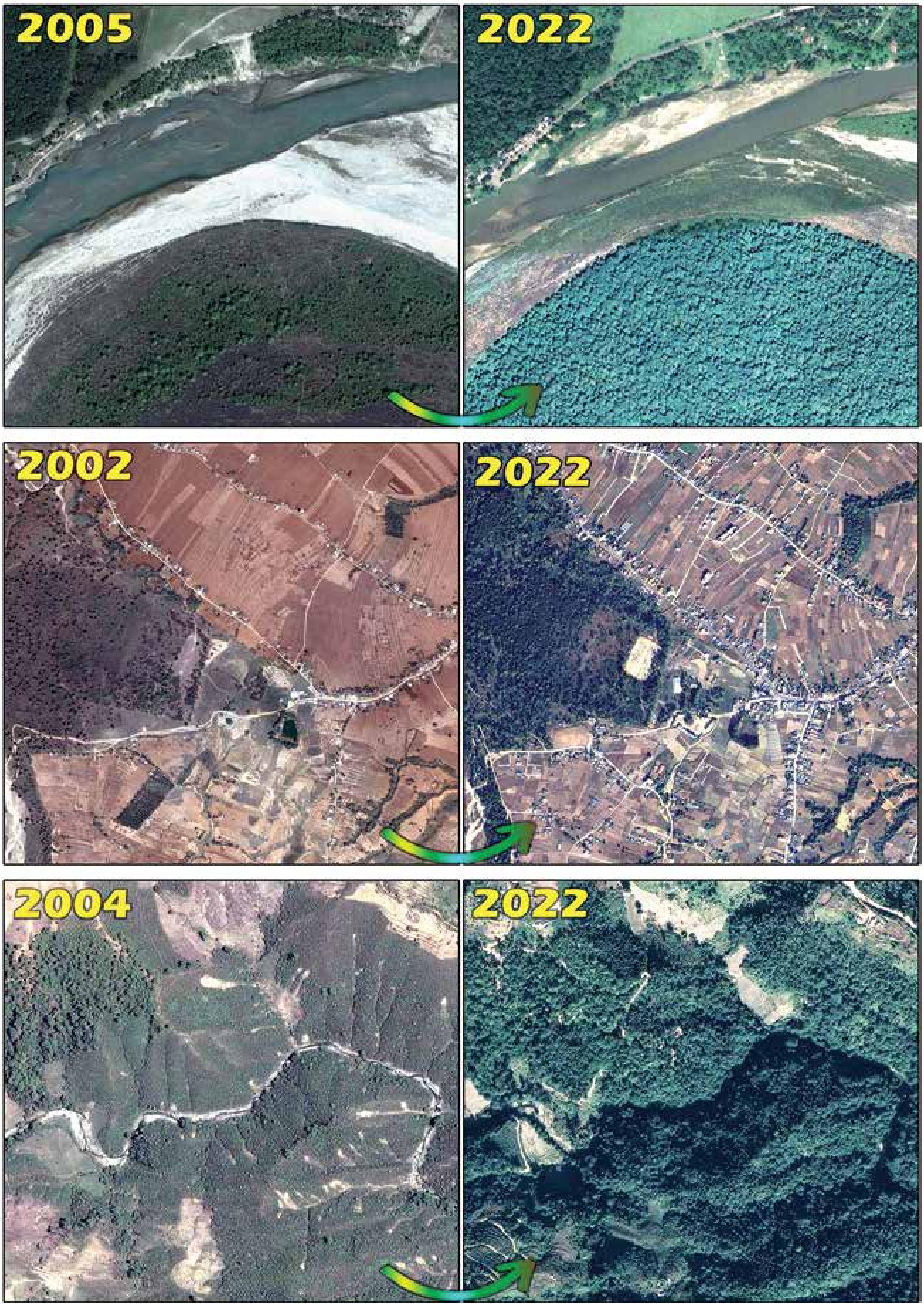


Figure 16: A few randomly selected high-resolution satellite image windows showing a gain in Nepal's forest cover and changes in other land cover

4.6 Accuracy assessment

The error matrix generated from the accuracy assessment of the 2022 land cover is shown in Tables 5 and 6. The overall accuracy of the classification for 2022 is 84.97%, and the overall kappa statistic is 0.76. The glacier class was one of the most challenging classes with the highest accuracy. This data was used from ICIMOD's glacier database produced by object-based image classification and visual interpretation (Bajracharya & Shrestha, 2011). User's accuracy for the forest was very high (98.74%) compared to the producer's accuracy (86.31%). A high user's accuracy (like 98.74%) suggests that the areas classified as forest are mostly correct, meaning there are very few false positives. Some of the reference samples were classified as other land cover classes. This is because some of the validation samples were collected from areas located at the edge of forested areas where pixels were mixed with cropland, OWL or grasslands with sparse trees. Accuracy for OWL was low because mapping this class using Landsat 30-meter satellite images was challenging. The OWL class is similar to a sparse forest and only differs in percent of tree cover. Similarly, the overall accuracy of the land cover (IPCC classes) 2022 is 89.13%, and the overall kappa statistic is 0.81.

