ISSN: 2676-1408 (Print)

JOURNAL OF LAND MANAGEMENT AND GEOMATICS EDUCATION

Volume VI

Asadh 2081 (July 2024)

Annual Publication of Land Management Training Center, Government of Nepal

Volume VI

Asadh 2081 (July 2024)

JOURNAL OF LAND MANAGEMENT AND GEOMATICS EDUCATION

An Annual Publication of LMTC

Published by:

Government of Nepal

Ministry of Land Management, Cooperatives and Poverty Alleviation

Land Management Training Center

Dhulikhel, Kavrepalanchok

Nepal

CONTACT US

info@lmtc.gov.np
Land Management Training Centre
Ministry of Land Management, Cooperatives and Poverty Alleviation
Dhulikhel, Kavre, Nepal
G.P.O. Box number. 12695, Kathmandu, Nepal
Phone number. 00977 11 415055/51
Fax. 00977 11 415078

SUBMISSION

Visit http://www.lmtc.gov.np for online manuscript preparation and submission guidelines. Contribution of original unpublished research, review articles, scholarly essays are welcome. The articles will be published only after peer review.

Copyright

Cover Page

Lecture of The Month Episode 1: Professional Ethics and Integrity in Civil Service/Workplace, Discussion about Conducting Field Camp at LMTC and KU Premises for Students from University of Southern Queensland, High Level Officials from Ministry and LMTC at Field Camp, Junior Survey Training (Fresh) Trainees Conducting DGPS Survey, Aerial View of Field Camp, Demonstration of Handheld LiDAR at LMTC Premises

This issue of "Journal of Land Management and Geomatics Education" is available at www.lmtc.gov.np. All contents can be accessed without registration or subscription.

ADVISORY COMMITTEE

Chairperson
Janak Raj Joshi
Executive Director
Land Management Training Center
M.Sc. in Geoinformation Science and Earth Observation

Members

Prof. Manish Pokharel, PhD
Dean, School of Engineering
Kathmandu University
Doctorate Degree in E-government

Damodar Wagle
Chief Survey Officer
Ministry of Land Management, Cooperatives and Poverty Alleviation
Masters in Geography

Rajendra Raut
Director
Land Management Training Center
Masters in Public Administration

Ram Kumar Sapkota
Director
Land Management Training Center
M.Sc. in Geodesy and Geoinformation

Sudeep Shrestha
Director
Land Management Training Center
M.Sc. in Photogrammetry and Geoinformatics

Lekha Nath Dahal
Director
Land Management Training Center
Masters in Land Administration

EDITORIAL COMMITTEE

EDITOR-IN CHIEF

Ram Kumar Sapkota
Director
Land Management Training Center
M.Sc. in Geodesy and Geoinformation

MEMBERS

Bigyan Banjara
Instructor
Land Management Training Center
M.Sc. in Earth Oriented Space Science and Technology

Bhagirath Bhatt
Instructor
Land Management Training Center
ME in Geoinformatics

Tina Baidar
Instructor
Land Management Training Center
M.Sc. in Geospatial Technologies

Shristi Paudel
Instructor
Land Management Training Center
M.Sc. in Photogrammetry and Geoinformatics

EDITORIAL

It's my great pleasure to present the sixth edition of the Journal of Land Management and Geomatics Education. As we mark up in an era with unprecedented spatial technological advancements and innovations, the field of land management and geoinformatics has emerged as a key cornerstone for the betterment of any country and society. The research and innovations in land management and geospatial technologies offer unparalleled opportunities to foster sustainable development, enhance efficiency in resource management, and mitigate the impacts of climate change.

I believe, this Journal continues to serve as a beacon for the geoinformatics students, researchers, academicians, and geospatial professionals dedicated to showcasing pioneering research and state-of-the-art applications in land management and geomatics domain. In this issue, we highlight several pioneering studies and innovative projects performed by geomatics students, researchers, and geo-professionals which have been cautiously peer-reviewed by the experts in the respective domain. The major highlights of this edition are systematic study and findings on Mapping and analyzing burn severity of wildfire, spatial-temporal analysis of air pollutants, modernizing height system in Nepal, Logical Errors identification of Cadastral Database, Ecotourism mapping, dependency of orientation of images on vegetation indices and practical learning of Sundial established in Land Management Training Center. It includes modern geospatial technologies such as remote sensing, global navigation satellite systems, modern cartography, and advanced spatial analysis.

Land Management Training Centre, the only government institution for developing human resources in land management and geoinformation, is always committed to advancing the frontiers of knowledge in a wide spectrum of geomatics and has been publishing journals annually since a few years back. I am quite confident that, this journal could be a pertinent platform for sharing the knowledge and findings of research in the field of geomatics and land management. Meanwhile, I would like to extend my sincere gratitude to the authors and reviewers, for their unwavering contributions. My special thank goes to Mr. Bhagirath Bhatt for his tireless efforts and my other team members of the editorial board, without whom it would not be possible to bring up this edition. Moreover, I am equally grateful to the Executive Director Mr. Janak Raj Joshi, and other members of the advisory committee for their insightful suggestions and valuable guidance.

Lastly, I would like to invite our readers to engage deeply and unlock their full potential with the diverse array of articles presented in this issue. We will surely be back again with the succeeding issue of this journal in the upcoming year.

Happy 56th anniversary to the Land Management Training Centre, a 9001:2015 ISO-certified institution!

Thank you!

Enjoy Reading!

Ram Kumar Sapkota
Editor in Chief
July, 2024

Executive Director's Message!

Welcome to the sixth edition of the Journal on Land Management and Geomatics Education, a pioneering publication brought forth by the Land Management Training Centre (LMTC). This journal represents a significant milestone in the realm of land management and geomatics education, aiming to foster academic discourse, share cutting-edge research, and advance knowledge in the field of Land Management and Geoinformation technology.

Land management and geomatics, at their core, are disciplines that intersect with various aspects of human society, economy, and environment. They are pivotal in shaping sustainable development, ensuring efficient resource utilization, and addressing complex spatial challenges. As our world evolves with challenges such as rapid urbanization, climate change, and human-induced and natural disasters, the relevance and importance of technological advancements in these disciplines will certainly grow. The LMTC, known for its commitment to excellence in education and training, has been publishing this journal as a platform for educators, researchers, practitioners, and policymakers to exchange ideas and innovations. By bridging theory and practice, this journal seeks to contribute to the advancement of knowledge and the enhancement of professional practices in land management and geomatics.

In this journal, you will find diverse articles covering a wide spectrum of topics within land management and geomatics education. From innovative techniques and methodologies to case studies highlighting successful applications in real-world scenarios, each contribution embodies the spirit of academic inquiry and practical relevance. Our contributors include experienced practitioners and emerging researchers, united in their dedication to advancing our understanding and capabilities in these disciplines. Their insights and discoveries will undoubtedly enrich the discourse and inspire future generations of professionals in the field.

Moreover, this journal serves as a testament to the LMTC's ongoing commitment to fostering excellence in academic education, professional training, and research.

By promoting and encouraging interdisciplinary collaboration with industries and academia, we aim to empower current and future leaders in land management and geomatics to tackle the multifaceted challenges of our time. As I embark on this journey with the publication of the sixth edition of the Journal on Land Management and Geomatics Education, I extend my gratitude to all who have contributed their time, expertise, and dedication to making this initiative a reality. I invite readers from academia, industry, and government sectors to engage with the journal, contribute their insights, and join us in shaping the future of land management and geomatics education in Nepal.

In conclusion, I am confident that this edition of the Journal of Land Management and Geomatics Education will be a valuable resource and an inspiration for advancing knowledge, fostering innovation, and driving positive change in our evolving society.

Warm regards,

Janak Raj Joshi
Executive Director
Land Management Training Center
July, 2024

Table of Contents

List of Peer Reviewers

Mr. Susheel Dangol
Deputy Director General, Survey Department

Mr. Punya Prasad Oli
Principal, Geomatic Institute of Technology
Former Director General, Survey Department

Dr. Reshma Shrestha
Associate Professor and Head of Department, Kathmandu University

Dr. Subhash Ghimire
Associate Professor, Kathmandu University

Dr. Dev Raj Poudyal
Lecturer, University of Southern Queensland, Australia

Mr. Tanka Dahal
Director, Survey Department

Mr. Bikash Kumar Karna
Chief Survey Officer, Survey Department

Mr. Uma Shankar Panday
Assisstant Professor, Kathmandu University

Mr. Prashant Ghimire
Chief Survey Officer, Survey Department

Mr. Sanjeevan Shrestha
Chief Survey Officer, Survey Department

Mr. Shanker KC
Survey Officer, Survey Department

Mapping Burn Severity of Wildfire and Its Analysis with Topographical Factors: A Case Study of Chitwan District

Aagya Dhungana[1], Anjali Singh[1], Anju Lage[1], Punam Koirala[1], Man Kumari Chaulagain[1], Sunil Thapa[2], Reshma Shrestha[1],

[1] Department of Geomatics Engineering, Kathmandu University, Dhulikhel, Nepal

aagyadhungana@outlook.com, anjalirajput2057@gmail.com, kuangeomet@gmail.com, poonamokoirala333@gmail.com, chaulagainasmita7@gmail.com, reshma@ku.edu.np

[2]International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal

sunilmagar@gmail.com

ABSTRACT

Forests and woodlands provide critical ecosystem services, but they are increasingly threatened by wildfires, driven by both natural and anthropogenic factors. This study focuses on the Chitwan district of Nepal, where forest fires are a recurring problem, particularly during the dry season. Using remote sensing techniques, this study aims to assess burn severity and analyze it in relation to topographical factors like slope, elevation, and aspects. By employing differenced Normalized Burn Ratio (dNBR) the analysis of the 2021 map reveals varying severity levels: 30.2 km^2 high severity, 299.8km^2 moderate severity, and 131.3km^2 low severity areas. Areas with dense and dry vegetation were found most impacted. The study also examined the relationship between burn severity and other topographic features such as slope, elevation, and aspect, providing insights into fire behavior. This research underscores the importance of continuous monitoring and effective management strategies to mitigate wildfire impacts and support ecosystem recovery. The findings suggest that remote sensing tools are invaluable for assessing burn severity, offering a cost-effective and efficient means of forest management. These insights can guide future conservation efforts, resource allocation, and the development of strategies to enhance the resilience of forest ecosystems in the face of increasing wildfire incidents.

KEYWORDS: Burn Severity, Forest Fire, Satellite Imageries, Wildfire

1. INTRODUCTION

Forests and woodlands provide a variety of essential ecosystem services, such as climate regulation, biomass production, soil stability, and water conservation (Liu et al., 2022). Forest fires are significant catastrophic events that remove plant biomass from the landscape, leading to loss of biodiversity, land degradation, and ecological imbalance (A. et al., 2022). Wildfires have major environmental and ecological issues threatening human lives, causing massive losses of lives and properties (Martin et al., 2016). A rise in global temperature by 2 °C has contributed to the increased frequency of forest fires, though only 3% of all forest fires have been caused naturally while the majority have been sparked off by anthropogenic activities (Thapa et al., 2021). Wildfire is a significant contributor to forest loss and degradation, biodiversity, and ecosystem functioning, as well as causing irrevocable harm to human health, lives, and property (Ba et al., 2019). Forest fires are a major driver in the destruction of biodiversity and habitats of many endangered species and a key factor in environmental transformation by the infusion of substantial amounts of greenhouse gas (Jaiswal et al., 2002). Forest fires are majorly influenced by vegetation cover and its moisture content as they hold fuel for the fire (Yebra et al., 2013). Areas with dry and dense vegetation are more prone to forest fires than those with moist and sparse vegetation (Thapa et al., 2021).

With technological advancements, the availability of remotely sensed data on forest cover and bioclimatic variables has significantly increased since the early 2000s (Sunar & Özkan, 2001). This data has proven invaluable for quantitative studies on the impact of forest fires. Researchers have extensively used remotely sensed data to study various aspects of forest fires, including active fire monitoring, burn severity, risk monitoring, and vegetation regrowth pattern analysis (Mishra et al., 2023). Remote Sensing (RS) techniques have emerged as an exceptional alternative to expensive and time-consuming field measurements for monitoring forest ecosystems across large and remote geographic areas (Abdulraheem et al., 2023). Multi-temporal satellite images of broad spatial resolution have been extensively used to measure forest areas before and after fires, aiding in the estimation of burn severity (Roy et al., 2006) and vegetation recovery(Leeuwen et al., 2010).

Forest fire frequency is increasing globally with the significant incidents occurring in Asia (Parajuli et al., 2020). According to (Martin et al., 2016), approximately 40,000 hectares of forest area in Nepal are burned every year. According to SERVIR highlights report from 2023, forest fires across Nepal dramatically rose by 76.5% between January and April 2023 – when compared with incidents reported over the entirety of the previous year. Despite the evident urgency, there is a notable lack of comprehensive studies on burn severity in the Chitwan district. However, there are many government bodies like the Division Forest Office, Community Forest User Group, and security agencies who are directly looking after the cases of wildfires(Paudel et al., 2022). However, there is room for improvement in fostering better coordination and teamwork among these organizations.

This study reports on the analysis of dNBR as an index to analyze fire severity in forest areas of the Chitwan district. dNBR is a bi-temporal approach by subtracting post-fire and pre-fire NBR values and a widely used index in remote sensing developed by Key and Benson (1999). The main objective of the study was to assess burn severity mapping across the Chitwan District. This study is essential for evaluating wildfires and their nature towards the topological factors like slope, elevation, and aspect. In addition, validate the identified burned area by applying the Area Under Curve (AUC) and analyze the relation of fire severity with topographical factors.

2. MATERIALS AND METHODS

2.1. Study Area

The study was conducted in Chitwan District.

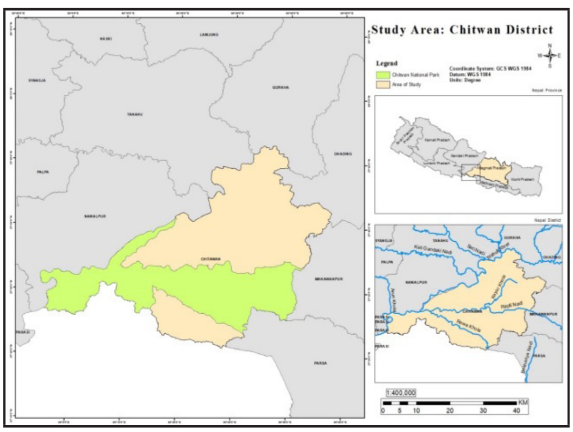


Figure 1: Map of the Study Area

Chitwan district is located in the southwestern corner of Bagmati Province, chosen due to the abundance of forest in Chitwan National Park in the study area, particularly rich in flora and fauna and is of high economic and ecological importance in Nepal (Pandey et al., 2022) For the study, Google Earth Engine, ArcGIS was particularly used and data was retrieved from Sentinel-2A and 2B images.

2.2. Methods

Major stages of work involved acquiring Sentinel 2 images for burn severity and applying Top of Atmospheric correction to calculate Pre-fire & Post-fire NIR and SWIR to delineate NBR of the study area which leads to the determination of burn severity of the study area through dNBR calculation. After a burn severity map was retrieved, validation was performed by overlaying it with active fire points (MODIS data) from the same period, provided by Nepal's Forest Fire Detection and Monitoring System. Additionally, the map was analyzed based on three factors relevant to forest fires: slope, elevation, and aspect.

This study adopted the AUC curve for the validation of the burn severity map which is a graphical representation of the performance of a classification model at different threshold values (Marzban, 2004). It plots the true positive rate (TPR) on the y-axis and the false positive rate (FPR) on the x-axis.