Barhaban Collaborative Forest at Kailali, Sudurpaschim province *(Photo by Rajendra KC)*

Table 7: Accuracy assessment of land cover 2022

Land cover	Water body	Glacier	Snow	Forest	Riverbed	Built-up	Crop	Bare soil	Bare rock	Grassland	Owl	Total	Users accuracy (%)
Water body	59	0	0	0	2	0	0	0	0	0	0	61	96.72%
Glacier	0	164	0	0	0	0	0	0	0	0	0	164	100.00%
Snow	0	1	140	0	0	0	0	0	29	3	0	173	80.92%
Forest	0	0	0	2428	0	0	5	0	0	0	26	2,459	98.74%
Riverbed	2	0	0	0	42	0	0	2	1	3	0	50	84.00%
Built-up	0	0	0	6	0	146	38	0	0	0	0	190	76.84%
Crop	0	0	0	227	5	2	558	1	1	46	3	843	66.19%
Bare soil	0	0	0	0	0	0	0	3	0	0	0	3	100.00%
Bare rock	0	0	3	0	0	0	0	2	90	2	0	97	92.78%
Grassland	1	0	3	40	7	2	16	12	42	97	20	240	40.42%
Owl	0	0	0	112	1	0	0	1	0	2	56	172	32.56%
Total	62	165	146	2813	57	150	617	21	163	153	105	4,452	
Producers accuracy (%)	95.16%	99.39%	95.89%	86.31%	73.68%	97.33%	90.44%	14.29%	55.21%	63.40%	53.33%		

Table 8: Accuracy assessment of land cover (IPCC class) 2022

Land cover		Forest	Cropland	Grassland	Wetland	Builtup	Others	Total	Users accuracy (%)
Classified data	Forest	2,629	5	3	1	0	1	2,639	99.62
	Cropland	229	559	46	5	2	2	843	66.31
	Grassland	56	16	96	8	2	56	234	41.03
	Wetland	0	0	3	105	0	3	111	94.59
	Builtup	4	37	0	0	146	0	187	78.07
	Others	0	0	5	0	0	433	438	98.86
	Total	**2,918**	**617**	**153**	**119**	**150**	**495**	**4,452**	
	Producers accuracy (%)	90.10	90.60	62,.75	88.24	97.33	87.47		

5. Conclusion

Nepal made remarkable strides in expanding forest coverage in between 2019 and 2022. An overall increase of 0.75% in forests, including other wooded land, brought the total to 46.08% over three years. This progress highlights the dedicated efforts of the Government of Nepal, conservation partners, community forestry user groups, private forest owners and other stakeholders.

The increase in forest growth can also be attributed to uncultivated lands resulting from outmigration, societal changes, and shifts in the usage patterns of forestry resources.

The 2.32% reduction in snow-covered areas—from 6.23% in 2019 to 3.91% in 2022—raises concerns for both Nepal and the global community. This decline could adversely affect people's livelihoods, biodiversity conservation, and the consistent provision of ecosystem services.The rate of growing built up areas (2.70%) and reduction in cropland (1.75%) have to be taken into account in future land use planning.

Nepal's Land Cover Monitoring System has developed as a breakthrough in land management and environmental monitoring. Since 2000, the system has provided medium-resolution annual land cover maps and developed a detailed framework for monitoring the county's land change trends. This has enabled researchers, policymakers, and conservationists to make data-driven decisions, which have helped provide adequate information on land use strategies and analyze environmental change at the local and national levels. One of NLCMS's key strengths is its ability to fill the data gap at the national level. It achieves a high level of accuracy in land cover classification by combining free satellite imagery, remote sensing technology, and field data through a user-friendly interface. This accurate information helps on the effects of deforestation, land degradation, and climate change, which are essential for ecosystems and communities.

NLCMS has been instrumental in meeting Nepal's environmental commitments in line with global goals, such as the SDGs and the REDD+ initiative. Of particular note is that Nepal has played a leading role in creating annual land cover maps. Using the cloud-based Google Earth Engine (GEE) platform, NLCMS efficiently analyzes large satellite datasets and generates an annual composite to handle seasonal effects. This process enables faster production of year-end land cover data.

Looking to the future, NLCMS will play an essential role in promoting sustainable land use and environmental resilience. The system will assist stakeholders in conserving Nepal's diverse landscape for long-term environmental and socio-economic stability and progress.

5.1 Implications of NLCMS

This dataset will be invaluable for both national and international reporting. It can be utilized in the preparation of reports for various conventions, including the Convention on Biological Diversity, UNFCCC, United Nations Convention to Combat Desertification, RAMSAR, Global Forest Resources Assessment and the FAO and others.

However, the data and methodology used for the NLCMS differ from those used in the Forest Resource Assessment project (DFRS, 2015). Still, no significant difference was found when comparing total forest and OWL cover in the NLCMS and Forest Resource Assessment project. As a result, this NLCMS data can potentially be considered to use in the REDD MRV process. It will also support the timely development or revision of a Long-Term Strategy (LTS) for Net-Zero Emissions and Nepal's 3rd Nationally Determined Contribution (NDC). Additionally, it will be essential for developing a land account system as part of the System of Environmental Economic Accounting (SEEA) process.

The primary use of this land cover change information will be in shaping policies and strategies for conservation and sustainable ecosystem management. These maps will also be instrumental in the detailed mapping of ecosystems and forest types throughout Nepal. Provincial governments can leverage this information and these maps for comprehensive management of forestry resources within their regions.

Similarly, other respective concern ministries and relevant organizations can utilize the data and statistics provided in this report for evidence-based policy development and program implementation. Furthermore, the land cover dataset is flexible and can be easily customized for various reporting frameworks. It can be categorized into six land cover classes for IPCC reporting and three land cover classes for GFRA reporting, ensuring compatibility with multiple international reporting standards.

5.2 Way forward

The forest area has increased to 46.08%, but this figure cannot be broken down by ownership type. This report does not specify how much the national or privately owned forest areas have changed over the past three years. Therefore, the forest cover change data should be interpreted carefully while planning forest interventions. There is an urgent need to differentiate between government-owned national forests and privately owned forests. Therefore, the FRTC, in collaboration with the Survey Department, should focus on identifying and estimating forest coverage separately for national and private forests. Furthermore, national forests should be mapped and classified according to whether they are located within or outside of Protected Areas of Nepal. Similar land cover maps should be created for all 753 municipalities, enabling local bodies to develop their land use plans and implement them in collaboration with the relevant agencies.

Land cover mapping methodologies are continuously advancing, with innovative technologies offering increased accuracy and flexibility. The NLCMS is built on an open platform architecture, enabling the integration of emerging technologies such as remote sensing, cloud computing, and artificial intelligence, which ensures ongoing usability for end-users. Notably, the incorporation of deep learning techniques can significantly enhance the system's ability to classify complex landscapes with greater precision, particularly in distinguishing various forest types.

The current data set comprises 11 land cover classes; however, a more detailed classification of forest types based on species distribution is essential for informed conservation strategies and effective ecosystem management. This finer classification could support ecosystem mapping, biodiversity preservation and sustainable forest resource management, benefiting both local communities and national stakeholders.

Furthermore, the increase in forest area underscores the necessity for sustainable forest management to optimize economic and environmental benefits. This approach can empower local communities through sustainable timber and non-timber forest production, ecotourism, enterprise development, ensuring continuous supply of ecosystem services and building resilience against climate induced disaster. Conversely, the observed decline in snow cover raises significant concerns regarding the impacts of global warming and climate change, highlighting the need to integrate climate-resilient strategies into land use planning. Based on the expertise and mandate of the organization, it is recommended that the Survey Department be included as part of the technical team from the start to the completion of future NLCMS work.

5.3 Limitations

A substantial number of spatially distributed training samples is essential for accurately generating land cover maps. However, during the reference data collection process, only satellite images from recent years were accessible freely on CEO desktop and online platforms. Having access to additional images from previous years would have enhanced efficiency and improved the generation of reference data for training and evaluating image classification. While using mobile apps for land cover validation was convenient, field-based methods do not permit the collection of historical data for specific land covers.

Furthermore, inaccessibility, rugged terrain and remoteness hindered the collection of validation points across Nepal. The land cover data is derived from Landsat imagery with a 30 m resolution, where each pixel corresponds to an area of 0.09 ha. When multiple land cover types are present within a pixel, only the dominant type is mapped based on the majority representation. Finer pixel resolution would have been more advantageous for accurately identifying smaller land cover types.

Forest cover errors resulting from the mixed pixel effect are extremely difficult to eliminate. The minimum mapping unit for this land cover is 0.5 ha, making it incompatible with land cover data at higher spatial resolutions. Additionally, mapping the OWL class presents technical challenges due to spectral similarities. A significant amount of field verifications is necessary to address this issue, and extensive efforts have been made to reduce this limitation during the report's preparation.

A large landslide in the middle of the dense, continuous high mountain forest along the Arun River in Sankhuwasabha *(Photo by Rajendra KC)*

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Annex-1

National-level land cover statistics

Land cover	2000*		2019*		2020		2021		2022	
	Area(Ha)	%	Area (Ha)	%	Area (Ha)	%	Arean(Ha)	%	Area (Ha)	%
Water body	66,087	0.45	71,834	0.49	52,463	0.36	53,347	0.36	60,237	0.41
Glacier	449,371	3.05	448,781	3.04	449,661	3.05	449,866	3.05	450,719	3.06
Snow	568,913	3.86	919,353	6.23	928,750	6.30	770,851	5.23	577,212	3.91
Forest	5,901,759	40.01	6,152,806	41.71	6,389,684	43.32	6,392,957	43.34	6,399,341	43.38
River bed	170,907	1.16	163,989	1.11	54,467	0.37	51,684	0.35	114,024	0.77
Built up	25,395	0.17	78,153	0.53	103,051	0.70	143,275	0.97	475,877	3.23
Crop land	3,900,458	26.44	3,590,492	24.34	3,520.366	23.86	3,425,536	23.22	3,332,566	22.59
Bare soil	151	0.001	4,010	0.03	986	0.01	1,073	0.01	1,885	0.01
Bare rock	1,083,416	7.34	830,695	5.63	892,301	6.05	1,042,250	7.07	772,360	5.24
Grassland	2,058,860	13.96	1,957,465	13.27	1,922,592	13.03	1,964,729	13.32	2,169,462	14.71
Other wooded land	526,281	3.57	534,022	3.62	437,278	2.96	456,034	3.09	397,916	2.70
Total	**14.751,600**		**14,751,600**		**14,751,600**		**1,4751,600**		**14751600**	

**Land Cover area is adjusted to Nepal's total area (147,516 sq km) so the statistic are slightly different from the NLCMS report 2022.*

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Annex-2

Province level land cover statistics

Province-level land cover statistics for the year 2000 (Area in Hectare)								
land cover	Koshi	Madhesh	Bagmati	Gandaki	Lumbini	Karnali	Sudurpaschim	Total
Water body	15,734	6,059	7,560	9,094	9,445	11,988	6,208	66,087
Glacier	105,157	0	43,633	168,874	1,047	93,762	36,897	44,9371
Snow	55,054	0	33,605	173,338	1,784	197,553	107,580	568,914
Forest	1,117,353	242,518	1,054,686	717,528	932,584	864,473	972,618	5,901,759
River bed	30557	48267	27310	9,659	29,735	4,845	20,536	170,908
Buil-tup	2164	2916	9736	4,113	1,726	4,135	604	25,395
Crop land	799060	604940	554506	340,233	733,801	390,620	477,298	3,900,459
Bare soil	8	0	0	6	0	10	127	151
Bare rock	126598	0	61814	224,563	10,861	589,106	70,474	1,083,416
Grass land	226552	48987	167314	422,243	142,422	797,197	254,145	2,058,860
Other wooded land	119730	2,559	62,566	120,266	56,012	108,190	56,959	526,281
Total	**2,597,967**	**956,245**	**2,022,730**	**2,189,916**	**1,919,417**	**3,061,878**	**2,003,447**	**14,751,600**