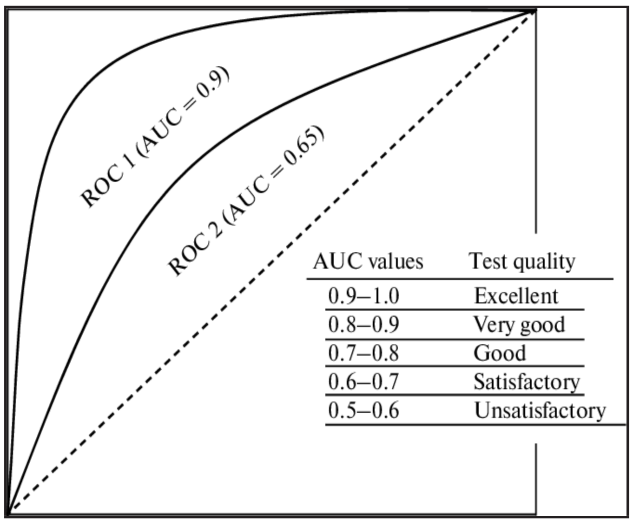


Figure 2: Area Under the Curve Threshold Values

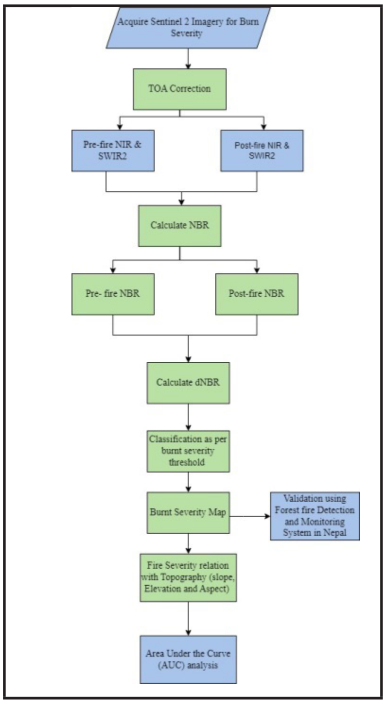


Figure 3: Methodological Framework of the Process

2.2.1. Image processing: Top of Atmospheric Correction

For TOA correction, a cloud mask algorithm to identify and remove cloud cover from satellite images was used to ensure that the pixels in the image were transparent and excluded for further analysis. Then pre and post-fire periods were defined and mosaicked with the smallest possible cloud extent and Chitwan District's area was clipped to increase the processing speed of the analysis.

2.2.2. Burn Severity Assessment

Burn severity was estimated by using NBR and dNBR indices derived from Sentinel-2 images. Data used for pre-fire was from 01 January 2021 to 30 February 2021 and for post-fire from 01 August 2021 to 30 September 2021. The dates were selected as close as possible to assess the same environmental conditions.

2.2.3. Normalized Burn Ratio (NBR) and dNBR

The range for NBR is -1 to +1. A high NBR value indicates healthy vegetation and a low value indicates bare ground and recently burnt areas.

$$\text{NBR} = \frac{\text{NIR} - \text{SWIR}}{\text{NIR} + \text{SWIR}}$$

Where; NIR is near-infrared (band 8 for sentinel-2) & SWIR is short wave infrared (band 12 for sentinel-2). Non-burnt areas usually have values close to zero. The burn severity spectral index dataset was divided into five categories based on Earth data science burn severity categories; Enhanced Regrowth, Unburned, Low severity, Moderate severity, and High severity.

Difference Normalized Burn Ratio (dNBR), a widely used index in remote sensing developed by Key and Benson (1999) is a bi-temporal approach by subtracting post-fire and pre-fire NBR values. The results range from -1 to 1, where positive values represent the region that was severely burned while negative represents the area that was less affected by the fire.

$$\text{dNBR} = \text{Prefire NBR} - \text{Postfire NBR}$$

The burn severity spectral index dataset was divided into five categories based on Earth data science burn severity categories; Enhanced Regrowth, Unburned, Low severity, Moderate severity, and High severity as all possibilities to create burn severity maps for research region.

2.2.4. Digitizing High Burn Severity Area

After the preparation of the burn severity map into several classes like enhanced regrowth, unburned, low severity, moderate severity, and high severity. The distributive nature of the high-severity area was manually digitized into a polygon. The shape file was created and exported and then the pixel values of the dNBR index were extracted into those polygons and zonal statistics were done to determine the mean pixel values of each polygon for further analysis and accuracy assessment.

2.2.5. Fire Severity Relation with Topography

From the DEM of the Chitwan district, the maps of elevation, slope, and aspect were obtained. By overlaying the active fire points of MODIS onto the obtained maps, the topographic relation of burn severity and the topographic factors were investigated. Understanding these topographical factors is essential for assessing fire risk, planning fire management strategies, and mitigating the impact of forest fires on both ecosystems and communities.

2.2.6. Validation of Burn Severity

Active fire points were acquired from the Forest Fire Detection and Monitoring System in Nepal, co-developed by ICIMOD and the Department of Forests and Soil Conservation (DoFSC), Ministry of Forests and Environment, Government of Nepal, were overlaid on the dNBR map to validate burn severity. The system incorporates MODIS data and provides information on historical forest fires and near real-time forest fires in Nepal. In that system, we specified our study area and the date ranges to download the fire points from MODIS. For this, months of peak forest fire season i.e. March/April of the year 2021 were taken as wildfires in CNP are high between February and April (Giri 2022.Pdf, n.d.). Then, these points were overlaid in the obtained map of dNBR for the year 2021.

2.2.7. AUC Analysis for Accuracy Assessment

AUC-ROC plots the true positive rate (TPR) on the y-axis and the false positive rate (FPR) on the x-axis. The TPR is the proportion of actual burned areas that are correctly classified by the model, while the FPR is the proportion of actual unburned areas that are incorrectly classified as burned by the model. For the calculation of AUC values and generation of the ROC curve, we used the ROC tool of ArcSDM toolbox in ArcGIS. The fire hotspot points downloaded from the Forest Fire Detection and Monitoring System in Nepal were considered as the true positives and the burn severity map was used as a classification model. Then the ROC curve was generated and the AUC value was calculated.

3. RESULTS AND DISCUSSION

3.1 Burn Severity Map

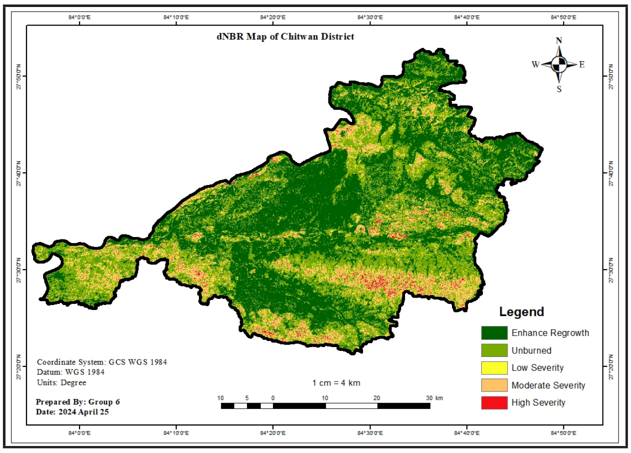


Figure 4: dNBR Map of Chitwan District of 2021

This is the final map of dNBR for Chitwan District, Nepal for monitoring the forest fire in 2021. The range for the dNBR map is -1 to +1 where positive values represent the region that was severely burned while negative represents the area that was less affected by the fire. Here in the above map red color represents high range dNBR; i.e. high severity area and the green color represents enhanced regrowth.

Table 1: Computed Severity Area in 2021

S.N.	Zone	Area (Sq. Km)
1	Enhanced Regrowth	1092.2265
2	Unburned	989.9838
3	Low Severity	131.3037
4	Moderate Severity	299.8341
5	High Severity	30.1995

The analysis of the 2021 map of Chitwan district, using NBR and dNBR indices, revealed the following: approximately 30.2 square kilometers were classified as high severity, 299.8 square kilometers as moderate severity, and 131.3 square kilometers as low severity. This study found that the core area of Chitwan National Park was predominantly affected by the 2021 fire, with the most severe damage occurring within the core areas. (Giri, 2022) noted that the core area experienced more significant fire impact compared to the buffer zones, largely due to the park's strict regulations. These rules restrict locals from gathering fodder and fuel wood only from the buffer zones, resulting in a greater accumulation of flammable materials in the core area than in the buffer zones.

This study found that the core area of Chitwan National Park was predominantly affected by the 2021 fire, with the most severe damage occurring within the core areas.

3.2 Influencing Factors of Forest Fires:

3.2.1 Slope

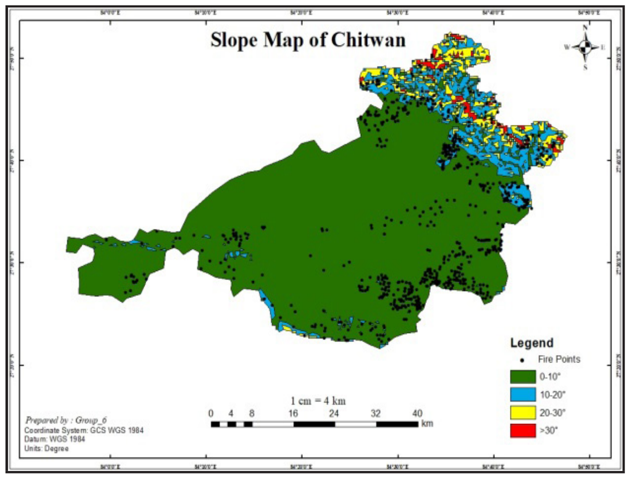


Figure 5: Slope Map of Chitwan

The above map shows that most fires have occurred on the lower slopes. Slopes ranging from 0 to 10 degrees contain higher fire severity compared to 30 degrees of slopes. A similar result was found in (Giri 2022,n.d.) highlighting the reason that forest fires are mainly caused by human activities in the Chitwan District This could be because the bulk of the study area is flat, has a low slope, and is covered in broad-leaved forests that are dominated by Sal trees rich in biomass acting as fuel for forest fire; as a result, the majority of fire occurrences happened in this slope that 73.6% of the fire threat in his study area was on slopes less than 25%.

3.2.2 Elevation

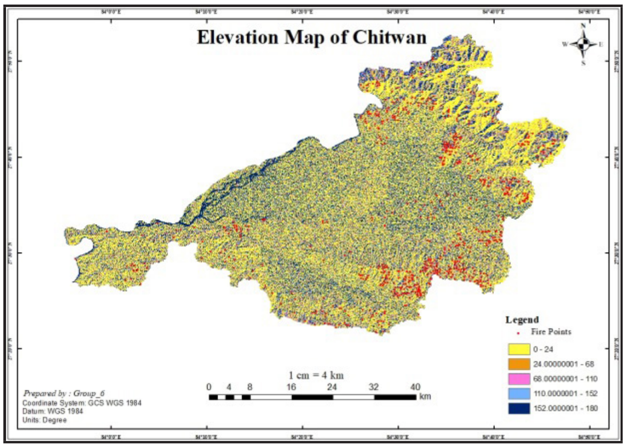


Figure 6: Elevation Map of Chitwan

Elevation also showed a similar trend as the slope in relation to the forest fire. From the above map, the most burned area was found in the range of 0 to 24 m i.e. low elevation, and the least burned area was found in the range of 152 to 180 m i.e. high elevation.

3.2.3 Aspect

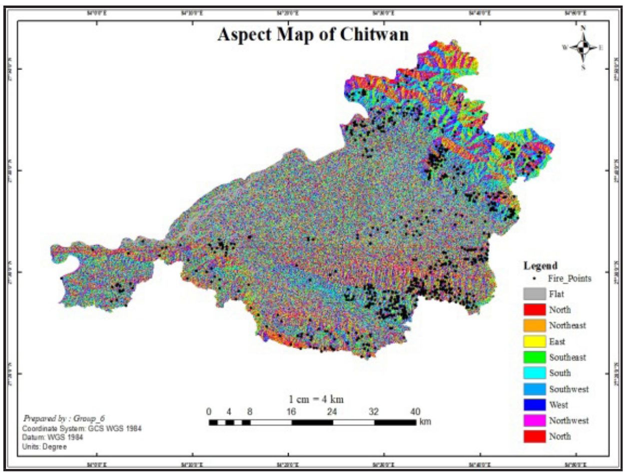


Figure 7: Aspect Map of Chitwan District

In the northern hemisphere, southern exposures suffer the greatest solar and wind influences, while northern slopes suffer the least. In general, cases of forest fire occur more in areas of the southern aspect than in areas of the northern aspect, because areas of southern exposure have higher burning points. The analysis showed that the south-facing slopes; i.e. southeast, southwest, and south pose higher fire severity than the north face.

With reference to the aspect which provides a direction of the slope faces, the analysis, showed that the south-facing slopes; i.e. south-east, and south-west, pose higher fire severity than the north face.

3.3 Validation and accuracy assessment

3.3.1 Validation of Burn Severity Using Forest Fire Detection and Monitoring System in Nepal

By overlaying the obtained dNBR map with MODIS active fire points, it was observed that the fire points aligned with high and moderate severity classes. The MODIS active fire points are accurately overlaid on areas of Moderate and High Burn Severity in the study area. To assess the accuracy of visual inspection, an AUC analysis was conducted.

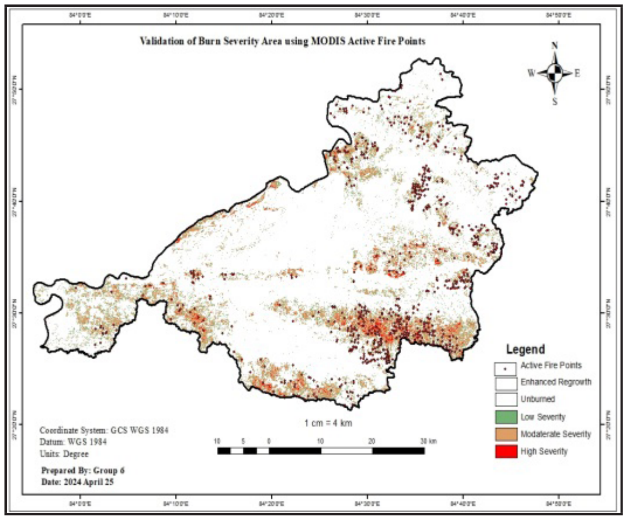


Figure 8: Validation of Durn Severity

3.3.2 Area Under the Curve Analysis for Burn Severity Index

The curve below shows the true positive rate on the y-axis and the false positive rate on the x-axis. This curve shows that the classification between burned and unburned areas is reasonably good, as indicated by the AUC value of 0.748.

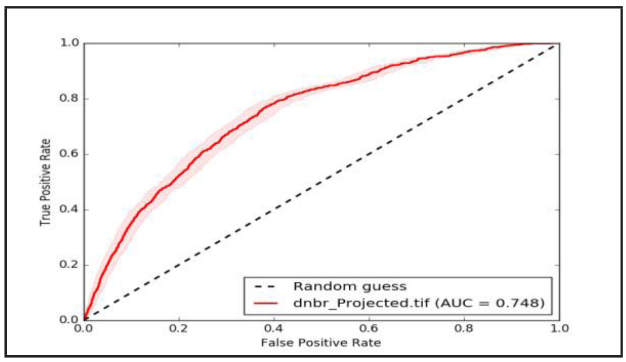


Figure 9: Area Under the Curve of dNBR Map

Therefore, AUC of 0.748 suggests that the dNBR values used in this analysis provide a reliable indicator of burn severity. Specifically, the model correctly classifies approximately 74.8% of the burned and unburned areas, demonstrating a significant improvement over random chance.

4. CONCLUSION AND RECOMMENDATIONS

By evaluating the massive forest fire that occurred in Chitwan district during the months of March and April in the year 2021, this study aimed to assess burn severity area. The study was conducted using two fire severity indices, NBR and dNBR to assess the severity of fire. The indices computation was done on Google Earth Engine (GEE) platform. For this computation, we used Sentinel-2 images due to their high spatial resolution which facilitated precise and accurate analysis. Severity distribution with the elevation factors, slope, and aspect were investigated which showed that the higher the slope lower the severity, and northern faced area showed the lowest burned area because, in the northern hemisphere, southern exposures suffer the greatest solar and wind influences, while northern slopes suffer the least. This study focused on physical factors like slope, elevation, and aspect, but other factors such as population density, forest type, and proximity to roads also influence forest fires and should be considered.

30.12 km² of the total area of Chitwan district was found to be a high-severity area due to wildfire in 2021. Similarly, 300 km² area was moderate severity and 132 km² was of low severity. To validate the obtained burn severity map, fire hotspot points from the Forest Fire Monitoring and Detection System in Nepal were overlaid in the obtained result of dNBR and to support this visual inspection, Area Under the Curve analysis was done using the same points as the true positive data. The result showed that the model correctly classifies approximately 74.8% of the burned and unburned areas, demonstrating a significant improvement over random chance.

It is recommended to incorporate additional indices that can help account for factors such as atmospheric conditions, which could improve the accuracy of burn fire monitoring and assessment. Moreover, combining remote sensing data with field measurements can validate and calibrate the satellite-derived indices, leading to more precise and reliable results.

Additional consideration must be taken during these months (March/April/May) as forests are most prone to high fire risk during these months in Nepal. Therefore, realizing Chitwan's vulnerability, reliable and effective fire mitigating measures should be adopted, and fire preparedness training to the local stakeholders and managers should be encouraged. Nepal faces tremendous forest fires during the dry season for which efficient forest fire risk assessment, warning, and monitoring system need to be improved. These variables should be taken into care, and areas under these features should be carefully monitored throughout the year by community-based firefighting groups.