Province-level land cover statistics for the year 2019 (Area in Ha)								
land cover	Koshi	Madhesh	Bagmati	Gandaki	Lumbini	Karnali	Sudurpashchim	Total
Water body	14,719	7,539	8,843	10,171	10,483	11,211	8,868	71,833
Glacier	105,027	0	43,551	168,745	1,045	93,589	36,824	448,781
Snow	104,013	0	49,383	172,834	5,998	458,042	129,082	919,354
Forest	1155276	230,499	1,162,992	788,700	985,408	842,584	987,346	6152,806
River bed	30481	46,894	24,706	8,768	29,334	4,598	19,209	163,989
Buil-tup	10681	7,609	25,450	7,928	12,380	10,208	3,896	78,153
Crop land	741524	597,873	447,575	271,552	681,572	386,248	464,148	3590,493
Bare soil	35	98	38	3,226	11	366	236	4,010
Bare rock	77079	0	44,116	194,343	11,80	439,199	64,177	830,695
Grassland	241691	54,337	156,336	445,147	111,490	716,105	232,359	1957,465
Other wooded land	117440	11,395	59,742	118,502	69,914	99,728	57,302	534,022
Total	**2,597,967**	**956,245**	**2,022,730**	**2,189,916**	**1919,417**	**3061,878**	**2,003,447**	**14,751,600**

Province-level land cover statistics for the year 2020 (Area in Ha)								
land cover	Koshi	Madhesh	Bagmati	Gandaki	Lumbini	Karnali	Sudurpashchim	Total
Water body	11,365	5,663	6,089	7,275	7,327	9,040	5,703	52,463
Glacier	105,169	0	43,678	169,005	1,049	93,826	36,934	449,661
Snow	69,148	0	46,479	156,489	12,725	478,701	165,209	928,751
Forest	1,201,935	242,965	1,169,943	854,655	1,042,922	841,475	1,035,789	6,3896,84
River bed	9,475	17,956	6,131	1,085	9,978	2,361	7,480	54,467
Buil-tup	12,611	18,135	30,747	9,710	14,322	12,329	5,197	103,051
Crop land	705,226	602,297	443,553	261,473	661,075	3935,02	453,240	3,520,366
Bare soil	182	131	22	196	65	39	352	986
Bare rock	138,146	2	44,511	250,377	9,204	393,751	56,311	892,301
Grassland	229,712	62,602	170,158	415,147	122,341	734,856	187,775	1,922,592
Other wooded land	114,997	6,495	61,418	645,05	38,408	101,999	49,456	437,278
Total	**2,597,967**	**956,245**	**2,022,730**	**2,189,916**	**1,919,417**	**3,061,878**	**2,003,447**	**14,751,600**

Province-level land cover statistics for the year 2021								
land cover	Koshi	Madhesh	Bagmati	Gandaki	Lumbini	Karnali	Sudurpashchim	Total
Water body	12,147	7,328	6,069	7,489	6,897	8,487	4,928	53,346
Glacier	105,189	0	43,688	169,115	1,046	93,864	36,964	449,866
Snow	78,632	0	33,803	1,047,89	7,992	431,583	114,052	77,0851
Forest	1,217,954	248,533	1,177,762	8,440,88	1,047,796	846,103	1,010,723	6,392,957
River bed	8,502	16,415	5,576	1,154	9,470	2,474	8,095	51,685
Buil-tup	17,056	25,652	40,666	13,509	20,782	15,758	9,852	143,274
Crop land	685,205	595,677	422,955	257,735	647,334	369,827	446,803	3,425,536
Bare soil	90	320	13	153	86	58	353	1,073
Bare rock	134,151	0	66,796	287,168	15,280	476,721	62,132	1,042,249
Grassland	229,040	56,723	161,527	440,074	112,126	712,793	25,2447	1,964,729
Other wooded land	110,003	5,597	6,3876	6,4642	50,608	104,211	57,098	456,034
Total	**2,597,967**	**956,245**	**2,022,730**	**2189,916**	**1,919,417**	**3,061,878**	**2,003,447**	**14,751,600**

Province-level land cover statistics for the year 2022								
land cover	Koshi	Madhesh	Bagmati	Gandaki	Lumbini	Karnali	Sudurpashchim	Total
Water body	13,650	6,750	7,093	7,403	7,878	10,048	7,415	60,237
Glacier	105,427	0	43,792	169,343	1,051	94,089	37,016	450,719
Snow	55,406	0	29,646	122,345	9,511	274,361	85,942	577,212
Forest	1,201,218	247,273	1,185,767	831,694	1,049,408	855,304	1,028,678	6,399,342
River bed	13,758	23,661	10,095	24,276	15,294	15,813	11,127	114,025
Built-up	95,486	57,281	102,871	54,629	76,366	40,848	48,395	475,877
Crop land	640,636	565,099	383,454	236,429	614,521	445,302	447,124	3,332,566
Bare soil	221	79	31	1,042	75	65	373	1,885
Bare rock	78,927	0	39,030	173,023	7,972	424,006	49,403	772,360
Grass land	283,083	50,906	174,304	482,077	92,272	833,054	253,767	2,169,462
Other wooded land	110,155	5,196	46,646	87,655	45,069	68,988	34,207	397,916
Total	**25,97,967**	**956,245**	**2,022,730**	**2,189,916**	**1,919,417**	**3,061,878**	**2,003,447**	**14,751,600**

Province wise forest and OWL changes in between 2019 and 2022

Province	2019						2022					
	Forest	%	OWL	%	Total	%	Forest	%	OWL	%	Total	%
Koshi	1,155,276	18.78	117,440	21.99	1,272,716	19.03	1,202,320	18.77	121,458	26.42	1,323,778	19.28
Madhesh	230,499	3.75	11,395	2.13	241,894	3.62	247,620	3.87	5,573	1.21	253,193	3.69
Bagmati	1,162,992	18.90	59,742	11.19	1,222,734	18.29	1,187,308	18.54	56,202	12.22	1,243,510	18.12
Gandaki	788,700	12.82	118,502	22.19	907,202	13.57	832,198	12.99	93,202	20.27	925,400	13.48
Lumbini	985,408	16.02	69,914	13.09	1,055,322	15.78	1,050,553	16.40	51,011	11.10	1,101,564	16.05
Karnali	842,584	13.69	99,728	18.67	942,312	14.09	854,823	13.35	87,062	18.94	941,885	13.72
Sudurpashchim	987,346	16.05	57,302	10.73	1,044,648	15.62	1,029,772	16.08	45,235	9.84	1,075,007	15.66
Total	6,152,806		34,022		6,686,828		6,404,594		459,743		6,864,337	

Annex-3

Physiographic region-wise land cover statistics

F/Physiographic region-wise land cover statistics for the year 2000 (Area in Ha)						
land cover	Terai	Chure	Middle Mountain	High Mountain	High Himal	Total
Water body	20,506	12,366	14,971	4,928	13,317	66,087
Glacier	0	0	0	114	449,256	449,370
Snow	0	0	0	8,615	560,299	568,914
Forest	360,518	1,315,028	2,359,038	1,726,923	140,254	5,901,761
River bed	87,047	62,461	17,893	972	2,535	170,908
Built-up	5,537	1,817	10,306	1,614	6,120	25,395
Crop land	1,470,997	376,613	1,586,091	463,436	3,317	3,900,454
Bare soil	0	0	0	0	151	151
Bare rock	0	0	0	14,273	1,069,143	1,083,416
Grassland	58,845	107,310	138,121	508,430	1,246,154	2,058,861
Other wooded land	9,845	14,696	163,798	268,992	68,950	526,282
Total	**2,013,295**	**1,890,291**	**4,290,219**	**2,998,298**	**3,559,497**	**147,51,600**

Physiographic region-wise land cover statistics for the year 2019 (Area in Ha)						
land cover	Terai	Chure	Middle Mountain	High Mountain	High Himal	Total
Water body	23,483	14,068	17,596	4,844	11,842	7,1834
Glacier	0	0	0	114	448,666	448,780
Snow	0	0	2	13,758	905,594	919,354
Forest	379,785	1,337,749	2,607,612	1,702,044	125,618	6,152,808
River bed	86,241	58,946	15,127	806	2,870	163,989
Buil-tup	24,491	9,545	28,279	6,050	9,788	78,153
Crop land	1,437,146	344,123	1,353,007	452,970	3,242	3,590,488
Bare soil	109	31	9	23	3,839	4,010
Bare rock	0	1	45	12,878	817,772	830,696
Grassland	45,243	88,112	113,337	540,220	1,170,555	1,957,466
Other wooded land	16,797	37,716	155,205	264,593	59,711	534,022
Total	**2,013,295**	**189,0291**	**4,290,219**	**2,998,298**	**3,559,497**	**14,751,600**