ACKNOWLEDGEMENT

First and foremost, profound gratitude is extended to Mr. Sujan Sapkota and Mr. Sandesh Sharma, whose invaluable guidance, insightful feedback, and unwavering support have been instrumental in shaping this research.

REFERENCES

A., A., Ashraf, A., & Ks, A. (2022). Impact of Forest Fire on Forest Ecosystem.

Abdulraheem, M. I., Zhang, W., Li, S., Moshayedi, A. J., Farooque, A. A., & Hu, J. (2023). Advancement of Remote Sensing for Soil Measurements and Applications: A Comprehensive Review. Sustainability, 15(21), Article 21. https://doi.org/10.3390/su152115444

Franco, M. G., Mundo, I. A., & Veblen, T. T. (2020). Field-Validated Burn-Severity Mapping in North Patagonian Forests. Remote Sensing, 12(2), Article 2. https://doi.org/10.3390/rs12020214

Giri 2022.pdf. (n.d.). Retrieved December 26, 2023, from https://brage.inn.no/inn-xmlui/bitstream/handle/11250/3058697/Giri%202022.pdf?sequence=1

Jaiswal, R., Mukherjee, S., Raju, D., & Saxena, R. (2002). Forest fire risk zone mapping from satellite imagery and GIS. International Journal of Applied Earth Observation and Geoinformation, 4, 1–10. https://doi.org/10.1016/S0303-2434(02)00006-5

Leeuwen, E. S., Nijkamp, P., & de Noronha, T. (2010). The multifunctional use of urban greenspace. International Journal of Agricultural Sustainability, 8, 20–25. https://doi.org/10.3763/ijas.2009.0466

Liu, J., Freudenberger, D., & Lim, S. (2022). Mapping burned areas and land-uses in Kangaroo Island using an object-based image classification framework and Landsat 8 Imagery from Google Earth Engine. Geomatics, Natural Hazards and Risk, 13(1), 1867–1897. https://doi.org/10.1080/19475705.2022.2098066

Martin, D., Tomida, M., & Meacham, B. (2016). Environmental impact of fire. Fire Science Reviews, 5. https://doi.org/10.1186/s40038-016-0014-1

Marzban, C. (2004). The ROC Curve and the Area under It as Performance Measures. Weather and Forecasting, 19. https://doi.org/10.1175/825.1

Matin, M. A., Chitale, V. S., Murthy, M. S. R., Uddin, K., Bajracharya, B., & Pradhan, S. (2017). Understanding forest fire patterns and risk in Nepal using remote sensing, geographic information system and historical fire data. International Journal of Wildland Fire, 26(4), 276–286. https://doi.org/10.1071/WF16056

Mishra, B., Panthi, S., Ghimire, B. R., Poudel, S., Maharjan, B., & Mishra, Y. (2023). Gridded precipitation products on the Hindu Kush-Himalaya: Performance and accuracy of seven precipitation products. PLOS Water, 2(8), e0000145. https://doi.org/10.1371/journal.pwat.0000145

Pandey, H. P., Pokhrel, N. P., Thapa, P., Paudel, N. S., & Maraseni, T. N. (2022). Status and Practical Implications of Forest Fire Management in Nepal. Journal of Forest and Livelihood, 21(1), 32–45. https://doi.org/10.3126/jfl.v21i1.56583

Parajuli, A., Gautam, A. P., Sharma, S. P., Bhujel, K. B., Sharma, G., Thapa, P. B., Bist, B. S., & Poudel, S. (2020). Forest fire risk mapping using GIS and remote sensing in two major landscapes of Nepal. Geomatics, Natural Hazards and Risk, 11(1), 2569–2586. https://doi.org/10.1080/19475705.2020.1853251

Paudel, G., Carr, J., & Munro, P. (2022). Community forestry in Nepal: A critical review. International Forestry Review, 24, 43–58. https://doi.org/10.1505/146554822835224810

Piao, Y., Lee, D., Park, S., Kim, H. G., & Jin, Y. (2022). Multi-hazard mapping of droughts and forest fires using a multi-layer hazards approach with machine learning algorithms. Geomatics, Natural Hazards and Risk, 13(1), 2649–2673. https://doi.org/10.1080/19475705.2022.2128440

Roy, D., Boschetti, L., & Trigg, S. N. (2006). Remote Sensing of Fire Severity: Assessing the Performance of the Normalized Burn Ratio. Geoscience and Remote Sensing Letters, IEEE, 3, 112–116. https://doi.org/10.1109/LGRS.2005.858485

SERVIR Highlights from 2023 | SERVIR GLOBAL. (n.d.). Retrieved January 24, 2024, from https://servirglobal.net/news/servir-highlights-2023

Sunar, F., & Özkan, C. (2001). Forest fire analysis with remote sensing data. International Journal of Remote Sensing, 22(12), 2265–2277. https://doi.org/10.1080/01431160118510

Thapa, S., Chitale, V., Pradhan, S., Shakya, B., Sharma, S., Bajracharya, S., Adhikari, S., & Dangol, G. (2021). Forest Fire Detection and Monitoring (pp. 147–167). https://doi.org/10.1007/978-3-030-73569-2_8

Yebra, M., Dennison, P. E., Chuvieco, E., Riaño, D., Zylstra, P., Hunt, E. R., Danson, F. M., Qi, Y., & Jurdao, S. (2013). A global review of remote sensing of live fuel moisture content for fire danger assessment: Moving towards operational products. Remote Sensing of Environment, 136, 455–468. https://doi.org/10.1016/j.rse.2013.05.029

AUTHOR INFORMATION

Name	:	**Aagya Dhungana**
Academic Qualification	:	BE in Geomatics Engineering
Organization	:	Creasion Nepal
Current Designation	:	Program Development Associate
Work Experience	:	2 years

SPATIO-TEMPORAL ANALYSIS OF AIR POLLUTANTS BEFORE, DURING AND AFTER COVID-19 OUTBREAK OVER KATHMANDU VALLEY

Binod Prasad Bhatta[1], Mamta Kadel[1], Gorakh Nath Pandey[1], Sadikshya Adhikari[1], Manoj Kumar Bhat[1]

[1]*Kathmandu University, Dhulikhel*

Prasad.binodbhatta11@gmail.com, mamtakadel88@gmail.com, aarogya.pandey5@gmail.com, sa04071319@student.ku.edu.np, manojbhat2050@gmail.com

ABSTRACT

This study investigates the temporal variations in air quality in Kathmandu Valley during different phases of the COVID-19 pandemic using Sentinel satellite data and Google Earth Engine (GEE). The focus is on three key air pollutants: Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), and Sulfur Dioxide (SO_2), analyzing their levels from September 2019 to March 2022. Baseline measurements from September 2019 to March 2020 establish typical air quality conditions: CO levels at 32.65 milli mol/m², SO_2 levels at 191.87 µmol/m², and NO_2 levels at 27.018 µmol/m². During the COVID-19 lockdown periods (March 2020 to March 2021), despite expectations of reduced emissions due to decreased vehicular activity, CO levels showed a slight increase to 33.96 and 34.78 milli mol/m². SO_2 levels initially decreased to 36.20 µmol/m² but subsequently rose to 227.67 µmol/m², while NO_2 levels decreased to 19.531 µmol/m² and then increased to 28.567 µmol/m². These findings suggest that factors beyond reduced traffic, such as industrial activities and meteorological conditions, significantly influenced air quality during lockdowns. In the post-COVID-19 recovery phases (March 2021 to March 2022), further fluctuations in air quality were observed. CO levels peaked at 41.21 milli mol/m² before decreasing to 31.11 milli mol/m². SO_2 levels reached a maximum of 259.92 µmol/m² before declining to 52.97 µmol/m², reflecting the resumption of economic activities. NO_2 levels stabilized, indicating persistent emissions despite varying levels of other pollutants. The study underscores the complex interplay between human activities, environmental conditions, and air quality dynamics in Kathmandu Valley. Effective air quality management strategies require comprehensive approaches that address diverse pollution sources, including industrial emissions and biomass burning. Continuous monitoring is crucial for capturing temporal variations and informing adaptive environmental policies. Public awareness campaigns play a pivotal role in promoting behavior change and fostering community participation in air quality improvement efforts. Moreover, regional collaboration is essential for addressing cross-border pollution challenges and achieving sustainable air quality improvements across the region.

KEYWORDS: Air Pollutants, CO, NO_2, SO_2, COVID-19, Google Earth Engine

1. INTRODUCTION

1.1 Background

The coronavirus disease (COVID-19) pandemic had a profound influence on society, the economy, and the environment, regardless of geographical or political boundaries (Elsaid et al., 2021; Poudel & Subedi, 2020). Since the start of 2020, governments around the world have implemented lockdowns and rigorous health and safety regulations, which have restricted outside activities and travel. As a result, there has been a considerable decrease in worldwide vehicular traffic as well as industrial and commercial activities (Madineni et al., 2021; Zhang et al., 2020). These limitations had an impact on global urban and commercial air quality (Dasgupta & Srikanth, 2020). Numerous recent studies have demonstrated that while COVID-19-related restrictions and lockdowns decreased levels of air pollutants such as nitrogen dioxide (NO_2), and carbon monoxide (CO) (Ghahremanloo et al., 2021).

The relationship between the COVID-19 lockdown and air quality is being investigated by a number of assessments carried out at the national, regional, or international levels (Upadhyay et al., 2022). Regarding the change in air quality measures throughout the lockdown period compared to the baselines, those studies have revealed a mixed bag of results with notable regional variation. Lockdowns also varied in their effect on the atmospheric concentrations of various air pollutants. For instance, during the first month of the COVID-19-related restrictions' implementation in Brazil, significant drops in CO (-53% in the State of Rio Grande do Sul), NO_2 (-34% in Rio de Janeiro), and PM10 (-23% in Espírito Santo) concentrations were recorded, however, an increase in Ozone O_3 concentration (40% in Paraná) (Rudke et al., 2022). Similarly, in the UK, O_3 increased by 7.6% while mean NO_2 and PM2.5 levels dropped by 38.3% and 16.5%, respectively (Jephcote et al., 2021).

Nepal is a country located in South Asia that is surrounded by high mountains and deep valleys that are crisscrossed by rivers. Nepal is situated in the centre Himalayan area. A study carried out by Panday et al., (2009) suggested that Kathmandu Valley's bowl-shaped terrain restricts ventilation and results valley's poor air quality. The Kathmandu Valley's citizens are particularly vulnerable to air pollution because of the valley's unique topography, fast urbanization, and dense population (Saud & Paudel, 2018). During the first wave of the COVID-19 pandemic, Nepal implemented a nationwide lockdown from 24 March to 20 July 2020 in an effort to stop the spread of the SARS-CoV-2 virus. Geographically homogeneous changes in air quality during lockdowns are caused by a variety of reasons, including the terrain and weather of a region, as well as major sources of air pollution (Moore & Semple, 2021).

A recent study examined the air quality in Nepal and its topographically distinctive metropolitan centre, the Kathmandu Valley, taking an advantage of the exceptional occurrence of the nationwide lockdown (Dhital et al., 2022). This study integrated data obtained from ground-based air quality monitoring systems and satellite remote sensing, and examined how the air quality changed over the course of the lockdown, separating it into dry and wet seasons. Nevertheless, no earlier research examined the impact of lockdown on air quality in the Kathmandu Valley, for the pre, during and post lockdown duration.

This study took advantage of the rare occurrence of the statewide lockdown to investigate the quality of the air in the Kathmandu Valley. We investigated the changes in air quality prior to, during, and following the lockdown using satellite imagery. Since people's movement was restricted during the lockdown, which in turn influenced emissions from the transport sector, our findings provide insight into the potential benefits of reducing emissions from this sector in Nepal's urban areas with regard to improved air quality.

The primary focus of this project's research has been to determine the air quality before, during, and after lockdown. For this, Carbon Monoxide (CO), Nitrogen Dioxide (NO_2) and Sulphur Dioxide (SO_2) content in the air has been studied.

2. MATERIALS AND METHODS

2.1 Software and applications used

For this research, Google Earth Engine, a cloud-based geospatial analysis platform, was used to extract the information about air quality. Google Earth Engine is a cloud-based geospatial analysis platform by Google, offering access to extensive satellite imagery and environmental datasets. It supports geospatial analysis through JavaScript codes. GIS environment was also used for making final layout.

2.2 Study Area

The study area encompasses the Kathmandu Valley, which includes the districts of Kathmandu, Lalitpur, and Bhaktapur in Nepal. Geographically, it is situated at a latitude of 27° 43' 1.92'' N and a longitude of 85° 19' 26.4'' E. As the capital city of Nepal, Kathmandu attracts a significant number of individuals seeking improved employment opportunities, healthcare, and education. This inflow of people contributes to the valley's high population density.

Unfortunately, the region suffers from serious pollution problems, mostly as a result of the districts' inadequate implementation of control measures. Due to the COVID-19 pandemic, many people left Kathmandu, which led to a noticeable drop in both pollution and vehicle traffic. However, both before and after the lockdown, increased traffic contributed to higher pollution levels.

This study illustrates the importance for pollution control measures in this heavily populated and economically vital area by demonstrating a direct link between vehicle activity and air quality in the Kathmandu Valley.

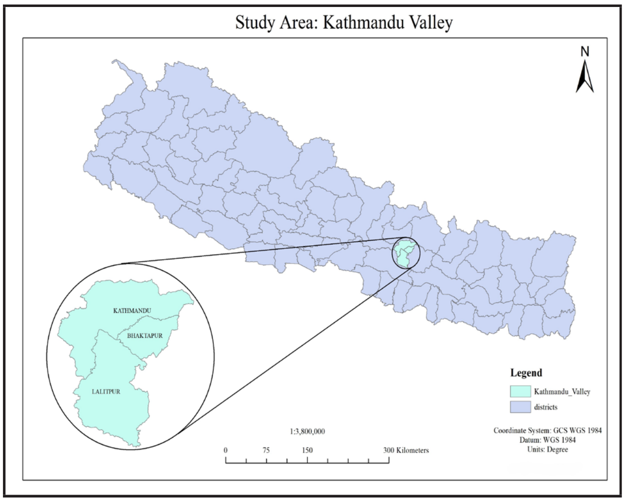


Figure 1: Study Area: Kathmandu Valley

2.3 Methodology

The methodology for this project is breakdown into various steps. The workflow is shown in figure 2.

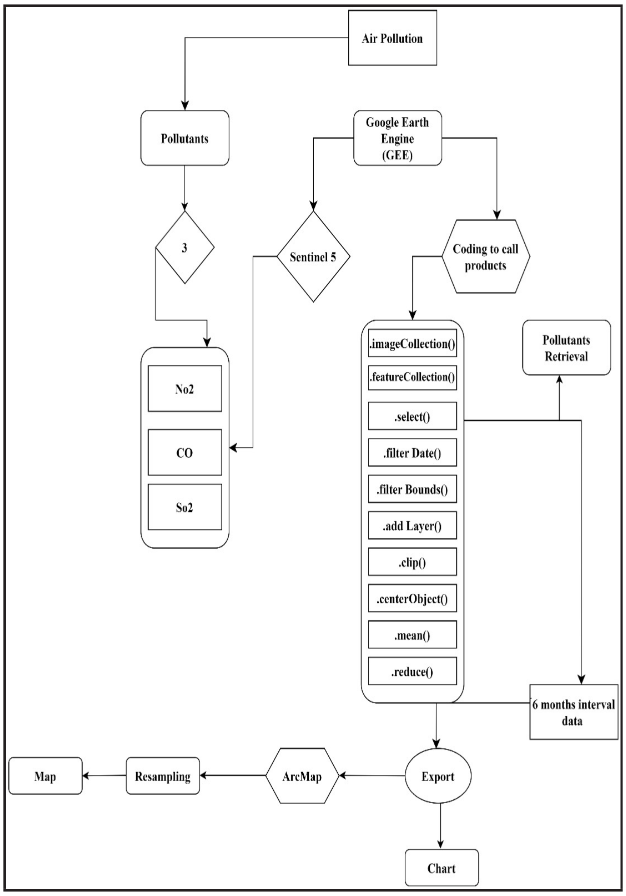


Figure 2: Methodological Flowchart

2.3.1 Data Acquisition and Preparation

2.3.1.1 Access Sentinel-5 Data

Initially, the Sentinel-5 satellite image were retrieved using google earth engine platform. The java script codes were employed to retrieve the data. This platform ensures better capacity to manage and process the large-scale geospatial datasets as this study has been done in multiple phases for the exploration of air quality dynamics.

2.3.1.2 Specification of Pollutants

The air quality indicators selected for the study were Nitrogen Dioxide (NO_2), Carbon Monoxide (CO), Sulphur Dioxide (SO_2) as they are reliable indicators for analysis of atmospheric pollution. The choice of these pollutants reflects a strategic approach to capturing diverse dimensions of air quality variations.

2.3.1.3 Retrieval of Image Collections

A temporally rich dataset was generated through the systematic retrieval of Sentinel-5 image collections, made possible by GEE's imageCollection() tool. The integration of multi-temporal satellite imagery provided the basis for a detailed analysis of the dynamics of air quality over various time periods.

2.3.1.4 Application of Filters

By defining the geographic limits of the study region, spatial filters like featureCollection() and filterBounds() were used to refine the data both spatially and temporally. Using filterDate(), temporal segmentation was carefully carried out, allowing for the isolation of particular time periods that were important for pre-lockdown, lockdown, and post-lockdown analysis.

2.3.1.5 Extraction of Pollutant Bands

For the extraction of the pollutant bands the select () function was used. The pollutant bands were identified by isolating key bands for NO_2, CO, and S02. This pollutant band extraction laid the foundation for later quantitative analyses.

2.3.2 Data Processing and Analysis

2.3.2.1 Calculation of Mean Pollutant Concentrations

The study measured the average concentration of each targeted pollutant over predetermined spatial and temporal extents using GEE's mean () reducer. This statistical study offered a solid framework for comprehending differences in air quality measurements.

2.3.2.2 Generation of Pollution Maps

The generation of high-resolution pollution maps involved a systematic application of Google Earth Engine (GEE) functions. Using the imageCollection(), featureCollection(), and filterBounds() functions, Sentinel-5 satellite imagery was retrieved and confined to the Kathmandu Valley.

Temporal segmentation was achieved through filterDate(), isolating distinct periods. select() was employed to pinpoint relevant pollutant bands (NO_2, CO, SO_2). The integration of addLayer(), clip(), and centerObject() functions facilitated visually compelling maps, emphasizing spatial dynamics. Statistical precision was attained with the mean() reducer, calculating average pollutant concentrations. The resulting maps, centered on specific coordinates via centerObject(), were exported for further analysis in ArcMap, enhancing the scholarly exploration of air quality variations.

2.3.2.3 Temporal Analysis

During the temporal analysis phase, we carefully looked at the data in chunks of 6 months each. This helped uncover subtle changes that happen with the seasons. Using the filterDate() function, the data was separated into distinct periods, making it easier to identify any notable shifts in air quality.

This approach is like zooming in on different parts of the year to see if there are any patterns. We paid special attention to times when lockdown measures were in place during the COVID-19 pandemic. By doing this, this research aimed to catch any significant changes in air pollution linked to these specific timeframes. This method follows common practices in environmental analysis, offering a detailed look at how air quality shifts over time. The focus on 6-month intervals adds more detail to our observations, making our analysis more precise and enhancing the academic strength of our temporal exploration.

2.3.3 Data Visualization

2.3.3.1 Raster File Export and Resampling

For more sophisticated visualization, Google Earth Engine (GEE) pollution data was produced in TIFF format. A method known as cubic convolution resampling was used to fix pixel clarity problems. This improvement made for a more accurate depiction of the ongoing spatial fluctuations in air quality, which improved and strengthened the visualization.

2.3.3.2 Color Adjustment for Enhanced Interpretation

A key component of good data visualization is the use of suitable color schemes. Color ramps were carefully altered in this context to highlight fluctuations in pollution concentrations. In addition to making the pollution map easier to understand, this intentional use of color mapping makes it easier to identify small variations in the levels of air quality throughout the research region

2.3.4 Final Map Preparation

Pollution map was prepared using ArcGIS software. Legend, scale, annotation, and other cartographic information were added to make map informative and visually appealing. This step aimed to provide a user-friendly and insightful representation of air quality variations in the study area.

3. RESULTS AND DISCUSSION

This study uses Sentinel-5 satellite data to look closely at how the levels of pollutants like CO, NO_2, and SO_2 in the air changed during different times of the COVID-19 pandemic. Maps has been created to show these changes, making it easier to understand how human activities affect the air in the study area.

3.1 CO composition in Air

Carbon monoxide (CO) is an important atmospheric trace gas for understanding tropospheric chemistry. In certain urban areas, it is a major atmospheric pollutant. Main sources of CO are combustion of fossil fuels, biomass burning, and atmospheric oxidation of methane and other hydrocarbons. Here is the composition chart of the carbon monoxide in different phase duration of COVID-19.

Table 1: CO Composition in Air

Time Duration	Amount of CO Composition in air (milli mol / m^2)
Sept(2019)-March(2020)	32.65
March(2020)-(Sept 2020)	33.96
Sept(2020)-March(2021)	34.78
March(2021)-(Sept 2021)	41.21
Sept (2021)-March(2022)	31.11

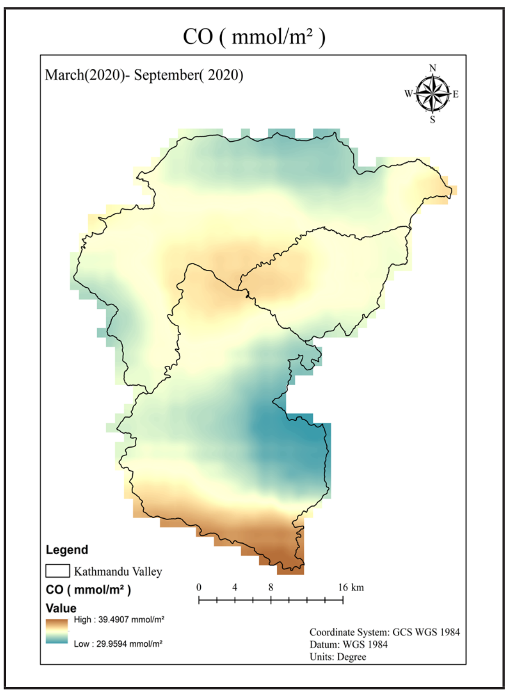
Pre-COVID Periods (September 2019 - March 2020): The initial time frame, spanning from September 2019 to March 2020, offers a baseline measurement of Carbon Monoxide (CO) concentration in Kathmandu Valley at 32.65 milli mol/m². This period serves as a reference point for understanding the typical air quality conditions before the onset of the COVID-19 pandemic.

During COVID Periods (March 2020 - September 2020 and September 2020 - March 2021): Moving into the COVID-19 periods, namely March 2020 to September 2020 and September 2020 to March 2021, an engaging trend emerges. Despite the implementation of lockdown measures, traditionally associated with decreased vehicular activity and improved air quality, the recorded CO levels show a slight increase from 32.65 to 33.96 milli mol/m² and further to 34.78 milli mol/m². This unexpected rise suggests that factors beyond reduced traffic, such as industrial operations or shifts in meteorological conditions, may have contributed to the observed fluctuations during these phases.

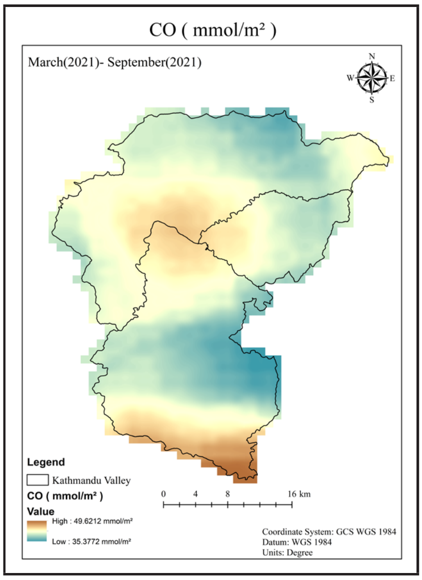
Post-COVID Periods (March 2021 - September 2021 and September 2021 - March 2022): CO levels rise noticeably during the post-COVID periods, March 2021 to September 2021 and September 2021 to March 2022. There is a noticeable increase in CO levels, which reach 41.21 milli mol/m². But a significant decrease is noted in the next phase, when CO levels fall to 31.11 milli mol/m². This fluctuation demonstrates the dynamic nature of environment and human activity impacts on the environment after lockdown.

Following maps has been created to visualize the CO composition in area.

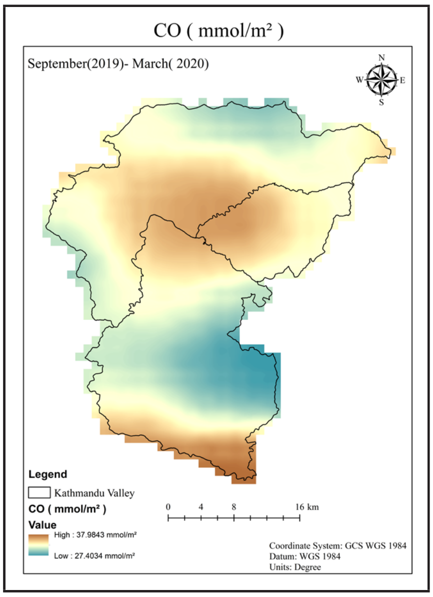
(a)



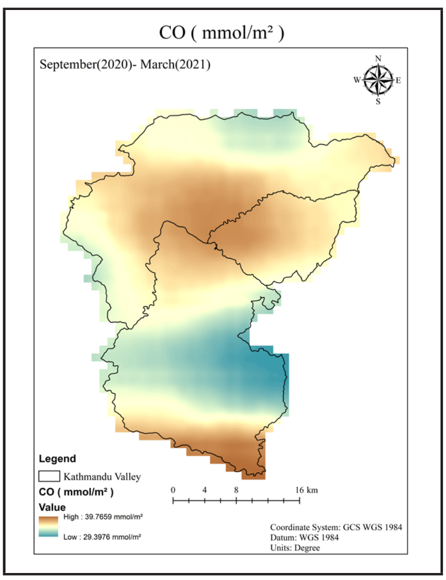
(b)



(c)



(d)



(e)

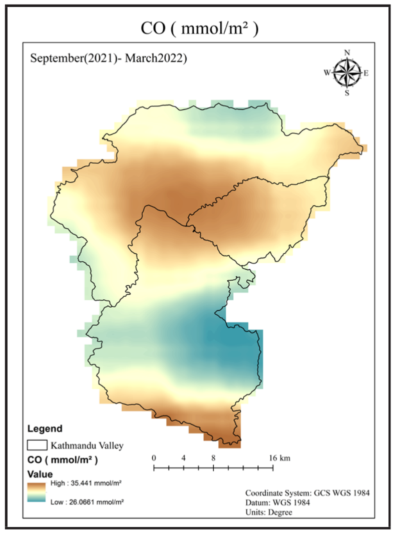


Figure 3: CO composition in Air in different time phases a) September (2019)-March (2020) b) March (2020) -(September 2020) c) September (2020)-March (2021) d) March (2021)-(September 2021) e) September (2021) – March (2022)

To show the different concentrations in different places, the CO air quality map uses a bright color gradient. It is easier to quickly understand spatial variations when cooler tones indicate lower CO levels and warmer hues highlight higher concentrations. Maps like the ones above are a great way to understand how different air quality is in different places and to pinpoint areas with higher pollution and areas with cleaner air.

High amounts of carbon monoxide (CO) were noted on the map before the lockdown, particularly in the lower, industrialized areas of Kathmandu. Significant decreases in CO levels during the lockout demonstrated that fewer emissions were mostly caused by less traffic.

3.2 SO_2 Composition in Air

Important atmospheric trace gas that has consequences on our knowledge of air quality and tropospheric chemistry is Sulphur Dioxide (SO_2). It is one among the most prominent air pollutants in cities, mostly from burning biomass, burning fossil fuels, and the atmospheric oxidation of methane and other hydrocarbons. The dynamics of air quality in the wake of the pandemic are given in terms of composition. Estimated in micromoles per square metre (µmol/ m^2), the levels of Sulphur Dioxide (SO_2) in the air fluctuate over time and reflect patterns resembling the carbon monoxide (CO) air quality map. This helps in our understanding of how various human activities affect the air.

Table 2: $S0_2$ Composition in Air

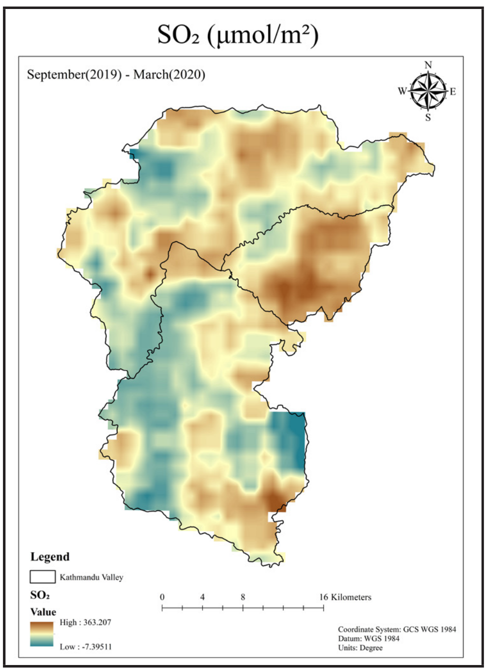
Time Duration	SO_2 Composition in Air (µmol/ m^2)
Sept(2019)-March(2020)	191.87
March(2020)-(Sept 2020)	36.20
Sept(2020)-March(2021)	227.67
March(2021)-(Sept 2021)	52.97
Sept (2021)-March(2022)	259.92

Pre-COVID Periods (September 2019 - March 2020): During the period from September 2019 to March 2020, the baseline measurement of SO_2 concentration in Kathmandu Valley stands at 191.87 µmol/m². This timeframe serves as a foundational reference for comprehending the typical air quality conditions preceding the COVID-19 pandemic.

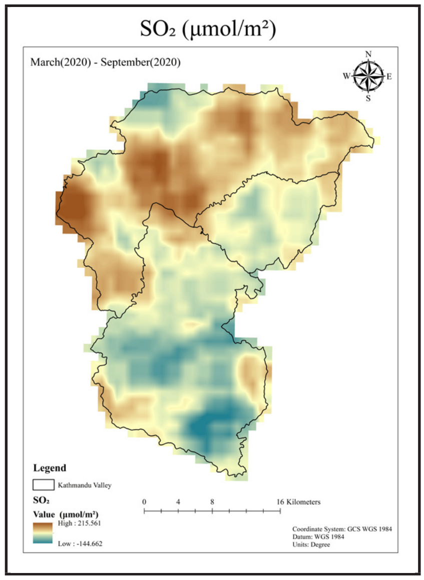
During COVID Periods (March 2020 - September 2020 and September 2020 - March 2021): Transitioning into the COVID-19 periods, namely March 2020 to September 2020 and September 2020 to March 2021, a distinct pattern emerges. Despite the implementation of lockdown measures typically associated with reduced industrial activity and improved air quality, there is a substantial decrease in SO_2 levels from 191.87 to 36.20 µmol/m² and a subsequent increase to 227.67 µmol/m². This unexpected rise suggests that factors beyond reduced industrial emissions, such as shifts in meteorological conditions or other anthropogenic activities, may contribute to the observed fluctuations during these phases.

Post-COVID Periods (March 2021 - September 2021 and September 2021 - March 2022): In the post-COVID periods, spanning from March 2021 to September 2021 and September 2021 to March 2022, a significant spike in SO_2 levels is observed, reaching 259.92 µmol/m². However, a noteworthy decline is noted in the subsequent period, with SO_2 levels dropping to 52.97 µmol/m². This temporal fluctuation implies a dynamic response to changes in human activity and environmental conditions post-lockdown, highlighting the nature of air quality dynamics in the aftermath of the pandemic.