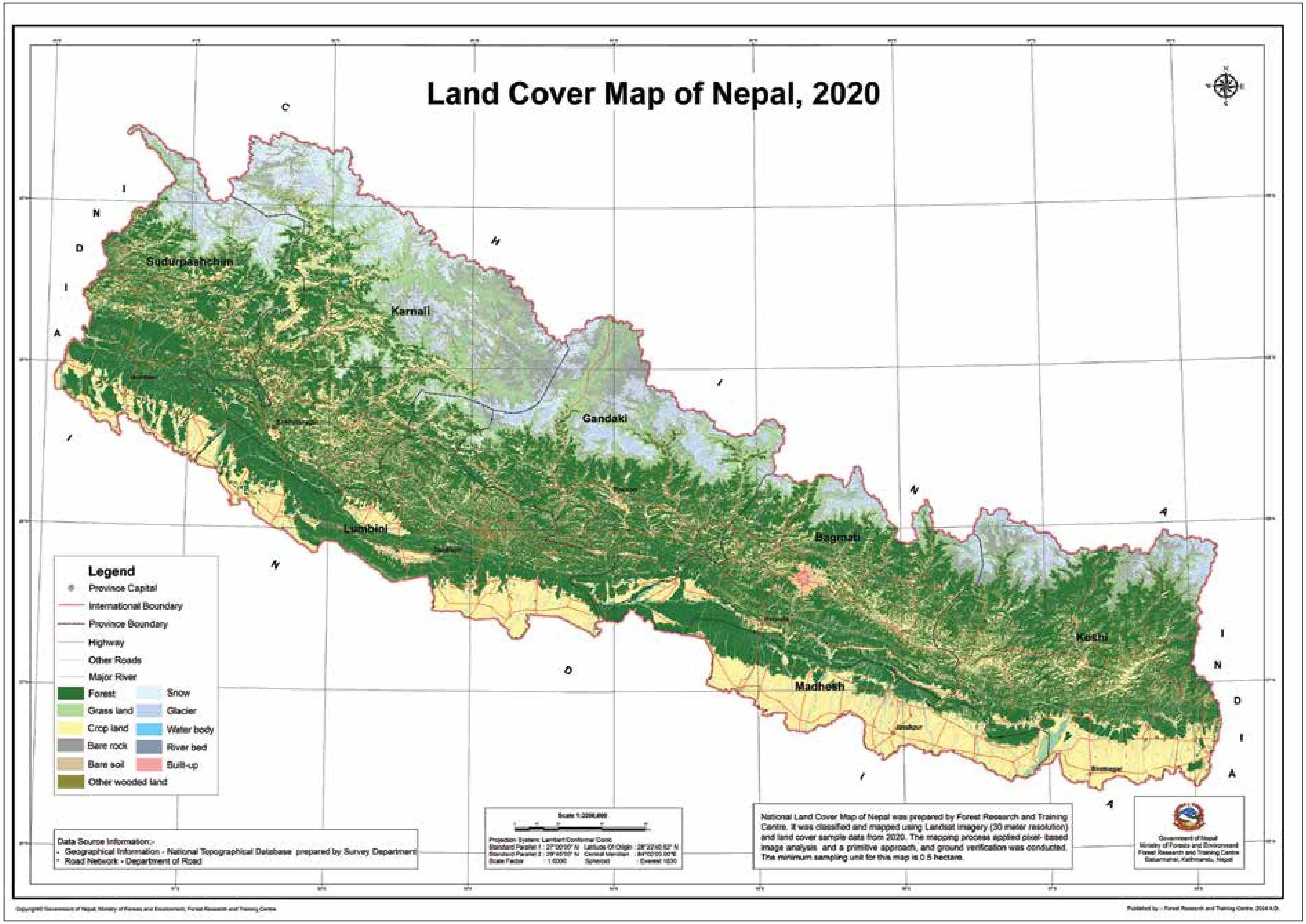
Physiographic region-wise land cover statistics for the year 2020 (Area in Ha)						
land cover	**Terai**	**Chure**	**Middle Mountain**	**High Mountain**	**High Himal**	**Total**
Water body	16,321	9,679	13,075	3,072	10,315	52,463
Glacier	0	0	0	114	449,546	449,660
Snow	0	0	0	23,779	904,972	928,751
Forest	399,198	1,373,063	2,7284,52	1,762,210	126,764	6389,687
River bed	29,054	20,629	4,614	134	35	54,467
Built-up	37,536	11,043	34,498	8,288	11,686	103,051
Crop land	144,6222	354,835	1,228,289	477,615	13,400	3,520,362
Bare soil	360	62	20	11	532	986
Bare rock	2	5	211	26,530	865,553	892,301
Grassland	74,563	103,530	142,518	483,167	1,118,815	1,922,593
Other wooded land	10,038	17,444	138,541	213,377	57,878	437,278
Total	**2,013,295**	**1,890,291**	**4,290,219**	**2,998,298**	**3,559,497**	**147,51,600**

Physiographic region-wise land cover statistics for the year 2021 (Area in Ha)						
land cover	**Terai**	**Chure**	**Middle Mountain**	**High Mountain**	**High Himal**	**Total**
Water body	18,467	9288	12,310	2,905	10,376	5,3346
Glacier	0	0	0	115	449,750	449,865
Snow	0	0	0	3,915	766,937	770,852
Forest	402,467	1,384,926	2,732,193	1,751,014	122,360	6,392,959
River bed	26,902	19,981	4,648	119	35	51,685
Built-up	53,552	16,450	46,980	13,262	13,031	143,274
Crop land	1,429,552	344,532	1,195,740	448,329	7,378	3,425,532
Bare soil	464	73	24	21	491	1,073
Bare rock	1	5	237	58,137	9,83,871	1,042,250
Grass land	71,594	92,162	144,358	510,894	1,145,723	1,964,731
Other wooded land	10,295	22,875	153,730	209,588	59,546	456,034
Total	**2,013,295**	**1,890,291**	**4,290,219**	**2,998,298**	**3,559,497**	**14,751,600**

Physiographic region-wise land cover statistics for the year 2022 (Area in Ha)						
land cover	**Terai**	**Chure**	**Middle Mountain**	**High Mountain**	**High Himal**	**Total**
Water body	20,762	11,461	13,587	2,908	11,520	60,237
Glacier	0	0	0	114	450,603	450,718
Snow	0	0	2	3,108	574,101	577,212
Forest	401,089	1,392,791	2,769,246	1,714,722	12,1495	6,399,344
River bed	42,421	27,883	7,414	1,315	34,991	1,14,025
Built-up	164,498	62,389	193,135	42,551	13,304	475,876
Crop land	1,316,635	304,655	1,108,402	539,177	63,693	3,332,562
Bare soil	289	73	114	42	1,368	1,885
Barer ock	0	0	0	6,860	765,501	772,361
Grassland	55,267	76,513	67,577	489,629	1480,478	2,169,464
Other wooded land	12,334	14,527	130,741	197,872	42,442	397,916
Total	**2,013,295**	**1,890,291**	**4,290,219**	**2,998,298**	**3,559,497**	**14751,600**