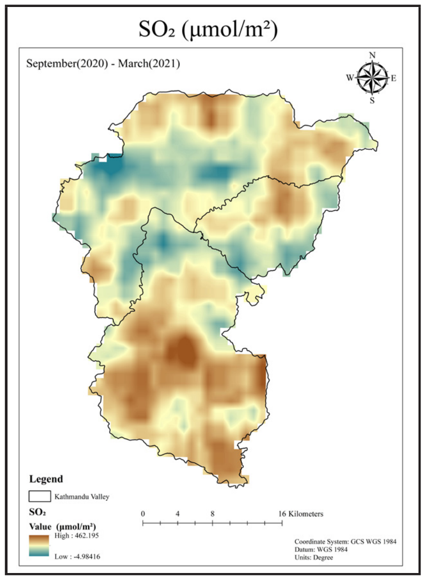
(a)



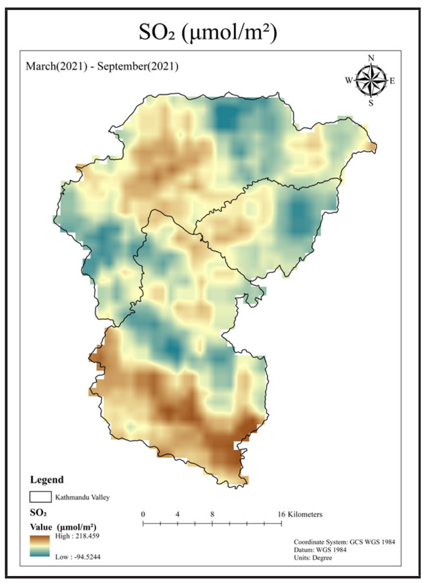
(b)



(c)



(d)



(e)

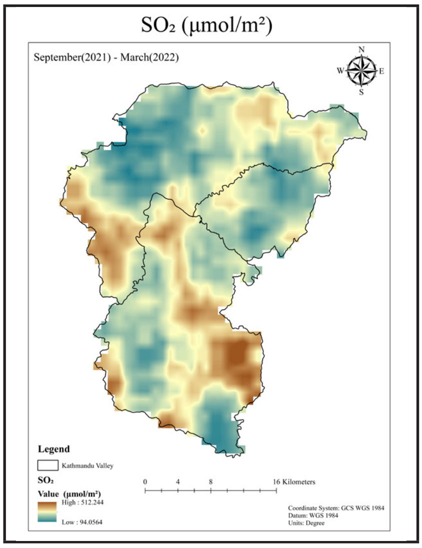


Figure 4: SO_2 Composition in Air in different time phases a) September (2019)-March (2020) b) March (2020)-(September 2020) c) September (2020)-March (2021) d) March (2021)-(September 2021) e) September (2021) – March (2022)

The levels of Sulfur Dioxide (SO_2) in the air, measured in micromoles per square meter (µmol/m²), change over time and follow patterns similar to the Carbon Monoxide (CO) air quality map. This helps us understand how the air responds to different human activities.

The baseline SO_2 level provides a point to compare to previous to the COVID-19 lockout. SO_2 substantially decreased during the lockdown, mostly as a result of fewer cars being used. Following the lockdown, SO_2 levels increased once more. It means that the air quality changed as people went back to their regular lives and engaged in activities like driving and industry. The following months saw a drop in SO_2 levels, most likely as a result of the ongoing impacts of security precautions. However, SO_2 later increased, nearly as much as it had previously to the lockdown. This implies that even after minor disruptions, industrial and vehicular activity have a major effect on air quality.

Understanding these shifts makes it easier to understand how important a role industries and automobiles play as producers of pollution in the air. It highlights the necessity of developing plans to lower emissions from various sources, particularly when human activity is at its peak. We can use these useful information representation and analysis results to make well-informed decisions on environmental management and governance.

3.3 NO_2 composition in Air

Nitrogen oxides (NO_2 and NO) are important trace gases in the Earth's atmosphere, present in both the troposphere and the stratosphere. They enter the atmosphere because of anthropogenic activities (notably fossil fuel combustion and biomass burning) and natural processes (wildfires, lightning, and microbiological processes in soils). Here, NO_2 is used to represent concentrations of collective nitrogen oxides because during daytime, i.e. in the presence of sunlight, a photochemical cycle involving ozone (O3) converts NO into NO_2 and vice versa on a timescale of minutes. The provided composition chart details the variations in NO_2 levels across different phases of the COVID-19 pandemic in Kathmandu Valley.

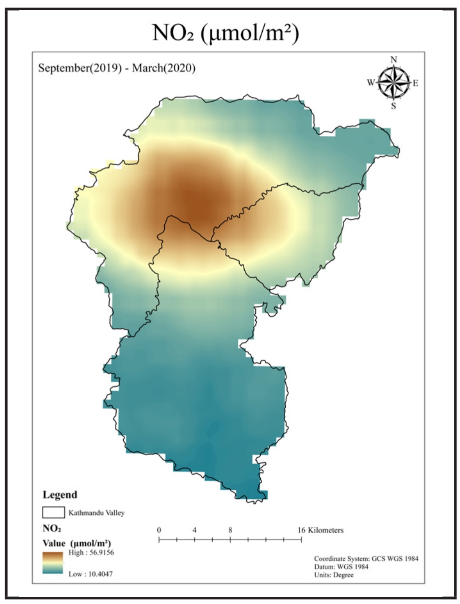
Table 3: NO_2 Composition in Air

Time Duration	NO_2 Composition in Air (µmol/ m²)
Sept(2019)-March(2020)	27.018
March(2020)-(Sept 2020)	19.531
Sept(2020)-March(2021)	28.567
March(2021)-(Sept 2021)	30.006
Sept (2021)-March(2022)	28.743

Periods prior to COVID-19 (September 2019–March 2020): The baseline measurement of SO_2 concentration in the Kathmandu Valley for the period September 2019 to March 2020 is 191.87 µmol/m². This period provides a baseline for understanding the normal air quality levels that existed before the COVID-19 pandemic.

When moving into the COVID-19 periods, which are March 2020 to September 2020 and September 2020 to March 2021, a clear pattern becomes apparent during the COVID Periods (March 2020 - September 2020 and September 2020 - March 2021). Lockdown measures, which are usually linked to decreased industrial activity and better air quality, have been put in place; nonetheless, NO_2 levels have significantly decreased from 27.018 to 19.531 µmol/m² and then increased to 28.567 µmol/m². This surprising increase implies that variables other than lower industrial emissions. Following maps has been created to visualize the NO_2 composition in area.

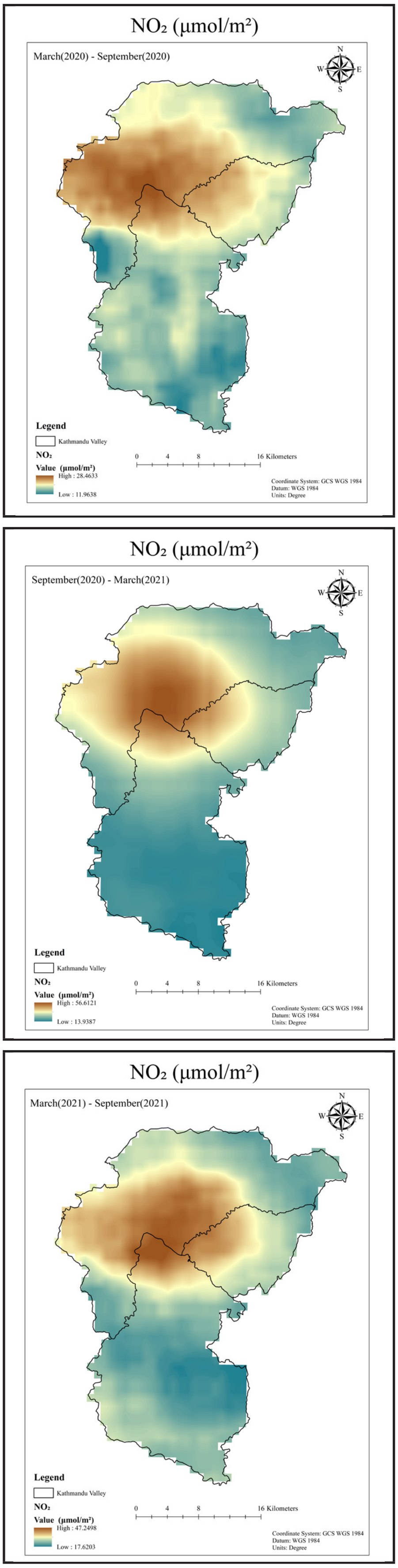
(a)



(b)

(c)

(d)



(e)

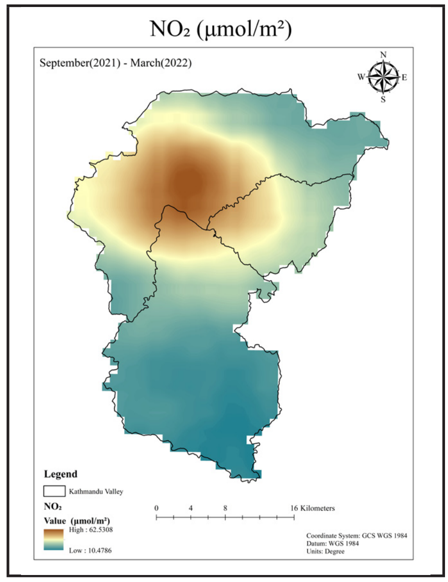


Figure 5: NO_2 composition in Air in different time phases a) September (2019)-March (2020) b) March (2020)-(September 2020) c) September (2020)-March (2021) d) March (2021)-(September 2021) e) September (2021) – March (2022)

The NO_2 values indicate some degree of stability in the following periods, suggesting that emissions are still present. The continuation of some levels after the lockdown highlights the long-lasting impact of human activity and the intricacy of the interacting environmental elements. A number of contributing factors, such as industrial operations, vehicle emissions, and meteorological circumstances, must be taken into account in order for the academic understanding of these changes in NO_2. Because of the complex interplay between human activity and air quality, focused environmental policies that mitigate particular sources of emissions, promote long-term gains in air quality, and support larger efforts to mitigate climate change are crucial.

4. CONCLUSION AND RECOMMENDATIONS

This study investigated the fluctuations in air quality in the Kathmandu Valley using satellite data, focusing on carbon monoxide (CO), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2). The analysis revealed a complex interplay of factors influencing air quality, extending beyond the immediate impacts of reduced vehicular traffic. The baseline data for the pre-COVID period served as a reference point to understand typical air quality conditions, showing CO levels at 32.65 milli mol/m², SO_2 levels at 191.87 µmol/m², and NO_2 levels at 27.018 µmol/m².

During the COVID-19 lockdown periods, a surprising trend was observed. Despite expectations of improved air quality due to decreased vehicular activity, CO levels slightly increased to 33.96 milli mol/m² and 34.78 milli mol/m² in successive lockdown phases. Similarly, SO_2

levels exhibited a substantial decrease to 36.20 µmol/m² initially but then rose to 227.67 µmol/m². NO2 levels followed a similar pattern, decreasing to 19.531 µmol/m² and then increasing to 28.567 µmol/m². These unexpected increases suggest that factors such as continued industrial operations, meteorological changes, and other anthropogenic activities played significant roles in shaping air quality during the lockdown.

In the post-COVID periods, air quality dynamics further illustrated the complexity of environmental interactions. CO levels initially spiked to 41.21 milli mol/m² before dropping significantly to 31.11 milli mol/m². SO_2 levels also saw a marked increase to 259.92 µmol/m², followed by a notable decline to 52.97 µmol/m². These fluctuations indicate a dynamic response to the resumption of human activities and industrial processes, highlighting the intricate balance between emissions sources and environmental conditions. NO_2 levels stabilized somewhat, reflecting ongoing emissions from persistent sources.

The findings underscore the necessity for comprehensive and multifaceted strategies to improve air quality in Kathmandu. Merely reducing vehicular traffic is insufficient; effective policies must address all major sources of pollution, including industrial emissions and biomass burning. Long-term monitoring of air quality is essential to capture the full scope of temporal variations and to inform adaptive management strategies. Public awareness campaigns can educate citizens about the impact of their actions on air quality, fostering a culture of environmental responsibility. Additionally, regional cooperation with neighboring countries can help tackle transboundary pollution issues, ensuring cleaner air for the entire region.

In conclusion, this study highlights the complex and multifaceted nature of air quality management in Kathmandu. To achieve sustained improvements, robust and comprehensive plans that address all pollution sources are crucial. Targeted interventions in high-traffic and industrial areas, continuous air quality monitoring, public education, and international collaboration are essential steps towards cleaner air and a healthier environment for all residents of Kathmandu Valley.

REFERENCES

Dasgupta, P., & Srikanth, K. (2020). Reduced air pollution during COVID-19: Learnings for sustainability from Indian Cities. *Global Transitions*, *2*, 271–282. https://doi.org/10.1016/j.glt.2020.10.002

Dhital, N. B., Bhattarai, D. R., Sapkota, R. P., Rijal, K., Byanju, R. M., & Yang, H. H. (2022). Comparing the Change in Air Quality during the COVID-19 Lockdown between Dry and Wet Seasons in Nepal. *Aerosol and Air Quality Research*, *22*(8). https://doi.org/10.4209/aaqr.220201

Elsaid, K., Olabi, V., Sayed, E. T., Wilberforce, T., & Abdelkareem, M. A. (2021). Effects of COVID-19 on the environment: An overview on air, water, wastewater, and solid waste. *Journal of Environmental Management*, *292*(April), 112694. https://doi.org/10.1016/j.jenvman.2021.112694

Ghahremanloo, M., Lops, Y., Choi, Y., & Mousavinezhad, S. (2021). Impact of the COVID-19 outbreak on air pollution levels in East Asia. *Science of the Total Environment*, *754*, 142226. https://doi.org/10.1016/j.scitotenv.2020.142226

Jephcote, C., Hansell, A. L., Adams, K., & Gulliver, J. (2021). Changes in air quality during COVID-19 'lockdown' in the United Kingdom. *Environmental Pollution*, *272*, 116011. https://doi.org/10.1016/j.envpol.2020.116011

Madineni, V. R., Dasari, H. P., Karumuri, R., Viswanadhapalli, Y., Perumal, P., & Hoteit, I. (2021). Natural processes dominate the pollution levels during COVID-19 lockdown over India. *Scientific Reports*, *11*(1), 1–14. https://doi.org/10.1038/s41598-021-94373-4

Moore, G., & Semple, J. (2021). *GeoHealth - 2021 - Moore - Himalaya Air Quality Impacts From the COVID-19 Lockdown Across the Indo-Gangetic Plain.pdf*.

Panday, A. K., Prinn, R. G., & Schär, C. (2009). Diurnal cycle of air pollution in the Kathmandu Valley, Nepal: 2. Modeling results. *Journal of Geophysical Research Atmospheres*, *114*(21), 1–20. https://doi.org/10.1029/2008JD009808

Poudel, K., & Subedi, P. (2020). Impact of COVID-19 pandemic on socioeconomic and mental health aspects in Nepal. *International Journal of Social Psychiatry*, *66*(8), 748–755. https://doi.org/10.1177/0020764020942247

Rudke, A. P., de Almeida, D. S., Alves, R. A., Beal, A., Martins, L. D., Martins, J. A., Hallak, R., & de Almeida Albuquerque, T. T. (2022). Impacts of Strategic Mobility Restrictions Policies during 2020 COVID-19 Outbreak on Brazil's Regional Air Quality. *Aerosol and Air Quality Research*, *22*(4), 1–16. https://doi.org/10.4209/aaqr.210351

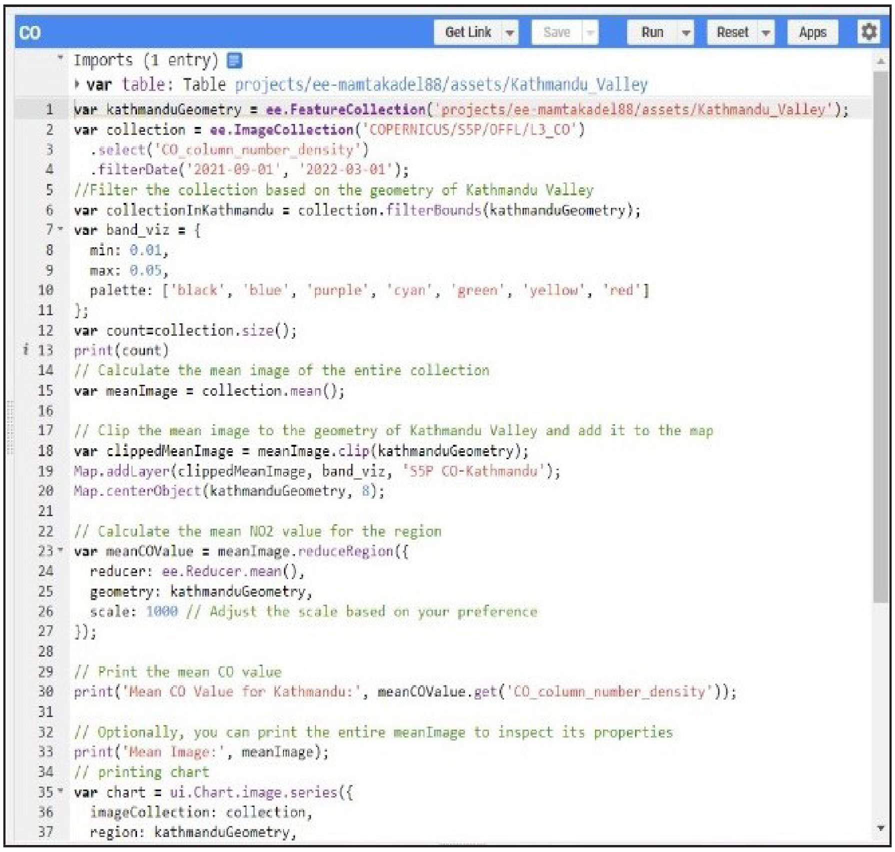
Saud, B., & Paudel, G. (2018). The Threat of Ambient Air Pollution in Kathmandu, Nepal. *Journal of Environmental and Public Health*, *2018*. https://doi.org/10.1155/2018/1504591

Upadhyay, A., Mahapatra, P. S., Singh, P. K., Dahal, S., Pokhrel, S., Bhujel, A., Joshi, I. B., Paudel, S. P., Puppala, S. P., & Adhikary, B. (2022). Learnings from COVID-19 Forced Lockdown on Regional Air Quality and Mitigation Potential for South Asia. *Aerosol and Air Quality Research*, *22*(4), 1–21. https://doi.org/10.4209/aaqr.210376

Zhang, X., Ji, Z., Zheng, Y., Ye, X., & Li, D. (2020). Evaluating the effect of city lock-down on controlling COVID-19 propagation through deep learning and network science models. *Cities*, *107*(May), 102869. https://doi.org/10.1016/j.cities.2020.102869

ANNEX

ANNEX 1: Code to extract CO information in Google Earth Engine



```
CO                                    Get Link | Save | Run | Reset | Apps
Imports (1 entry)
var table: Table projects/ee-mamtakadel88/assets/Kathmandu_Valley
var kathmanduGeometry = ee.FeatureCollection('projects/ee-mamtakadel88/assets/Kathmandu_Valley');
var collection = ee.ImageCollection('COPERNICUS/S5P/OFFL/L3_CO')
  .select('CO_column_number_density')
  .filterDate('2021-09-01', '2022-03-01');
//Filter the collection based on the geometry of Kathmandu Valley
var collectionInKathmandu = collection.filterBounds(kathmanduGeometry);
var band_viz = {
  min: 0.01,
  max: 0.05,
  palette: ['black', 'blue', 'purple', 'cyan', 'green', 'yellow', 'red']
};
var count=collection.size();
print(count)
// Calculate the mean image of the entire collection
var meanImage = collection.mean();

// Clip the mean image to the geometry of Kathmandu Valley and add it to the map
var clippedMeanImage = meanImage.clip(kathmanduGeometry);
Map.addLayer(clippedMeanImage, band_viz, 'S5P CO-Kathmandu');
Map.centerObject(kathmanduGeometry, 8);

// Calculate the mean NO2 value for the region
var meanCOValue = meanImage.reduceRegion({
  reducer: ee.Reducer.mean(),
  geometry: kathmanduGeometry,
  scale: 1000 // Adjust the scale based on your preference
});

// Print the mean CO value
print('Mean CO Value for Kathmandu:', meanCOValue.get('CO_column_number_density'));

// Optionally, you can print the entire meanImage to inspect its properties
print('Mean Image:', meanImage);
// printing chart
var chart = ui.Chart.image.series({
  imageCollection: collection,
  region: kathmanduGeometry,
```

AUTHOR INFORMATION

Name	:	**Binod Prasad Bhatta**
Academic Qualification	:	BE in Geomatics Engineering
Organization	:	Naxa Pvt. Ltd.
Current Designation	:	Intern
Published Article	:	1

Practical Learning about Time using Sundial at Land Management Training Center

Bhagirath Bhatt[1], Sushmita Timilsina[1], Shivaji K.C.[2], Hareram Yadav[2]

[1]Land Management Training Center, Dhulikhel, Kavre, Nepal

bhagirath.bhatt@nepal.gov.np, qust04sharma@gmail.com

[2]Survey Department, Minbhawan, Kathmandu, Nepal

shivagkc2014@gmail.com, hryadav4848@gmail.com

ABSTRACT

Upon study of different kinds of sundials, it is seen that sundials are a great source of information. To develop the teaching-learning aspect in the Land Management Training Center, by demonstrating astronomical devices like sundial it is easier to provide clear insight to the students. Even with the basic installation of a sundial, it is possible to know not only the local solar time but also can be used as a reference and prove many astronomical facts. The monument of the equatorial sundial itself portrays the model of the earth where the dial is the equator and the gnomon is the polar axis pointing in the north-south direction. The everyday movement of the shadow of the sun's shadow on the dial is evidence of Earth's rotation and having day and night on Earth. The sun's shadow falling on the upper side from vernal equinoxes to autumnal equinoxes and on the lower side is the proof of Earth's revolution around the sun. Besides these, the adjustment required in the sundial shows that the axis of the Earth's rotation is tilted and it does not move around the sun in a circular orbit.

KEYWORDS: Equatorial Sundial, Land Management Training Center

1. INTRODUCTION

In astronomy, we discuss two different types of time: Mean Solar Time and Apparent Solar Time. Mean Solar Time is based on the average length of the solar day, while Apparent Solar Time is determined by the sun's actual position in the sky. When we look at our wristwatch, we are referring to standard time based on mean solar time, whereas the time shown on a sundial represents apparent solar time. The sundial, one of astronomy's earliest timekeeping tools, consists of a stick that casts a shadow on a marked face displaying units of time (Benningfield, 2003). The exact origins of the sundial and its inventor are unclear. It is a device used to indicate the time of day based on the position of the Sun in the sky. However, it's important to note that the time indicated by a sundial, known as apparent solar time, maybe less precise than that of standard timekeeping mechanisms. A sundial primarily consists of:

- Stile or gnomon (a straight edge)
- The graduated circle on which the shadow of the gnomon is casted.

The gnomon is the straight edge seen on the sundial, and the graduated circle on which the shadow is cast is called the dial. When the sun shines, the shadow of the gnomon is cast upon the graduated circle or the dial. The reading on the circle provides the apparent solar time. However, due to the Earth's varying distance from the Sun throughout the year and its equator being inclined to its orbit by 23.5°, there is a difference between apparent solar time and mean solar time, which is the time kept into account by mechanical and electrical clocks. In fact, the Sun can be as much as a quarter of an hour fast or slow when compared with a clock that keeps mean solar time (Sabanski, 2021).

2. HISTORY OF SUNDIAL IN NEPAL

The use of sundial in Nepal was done from the former times. Earlier, the royal astrologer at the court of Hanuman Dhoka Royal Palace used to recommend the auspicious time (based on a sundial) and date to the army commander to get victory during a confrontation with the enemy. Even today the astrologer from Hanuman Dhoka recommends auspicious times and dates according to astrology for the ritual events (Maskey, 2010).

During the Malla dynasty, there was a sundial carved on stone at Swayambhu region during the period of King Pratap Malla (1641-1674). It is in a damaged condition to read the inscription and the principle under which it was constructed. Figure 1 shows the recent (December 2020) picture of a horizontal sundial at Swayambhunath Temple. Lacking the importance of the sundial to people and its almost no maintenance at all the condition of the sundial was not very good. The dial was made of stone and carvings were done over it. The gnomon placed was a fixed thick iron stick attached to the northern edge of the dial. The carvings are not good enough to read the dial readings. Also, the construction of small temples around it does not allow the sunlight to fall on it the whole day.

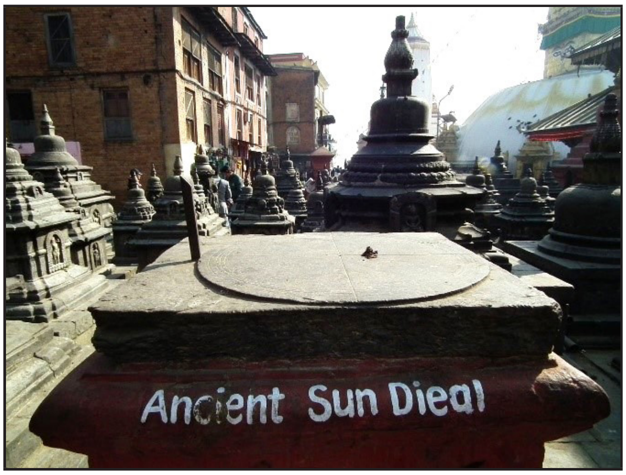


Figure 1: Sundial at Swyambunath

The need for a sundial was also felt in the Shah dynasty and a sundial was constructed under the supervision of Astrologer Laxmipati Pandey in 1790 A.D (Maskey, 2010). Presently, it is placed at the National Museum, Chhauni, Kathmandu.

The use of Tibetan alpine sticks that serve as sundials is mentioned in Kurt Boeck: Through India to the closed country Nepal, Ferdinand Hirt & Sohn, Leipzig 1903, page 311. According to the book, the stick had eight longitudinal sides, on which the names of the months and hour digits were carved at its upper end there was a hole above each longitudinal strip, into which a short rod was inserted, from whose shadow length the time can be read on the rod.

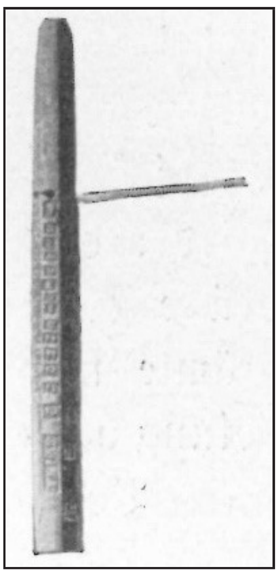


Figure 2: Sticks Serving as a Sundial (Source: Kurt Boeck: Through India to the Closed Country Nepal, Ferdinand Hirt & Sohn, Leipzig 1903, Page 311)

In 1911, Rana Prime Minister Chandra Shamsher erected a sundial manufactured in the UK on the premise of Tri-Chandra College on the eastern side of Ranipokhari, Kathmandu. This dial seems to be very informative. The inscription on the dial shows the clock reading for Nepal, Calcutta, Montreal, and Greenwich. This monument of the sundial also consists of a correction for Solar time.

At present (December, 2020), not only the gnomon (made of copper) is missing but the construction of a mosque and the police building across the road has made the sun unreachable to the sundial all day long. Figure 3 shows the recent picture of the sundial.

Figure 3: Sundial at Ghantaghar, Kathmandu

3. DESIGNING A SUN DIAL AT LMTC

Land Management Training Center (LMTC) is the oldest and the only government training institution that has been continually and significantly producing skilled human resources and conducting research activities in the field of geoinformation and land management. In order to develop a proper understanding of astronomy and astronomical terms, LMTC included the construction of Sundial in its premises in the yearly development plan for the fiscal year 2078/79. As a result of that plan, an equatorial sundial is constructed in LMTC. This has not only eased the teaching-learning practice but also added another milestone to the Center.

Before starting the design of a sundial, we need to collect information that is required during the creation process.

1. Location of installation
2. Type of sundial
3. Orientation of sundial
4. Adjustments in Sundial

3.1 Location and Installation

Sundial is designed for average latitude and can be customized specifically for our location. The location is defined by its latitude, longitude, and time zone. Duration of daily illumination should be maximum i.e.; the sundial must be located where sunlight is received the most. The visibility from the street or the garden and accessibility for the sundial installation must be taken care of. Furthermore, the risk that plants and bushes may obscure the sundial and the risk of deliberate defacement or robbery must be considered. The current sundial at LMTC is located at $27^0$37' latitude and $85^0$32' longitude where it is expected to have maximum sunlight throughout the year and less obstruction from buildings and trees.

Sundial is installed outside where the maximum sunlight is expected to fall, which also means, it would encounter other environmental factors such as wind and rainfall. Therefore, if we want to build a long-lasting sundial, it is necessary to appropriately choose the location and the materials from which it will be made. In the Land Management Training Center, we used stainless steel as the prime material to make the dial, stand, and gnomon of the sundial.

3.2 Types of Sundials

Sundials come in a wide variety of designs, but they all work in a similar way (Salev, 2022). Every sundial has an element that creates a shadow known as a gnomon, and a dial where the reading is carved and the shadow is projected. There are different kinds of sundials, such as horizontal dials, vertical dials, equatorial dials, polar dials, analemmatic dials, reflected ceiling dials, portable dials, etc. An Equatorial sundial was chosen to be constructed in the center therefore; this paper focuses on designing an equatorial sundial. An equatorial sundial is one of the easiest kinds of sundials to make but is perhaps the most common and the best-looking (Susan W, 2022).

3.2.1 Equatorial Sundial

In an equatorial sundial, a shadow is cast by a "gnomon" or pointer that points directly towards Polaris. The dial is stuck to this pointer, perpendicular to it, and then the shadow cast by the sun is of constant length throughout the day and moves around the card clockwise with the endpoint of the shadow lying on a circle. The gnomon of the equatorial sundial is parallel to the axis of rotation of the Earth and the dial plate is therefore parallel to the plane of the equator. Hence, the sundial is named as Equatorial sundial.

3.3 Orientation of Sundial

The following figure shows an example of an equatorial sundial where a gnomon is lifted at the angle of its local latitude (f) and forms a right angle with the dial. To read the time from this sundial, it will have to be placed facing True North and its local latitude will have to be determined. Equatorial Sundial has two faces, the North Face and the South Face. The South Face will show the time during winter and spring whilst the North Face will show the time during summer and autumn.

Earth is tilted 23.5 degrees to its orbit around the Sun (i.e., to the ecliptic plane). Visualizing sundial as Earth, the equatorial plane is the plane upon which the shadow will be casted and the polar axis is the gnomon projecting the shadow. This gnomon slices up the equator. Therefore, any plane passing through a certain latitude is parallel to the equator if it is oriented towards the true north, not magnetic north.

In order to properly align the sundial for appropriate time reading, the gnomon should be aligned at an angle equal to the latitude and pointing towards the true north and the dial plate must be positioned at an angle with a horizontal surface equal to the co-latitude (90° - latitude). Figure 4 illustrates how the equatorial sundial must be positioned.

Figure 4: Equatorial Sundial at LMTC

As the dial plate is parallel to the equator, there are periods when the sun is above the dial plate and others when it is below. From the Vernal equinox (~21 March) to the Autumnal equinox (~23 September), sunlight will fall on the upper side of the dial plate. To use the sundial during this period the gnomon must project a shadow above the dial plate. Again, from the autumnal equinox until the vernal equinox, sunlight will fall on the underside of the dial plate. To use the sundial during this period the gnomon must project a shadow below the dial plate as shown in Figure 5. Therefore, the hour lines must appear on both sides of the dial plate.

Since the sun is directly above the Earth's equator during equinoxes, it is possible to have no shadow on these days. These are days with equal day and night. Similarly, Solstices occur when the sun appears to reach its most northerly or southerly relative to the celestial equator. So, we can expect maximum sunlight during the summer solstice (June 21) and limited sunlight on Dec 21 (Winter Solstice). These are the longest and shortest days in the Northern hemisphere of the earth.

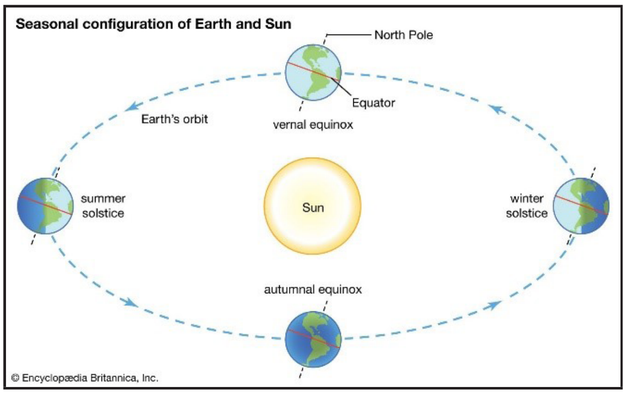


Figure 5: Seasonal Configuration of Earth and Sun

3.3.1 Graduation in Sundial

The Earth rotates on its axis through 360 degrees once every 24 hours, which means that in a single hour, the Earth rotates through 15 degrees. Each 15 degrees subtended on the equatorial scale therefore represents 1 hour's rotation of the Earth on its axis. The graduation on top and bottom dial plates for an equatorial sundial in the Northern Hemisphere is illustrated in Figure 6. The upper dial plate will show more hours as it is illuminated between the spring and fall equinoxes. The bottom dial plate will show fewer hours as it is illuminated between the fall and spring equinoxes. For the Southern Hemisphere just reverse the hour numbers. The numbering on the top of the plate will run clockwise while those on the bottom will run counter-clockwise.