Annex-4

Land Cover Maps 2020-2022


Land Cover Map of Nepal, 2020
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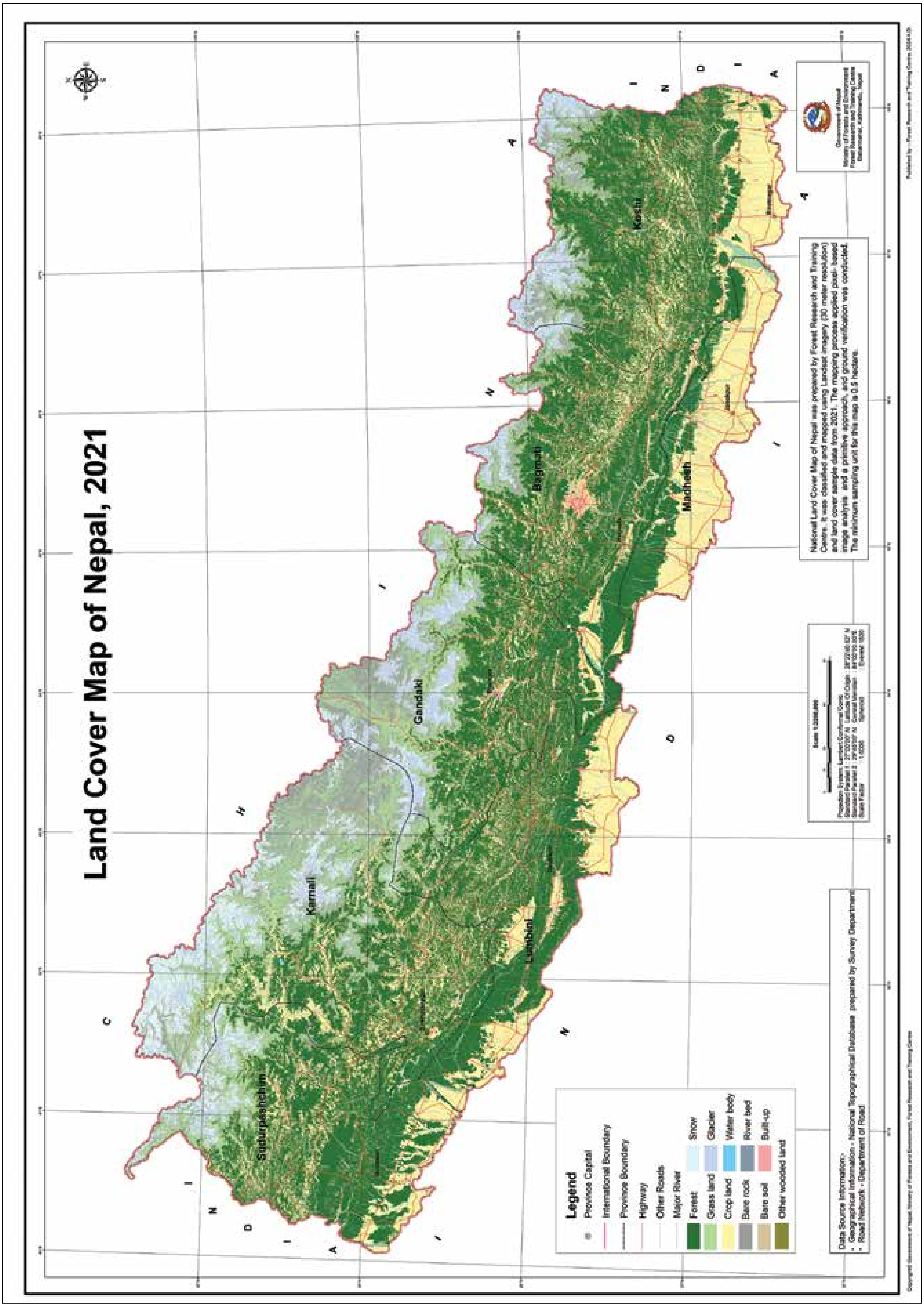
Bare soil
Other wooded land
Snow
Glacier
Water body
River bed
Built-up
Data Source Information:-
• Geographical Information - National Topographical Database prepared by Survey Department
• Road Network - Department of Road
Projection System: Lambert Conformal Conic
National Land Cover Map of Nepal was prepared by Forest Research and Training Centre. It was classified and mapped using Landsat imagery (30 meter resolution) and land cover sample data from 2020. The mapping process applied pixel- based image analysis and a primitive approach, and ground verification was conducted. The minimum sampling unit for this map is 0.5 hectare.