Since the hour divisions of an Equatorial sundial are equally spaced around the dial face regardless of the latitude of its location. However, we need to make some personal adjustments to our sundial to make it fully functional. Otherwise, the sun's angle created with the side of the sundial will give a faulty time so, we need some extra information about our geographical area to allow our sundial to perform at its very best.

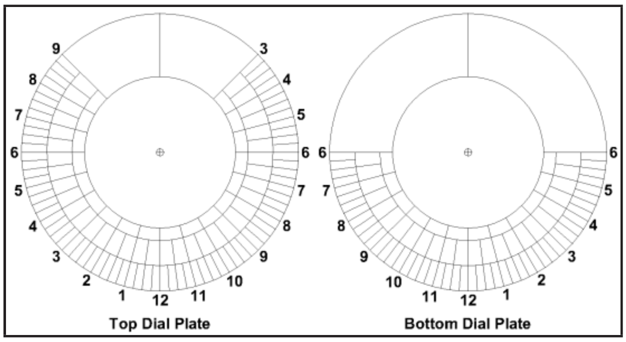


Figure 6: Top (Left) and Bottom (Right) Dial Plate of An Equatorial Sundial (Source: (Sabanski, 2021))

3.4 Adjustment of Sundial

The difference from the time shown by an ordinary clock follows from the fact that the axis of rotation of the Earth is tilted and the Earth does not move around the Sun in a completely circular orbit but in an elliptical orbit so that its orbital velocity varies slightly during the year. That's why the solar time can vary from clock time (standard) by a small amount. Therefore, some adjustments are necessary to convert the apparent solar time (as displayed in the sundial) to the standard time (clock time).

3.4.1 Equation of Time

The Equation of Time refers to the variance between regular clock time and time-based on the precise position of the Sun in the sky, such as that measured by a precise sundial. The graph below illustrates the equation of time based on universal time function, allowing for calculation for any period within 30 centuries with a precision of about 3 seconds (Hughes, 1989).

This compensates for two factors: the daily variation due to the Earth's orbit around the Sun and the tilt of the Earth's axis relative to the Sun. The Earth's elliptical orbit causes it to speed up and slow down at different points in its annual orbit, resulting in being ahead or behind where it is expected to be. As a result, the length of the solar day can vary by up to +- 15 minutes over a year.

3.4.2 Time zone Adjustment (Longitude Correction)

The time zone adjustment or Longitude correction is for the differences between the actual Longitude of the sundial and the central Longitude of the time zone, where correction of 4 minutes is necessary for each degree difference. A standard time zone covers roughly 15° of longitude, so any point within that zone not on the reference longitude (generally a multiple of 15°) will experience a difference from the standard time equal to 4 minutes per degree. The sundial at LMTC is located at 85° 32′, a longitude of 43′ west of the reference longitude (86° 15′), so its time will read 2.8 minutes slow. This is a constant correction throughout the year.

3.4.2 Summer (daylight saving) Time Correction

There are a couple of other significant causes of why a sundial might not be precisely accurate. Some areas of the world practice daylight saving time, which changes the official time, usually by one hour. Daylight saving time (DST) is the exercise of advancing clocks (typically by one hour) during summertime so that darkness falls at a later clock time. This shift must be added to the sundial's time to make it agree with the official time. Nepal has no daylight saving. Therefore, this adjustment is not required to convert solar time to standard time.

4. READING TIME ON AN EQUATORIAL SUNDIAL

The position of the shadow cast by the Gnomon on the dial plate indicates the solar time. The point where the gnomon's shadow intersects the hour lines on the dial plate indicates the current solar time. Here's a step-by-step guide on how to read the time on an equatorial sundial:

- First, read the solar time (the reading on the dial as per the shadow cast by gnomon) (ST)
- Verify the daylight savings applies (NA for Nepal) (DS)
- Make a time zone adjustment (+2.8 minutes) (TZ)
- Include the value from the equation of time (eg. -3 minutes on May 1st) (EOT)

The current standard time shall be equal to ST+DS+TZ+EOT. For verification check the current reading with the clock reading of your wrist or mobile phone.

5. CONCLUSION

The basic installation of a sundial allows one to not only determine the local solar time but also serves as a reference for defining various astronomical terms. The equatorial sundial monument itself represents a model of the earth, with the dial as the equator and the gnomon as the polar axis pointing north-south. The daily movement of the sun's shadow on the dial demonstrates the Earth's rotation and the occurrence of day and night. Additionally, the sun's shadow moving to the upper side from vernal equinoxes and to the lower side on autumnal equinoxes provides evidence of Earth's revolution around the sun. Sundial adjustments indicate that the Earth's axis of rotation is tilted and that its orbit around the sun is not circular.

Different types of sundials offer valuable information and can be used to enhance instruction at the Land Management Training Center. Demonstrating astronomical devices like sundials provides clear insights to students. Apart from their timekeeping and astronomical uses, sundials are also appreciated as decorative objects that can attract visitors to the center.

REFERENCES

Hughes, D. W. (1989). The equation of time. *Monthly Notices of the Royal Astronomical Society (ISSN 0035-8711), vol. 238* , 1529-1535.

Maskey, S. M. (2010). *MATHEMATICS IN NEPAL.*

ResearchGate, S. F. (2022, October). *Scientific Figure on ResearchGate*. Retrieved from Analemmatic Sundials: how to build one and why they work : https://www.researchgate.net/figure/The-completed-equatorial-sundial_fig4_2349151

Sabanski, C. (2021, Dec). *The Sundial Primer*. Retrieved from Equatorial Sundial: https://www.mysundial.ca/tsp/equatorial_sundial.html

Salev, K. (2022, December 10). *HOW HORIZONTAL AND EQUATORIAL SUNDIALS WORK*. Retrieved from Science of Gadgets: https://www.scienceofgadgets.com/post/how-horizontal-and-equatorial-sundials-work

W., S. (2022, Dec 15). *How To Make An Equatorial Sundial - With Photos*. Retrieved from Owlcation: https://owlcation.com/academia/How-To-Make-A-Simple-Sundial-With-Photos

AUTHOR INFORMATION

Name	:	Bhagirath Bhatt
Academic Qualification	:	ME in Geoinformatics
Organization	:	Land Management Training Center
Current Designation	:	Instructor
Work Experience	:	9 years
Published Article	:	1

Ecotourism and Ecovillage Mapping in Kavrepalanchowk District, Nepal

Prakash Ghimire [1], Rheecha Sharma[1]

[1]Land Management Training Centre, Dhulikhel, Kavrepalanchowk

mail4prakash2017@gmail.com, rheechasharma@gmail.com

ABSTRACT

Nature-based tourism, ecotourism is a burning segment of the tourism industry, promoting sustainable travel practices that conserve the environment and sustain well-being of local people. An ecovillage, characteristic of ecotourism is an intentional, traditional, or urban community that is consciously designed in all four dimensions (social, economic, ecological, and cultural) of sustainability. Kavrepalanchowk district, endowed with pristine natural assets: and cultural and environmental diversity, makes it a prime destination for ecotourism. And yet, most of the study areas are to be discovered in terms of nature-based attractions, even with its proximity to the capital city, Kathmandu. This study aims to identify potential ecotourism sites to contribute to sustainable development goals: for people, planet, and prosperity by responsibly utilising and conserving natural resources. Existing tourist attractions such as the visibility of snow-capped mountains, a rich diversity of cultures, diverse biodiversity, bilingual and hospitable people, and many more are present in the area. It is necessary to outline the potential ecotourism sites that lead to a sustainable lifestyle in harmony and preserve them. This study adopted a robust methodology for data collection, rasterization, criteria mapping setup, and the Analytical Hierarchy Process (AHP) for preparing the final suitability map. The ecotourism map was prepared based on the weightage of the slope, aspect, religious sites, tourist attractions, land use land cover, highways, and village roads. Ecovillage maps were prepared excluding aspect and village road criteria. The Geographic Information System (GIS) based Multi-Criteria Decision Approaches (MCDA) along with different weightage and AHP methods were applied for preparing ecotourism and ecovillage maps and analyzing different factors affecting them. The result of the ecotourism map shows that 2.5% area (of the total study area) is highly suitable for ecotourism and only 0.02 % area of the total study area is suitable for ecovillage. It indicates that the suitable areas for ecotourism and ecovillage are different as they have different types of weights. The map also indicates that ecotourism is relatively suitable for most of the areas inside Dhulikhel, Banepa, Namobuddha, Panauti, and Mandandeupur Municipalities. However, the ecovillage map depicts that it is highly suitable for 0.02% areas of the total study areas, suitable for 0.74% areas of the total study areas, and not suitable for the remaining areas. The highlighted locations of suitable sites were overlaid in Google Earth to check the results visually. So, it is concluded that Bethanchowk village has maximum potential areas for both ecotourism and ecovillage but Phulchowki although has high potential for ecotourism but least suitable for ecovillage. The identified areas (highly suitable) of ecotourism and ecovillage need to be preserved and promoted in the future.

KEYWORDS: Ecotourism, Ecovillage, Multi-Criteria Decision Approach (MCDA), Analytical Hierarchy Process (AHP), Criteria Map

1. INTRODUCTION

Ecotourism has been defined as a form of nature-based tourism in the marketplace, but it has also been formulated and studied as a sustainable development tool by Non-Governmental Organizations (NGOs), development experts, and academics since 1990. World Ecotourism Summit during the international year of ecotourism recognized that not only does ecotourism embrace the principles of sustainable tourism but it also embodies specific principles that contribute actively to the conservation of natural and cultural heritage; including local and indigenous communities in its planning, development and operation, and contributes to their well-being; interprets the natural and cultural heritage to visitors; encourages independent travellers, as well as organized tours for small size groups (Zeybek et al., 2017). Ecovillages are urban or rural communities of people who strive to integrate a supportive social environment with a low-impact way of life. To achieve this, they integrate various aspects of ecological design, permaculture, ecological building, green production, alternative energy, community-building practices, and much more. Ecovillages are living models of sustainability. The concept of an ecovillage is broad and has multiple interpretations. Based on a reading of the existing literature on ecovillages, some of their key characteristics are alternative lifestyles, governance, and self-sufficiency (Koduvayur & Joshi, 2022).

Kavrepalanchowk is popular for its natural beauty and ancient traditions. The Himalayan ranges from the twin crest of Mt. Langtang in the west to Mt. Everest in the east can be viewed on a clear day (more than 20 Himalayan peaks, including Mt.

Annapurna (8,091m), Mt. Ganesh Himal (7,429m), Mt. Langtang (7,234m), Mt. Phuribichyachu (6,637m), Mt. Gaurishankar (7,134m), Mt. Lhotse (8,516m) can be observed from different points of the city. Ecotourism has been gaining momentum in biodiversity hotspots because of its potential to boost both rural livelihoods and environmental conservation (Samal & Dash, 2023). Developing ecotourism services is a suitable solution to help developing countries improve the status of sustainable development indicators and protect their environment (Shang et al., 2023). In April 2019, Dhulikhel Municipality (DM), published an Integrated Urban Development Plan (IUDP) as the strategic response to the 20-year growth of DM sets out the planned urban expansion of Dhulikhel in three key areas to accommodate residential, tourism, and commercial growth over the coming 20 years (Poudel & Shrestha, 2020).

However, the Kavrepalanchowk district, has not been properly analyzed for ecotourism and ecovillage identification and preservation. Ecocultural tourism is trying to establish itself, together with the opportunities offered by local economies, for example, adventure travel, agricultural tourism, observation of flora and fauna, birdwatching, scientific tourism, potholing, and cultural tourism. It should be noted that the negative and destructive effects resulting from the massive and uncontrolled use of cultural goods and the surrounding landscapes cannot be ignored or minimized. Long-term political decision-making is key. Ultimately, the tourism project evaluates the archaeological historic heritage and its rehabilitation, local craftsmen, market

studies, technical-economic evaluation, financial studies, and environmental impact evaluation. Ecotourism helps in biodiversity conservation, poverty reduction, and business viability using sustainable principles and practices. Local government officials, local communities, NGOs, the private sector, and management committees had a great role in tourism development and maintaining healthy cooperation and coordination (KC, 2017).

A study was conducted in Bhadaure-Tamagi village of the Panchase Protected Forest Area of Gandaki Province, which was planned to be developed as an important tourist destination for tourists visiting Pokhara because of its cultural and natural importance (Neupane et al., 2021). However, no separate study was conducted in the Kavrepalanchowk district, and even not at local levels for the promotion of ecotourism and ecovillage. An increase in income from ecotourism is supporting education, health, women's empowerment, and capacity building. It has helped to maintain peace and preserve indigenous culture, tradition, and local food. There was an increase in expenditure, direct employment opportunities, and a source of revenue after ecotourism intervention (KC et al., 2021). Which can uplift the present conditions of the local people and minimize the poverty level.

Different criteria are chosen for different analyses for example, six criteria, including landscape and naturalness, wildlife, topography, accessibility, geology, and climate, were established based on experts' preferences and literature, and the thematic factors for suitability modelling were derived from freely accessible satellite imagery and existing geospatial data and combined using a Weighted Linear Combination (WLC) method (Yasin & Woldemariam, 2023). The objective of this study is to model and identify potential ecotourism sites by combining Geographic Information System GIS-based MCDA and AHP methods. However, these criteria can be adopted based on expert's opinions and AHP online calculations.

Hence, a study is necessary to develop a comprehensive ecotourism suitability index to guide policymakers in implementing tourism development policies. Given the considerable appeal of the study area to both local and international tourists, it is essential to conduct a systematic evaluation to pinpoint suitable areas for ecotourism development. This necessity arises from the study area's placement within a fragile ecosystem and its proximity to a United Nations Educational, Scientific and Cultural Organization (UNESCO) world heritage site. The study employed a GIS-integrated environment coupled with a fuzzy MCDA methodology for analysis (Withanage et al., 2024). The methods of AHP and MCDA are suitable for estimating and proposing suitable sites. Hence, the study of preparing ecotourism and ecovillage maps using MCDA and AHP has significance for the Kavrepalanchowk district.

2. METHODOLOGY

2.1 Study Area

The location for this study area is the Kavrepalanchok district, where a comprehensive analysis of eco-tourism and ecovillage is necessary. A very popular tourist area covering Dhulikhel and Kavrepalanchowk District, located in Bagmati Province, Nepal, covers an area of 1,396 km² (539 sq mi) and has a population of 364,039. It lies approximately 30 kilometers southeast of Kathmandu, on the eastern rim of the Kathmandu Valley, south of the Himalayas. The geographical extensions (latitudes and longitudes) of the location are shown in Figure 1.

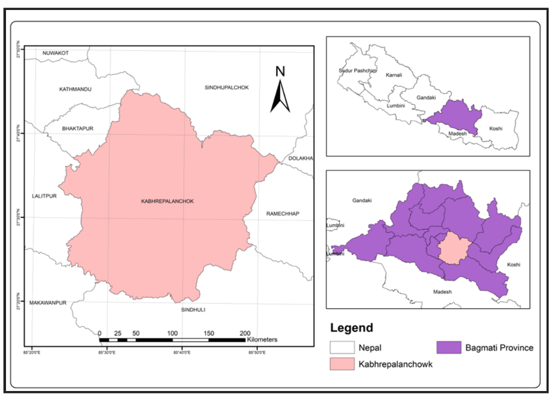


Figure 1: Study Area Map

2.2 Data and Software

The datasets used in this study were collected from a variety of sources. First, a questionnaire was created to get information from the locals regarding the main tourist attractions in Kavrepalanchowk. Secondary data sources were resampled at the same resolution after being obtained from a variety of sources at different resolutions. Some missing data in the Open Street Map (OSM) were digitized and prepared manually. Table 1 is the list of data, sources of the datasets, and their accessed date for this study.

Table 1. Summary of Datasets for Processing

Data	Sources	Accessed Date
Boundary Map	https://dos.gov.np/	05/03/2024
Open Street Map	https://extract.bbbike.org/	
Google Maps	https://www.google.com/maps	25/04/2024
Digital Elevation Model (DEM)	https://search.asf.alaska.edu/#/	05/03/2024
Land Cover	https://livingatlas.arcgis.com/landcoverexplorer	

The data preprocessing, data analysis, and mapping were performed in ArcGIS 10.5 software using the MCDA method.

2.3 Methodological Framework

The methodological framework was prepared after several literature reviews. It has been categorized into two parts firstly, the data collection and preparation part, and secondly, the data processing and mapping part as indicated in the figure below. The diagram of methodological framework for identification of the potential sites for ecotourism as well as ecovillage based on MCDA using AHP is presented in Figure 2.