Land Cover Map of Nepal, 2021
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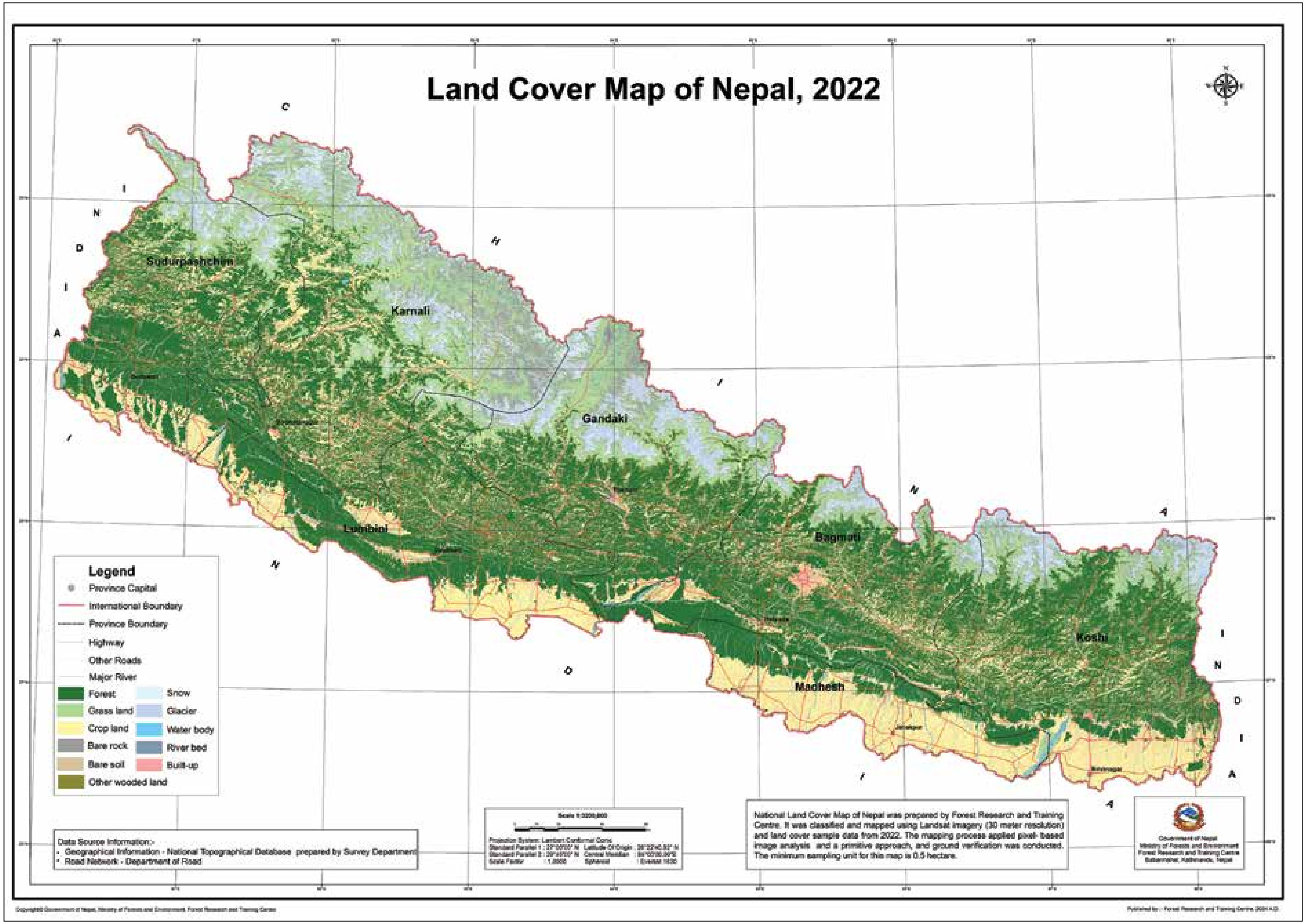
Water body
River bed
Built-up
Data Source Information:-
• Geographical Information - National Topographical Database prepared by Survey Department
• Road Network - Department of Road
National Land Cover Map of Nepal was prepared by Forest Research and Training Centre. It was classified and mapped using Landsat imagery (30 meter resolution) and land cover sample data from 2021. The mapping process applied pixel- based image analysis, and a primitive approach, and ground verification was conducted. The minimum sampling unit for this map is 0.5 hectare.
Government of Nepal
Ministry of Forests and Environment
Forest Research and Training Centre
Babarmahal, Kathmandu, Nepal


Land Cover Map of Nepal, 2022
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Province Capital
International Boundary
Province Boundary
Highway
Other Roads
Major River
Forest
Grass land
Crop land
Bare rock
Bare soil
Other wooded land
Snow
Glacier
Water body
River bed
Built-up
Data Source Information:-
• Geographical Information - National Topographical Database prepared by Survey Department
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Government of Nepal

नेपाल सरकार

भूमि व्यवस्था, सहकारी तथा गरिबी निवारण मन्त्रालय

नापी विभाग

(योजना तथा जग्गा प्रशासन शाखा)

फोन नं.: ४१०६७६९, ४१०६८४२, ४१०६५०८, ४१०६८३३

फ्याक्स नं.: ४१०६७५७

टोल फ्रि नं.: १६६००१७५८८८

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मिनभवन

काठमाडौं, नेपाल

पत्र संख्याः- ०८१।८२

प्राप्त पत्र संख्याः- ....

च.नं.:- ३२

मितिः २०८१/०७/२६

ने. सं. ११४५ कछलाथ्व, १० सोमबार

विषयः- नक्सा प्रकाशन अनुमति प्रदान गरिएको बारे।

श्री वन अनुसन्धान तथा प्रशिक्षण केन्द्र,

बबरमहल, काठमाडौं ।

प्रस्तुत विषयमा तहाँ केन्द्रवाट तयार भएको 'Land Cover Map' नक्सा प्रकाशन अनुमतिका लागि मिति २०८१/०७/२१ मा नापनक्सा समिति, प्राविधिक उपसमितिको बैठकमा पेश भएको सन्दर्भमा उप-समितिवाट उपलब्ध गराइएका सुझावहरु समावेश गरी पुनः पेश भएपश्चात नक्सा प्रकाशनका लागि अनुमति प्रदान गर्ने निर्णय भएकोमा, सुझावहरु समावेश भई आएको हुँदा cartographic दृष्टिकोणवाट प्रकाशन योग्य देखिएको भन्ने व्यहोरा कार्टोग्राफी तथा छपाई शाखाबाट जानकारी प्राप्त हुन आएकोले सो नक्सा प्रकाशनको लागि अनुमति प्रदान गरिएको व्यहोरा आदेशानुसार अनुरोध छ।

(दामोदर ढकाल)

निर्देशक

फोनः ०१-४१०६८३३, इमेल ठेगानाः planning@dos.gov.np , website: www.dos.gov.np

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