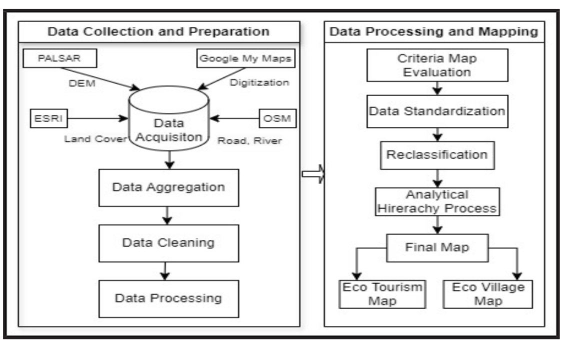


Figure 2: Methodological Framework Based on AHP Method

2.3.1 Data Collection and Preparation

The datasets downloaded from OSM like road, river, land cover, cultural heritages, slope and aspect were filtered for the study area. Major data gaps were found, the presence of incorrect data sets was removed, and the database was constructed by digitizing the features in Google Maps. The datasets were then loaded in ArcMap.

2.3.2 Criteria Map Evaluation and Standardisation

The factors for both ecotourism and ecovillage were then processed to create the spatial database resulting in the criteria map. Criteria such as slope and aspect are important factors for identifying the location of ecovillage created using the available tool in the GIS environment. Similarly, accessibility from highways and village roads, as well as major tourist attractions, was also generated by using the Euclidean distance tool. The land cover map was already in raster format, and classes were added in its attribute table. Final suitability maps for the ecovillage and ecotourism were evaluated by visualizing and overlaying the criteria maps.

Table 2. Factors, Criteria and Suitability Classification

Factors	Criteria	Suitability Classification			
		Highly Suitable	Suitable	Marginalized	Not Suitable
Landscape	Slope	0-12	12-18	18-25	>25
	Aspect	Southeast to Southwest	East, West	Northeast, Northwest	North
Accessibility	Proximity to highways	0-200	200-500	500-1200	>1200
	Proximity to village roads	0-100	100-300	300-800	>800,
Major Attraction	Religious Sites	0-200	200-800	800-1200	>1200
	Viewpoint, waterfall, caves	0-200	200-800	800-1200	>1200
Land Cover	Class	Rangeland	Bare land	Forest	Water-bodies, Built up, Cropland

2.3.3 AHP

The weight of different criteria was derived based on expert opinions, and various literatures. Final weights were assigned to each criterion through a free web-based AHP online calculator provided by K.D. Goepel. The summary matrix and weights of different criteria are shown in Figure 3-6. Consistency Ratio (CR) for Ecovillage and Ecotourism was 8.3% and 9.0% respectively which is lower than 10% and assumed to be fit for the analysis. Based on the weights, weighted overlay tools were used to prepare the final suitability maps. The same criteria maps were used for ecovillage and ecotourism, but aspect criteria were removed in the analysis of ecotourism suitability.

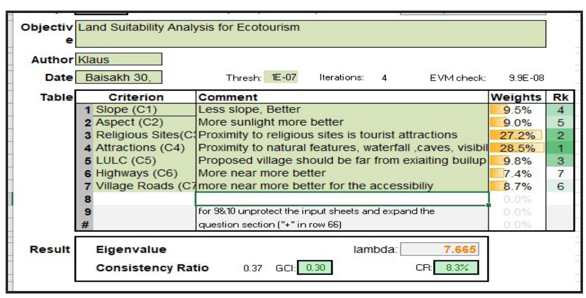


Figure 3. Land Suitability Analysis for Ecotourism

Matrix		1 Slope (C1)	2 Aspect (C2)	3 Religious Sites(C3)	4 Attractions (C4)	5 LULC (C5)	6 Highways (C6)	7 Village Roads (C7)	8 0	9 0	10 0	normalized principal Eigenvector
Slope (C1)	1	1	1	1/5	1/5	2	2	1	-	-	-	9.47%
Aspect (C2)	2	1	1	1/2	1/5	2	1	1/2	-	-	-	9.00%
Religious Sites(C3)	3	5	2	1	1	4	3	3	-	-	-	27.19%
Attractions (C4)	4	5	5	1	1	3	2	3	-	-	-	28.48%
LULC (C5)	5	1/2	1/2	1/4	1/3	1	3	2	-	-	-	9.76%
Highways (C6)	6	1/2	1	1/3	1/2	1/3	1	1	-	-	-	7.36%
Village Roads (C7)	7	1	2	1/3	1/3	1/2	1	1	-	-	-	8.74%

Figure 4: Summary Matrix for Ecotourism

Objective: Land Suitability Analysis for EcoVillage

Author: Klaus

Date: Baisakh 30,   Thresh: 1E-07   Iterations: 6   EVM check: 3.5E-09

Table

	Criterion	Comment	Weights	Rk
1	Slope (C1)	Less slope, Better	4.7%	6
2	Religious Sites(C	More sunlight more better	30.9%	2
3	Attractions(C3)	Proximity to religious sites is tourist attractions	33.2%	1
4	LULC(C4)	Proximity to natural features, waterfall ,caves, visibilit	13.2%	3
5	Highways (C5)	Proposed village should be far from exiaiting builup	10.6%	4
6	Village Roads (C7	More near more better	7.4%	5
7			0.0%	
8			0.0%	
9		for 9&10 unprotect the input sheets and expand the	0.0%	
#		question section ("+" in row 66)	0.0%	

Result

Eigenvalue   lambda: 6.561

Consistency Ratio   0.37   GCI: 0.32   CR: 9.0%

Figure 5: Land Suitability Analysis for Ecovillage

Matrix		1 Slope (C1)	2 Religious Sites(C2)	3 Attractions(C3)	4 LULC(C4)	5 Highways (C5)	6 Village Roads (C7)	7 0	8 0	9 0	10 0	normalized principal Eigenvector
Slope (C1)	1	1	1/4	1/5	1/3	1/3	1/2	-	-	-	-	4.67%
Religious Sites(C2)	2	4	1	1	5	3	3	-	-	-	-	30.91%
Attractions(C3)	3	5	1	1	5	4	3	-	-	-	-	33.24%
LULC(C4)	4	3	1/5	1/5	1	3	2	-	-	-	-	13.20%
Highways (C5)	5	3	1/3	1/4	1/3	1	3	-	-	-	-	10.62%
Village Roads (C7)	6	2	1/3	1/3	1/2	1/3	1	-	-	-	-	7.35%

Figure 6: Summary Matrix for Ecovillage

3. RESULT AND DISCUSSION

The result and discussion sections for ecotourism and ecovillage are separately described in sections 3.1 and 3.2. Making different criteria for ecotourism and ecovillage a comparative analysis has been performed.

3.1 Ecotourism

As a result of the AHP process, the analysis led to the identification of potential ecotourism and ecovillage suitable sites, which are illustrated in Figures 7 and 8, respectively. Notably, highly favourable sites for ecotourism appear to be in the Namobuddha, Banepa Dhulikhel areas.

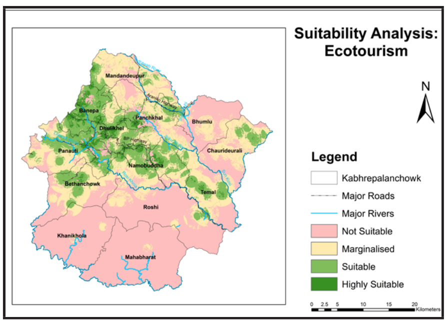


Figure 7. Suitability Analysis Ecotourism

However, it appears that Bhumlu, Mahabharat, Khanikhola, and Roshi are less appropriate. The accessibility, variety of tourist attractions, and land use/ cover are likely the root causes of this.

Table 3. Areas of Suitability Class for Ecotourism

OBJECTI	Value	Count	Area (in meter	Total Area	Percentage	Suitability Class
1	0	45682	41113800	1390860900	2.955997	Not Suitable
2	1	264058	237652200	1390860900	17.086698	Not Suitable
3	2	450468	405421200	1390860900	29.148939	Not Suitable
4	3	459035	413131500	1390860900	29.703294	Marginalsied
5	4	286617	257955300	1390860900	18.546448	Suitable
6	5	39541	35586900	1390860900	2.558624	HIghly Suitable

Table 3 shows that 2.55% of the total area is highly suitable for ecotourism and 18.6% as suitable.

3.2 Ecovillage

Despite having similar specifications, only tourist destinations with elevations above 2000m were chosen for the ecovillage.

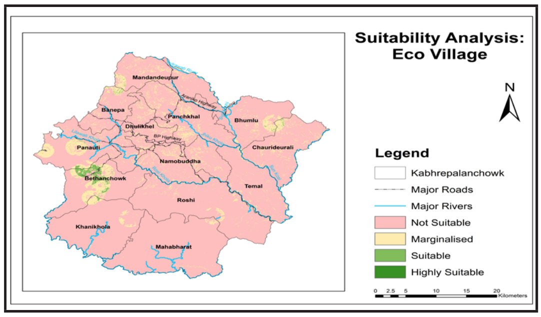


Figure 8: Suitability Analysis Ecovillage

The village should be situated far from settlements and in a location with a wealth of natural, cultural, and ecological attractions. Here, the proper location for the ecovillage was based substantially on criteria like aspect elevation and land cover. The suggested new locations are located far from the current developed and agricultural areas and are the most ideal ones. The Bethanchowk has a highly suitable area indicated in dark green color and only a few areas are suitable but most of the area is not suitable as shown in Table 4.

Table 4. Areas of Suitability Class for Ecovillage

OBJ	Value	Count	Area(in	Total Area(in m	Percentag	Suitability Class
1	0	167887	15109830	1390860900	10.863653	Not Suitable
2	1	272920	24562800	1390860900	17.660141	Not Suitable
3	2	936437	84279330	1390860900	60.595082	Not Suitable
4	3	156343	14070870	1390860900	10.116662	Marginalised
5	4	11517	10365300	1390860900	0.745243	Suitable
6	5	297	267300	1390860900	0.019218	Highly Suitable

Bethanchowk rural municipality of Kavrepalanchowk district has the most potential for an ecovillage out of all 13 local levels. The existence of attractive characteristics rich in natural resources, such as waterfalls, caves, and woods with ecological diversity, along with its popularity as a religious site, may be the reason that Bethanchowk is an ideal location for an ecovillage. Figure 9 shows a detailed view of the potential ecovillage area of Bethanchowk.

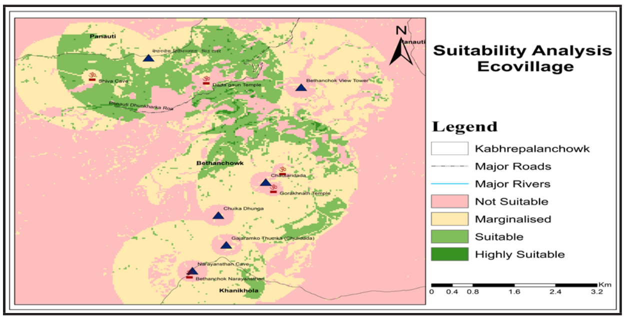


Figure 9: Suitability Analysis of Ecovillage Near Bethanchowk

Additionally, Bethanchowk, being the highest place in the Kavrepalanchowk district, offers views of the snow-capped mountains that are part of the Mahalangur range in addition to complex geodiversity.

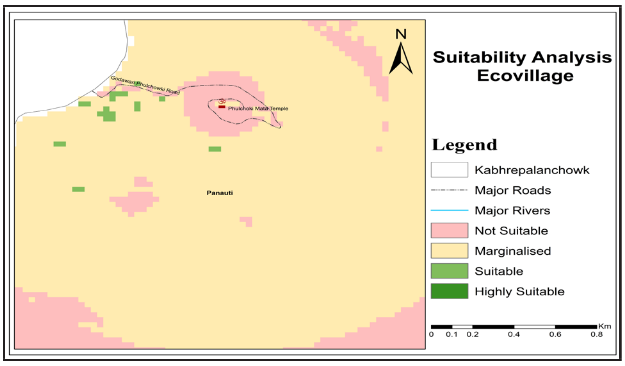


Figure 10: Suitability Analysis of Ecovillage Near Phulchowki

Due to the location's remoteness, lack of access to main roads, and metropolitan area, it takes several days for visitors to arrive and enjoy their stay. Therefore, Bethanchowk is a perfect location for the Ecovillage that can provide hospitality to the tourists which can uplift the economic status of local people. In Panauti municipality, an area near Phulchowki is the least likely location for the ecovillage in the Kavrepalanchowk district (Figure 10).

Situated at the second highest elevation in the Kavrepalanchowk district, it is home to the well-known temple. Godawari-Phulchowki route connects the two local levels of Panauti of Kavrepalanchowk district with the neighbouring district of Lalitpur that lies in Kathmandu valley, the Capital city of Nepal played a considerable role in having the least sites for ecotourism. Travellers may visit the Phulchowki Temple easily provided the route to the destination is readily accessible from the capital city. Accordingly, this location is good for ecotourism but not for ecovillage. Visitors rarely intend to stay for several days. There appears to be a more marginalized area within the proximity to the view tower in Figures 11 and 12 and the suitable locations are close to the Panauti Kushadevi Road in Figure 12. The area may not benefit from the criteria like slope, elevation and aspect for the favourable ecovillage.

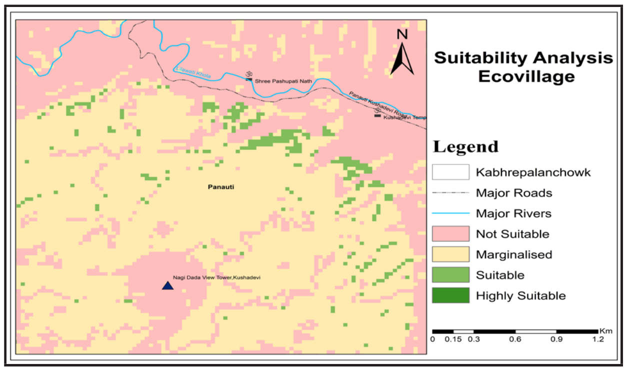


Figure 11: Suitability Analysis of Ecovillage Near Panauti

The suitable ecovillage locations shown in Figure 12 are located within some distance from the viewpoint. One possible explanation could be that visitors can schedule a one-day hike to get a viewpoint.

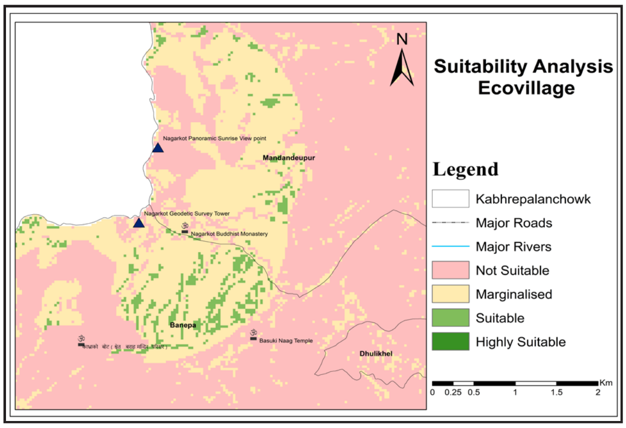


Figure 12: Suitability Analysis of Ecovillage Near Banepa

3.3 Validation

The final suitability map of ecotourism and ecovillage was validated based on visual interpretation and rational analysis. Firstly, by overlaying the map on Google Earth, a visual inspection was performed to analyze whether the suitable area was within appropriate locations according to the criteria. For example, Banpea, Panauti, Dhulikhel, Chauri Deurali, Temal, and Namobuddha seem to have good ecotourism sites due to scenic beauty, access to the village road, much cultural heritages, and fewer slope areas. Similarly, ecovillage was visually and logically analyzed before finalizing the map. For example, tourists may visit the Phulchowki Temple easily provided the route to the destination is readily accessible. But due to a lack of access to highways and lack of cultural heritages an area suitable for ecotourism is not suitable for ecovillage.

3.4 Discussion

There is a quite difference between the concept of ecotourism and ecovillage as described in the introduction section. Different literatures are focused either on ecotourism or on ecovillage. However, a comparative study in the same study for both ecotourism and ecovillage is interesting. In, this research, based on slightly different criteria and making analysis gave interesting results as discussed below.

3.4.1 Ecotourism Map

The statistics of the ecotourism map show that 2.5% area is highly suitable, 18.54% is suitable, 29.70% is marginalized, and the rest of the area 49.26% is not suitable areas. The major areas of Banepa, Panauti, Dhulikhel, Chaurideurali, Temal, and Namobudhha seem to have good ecotourism areas. However, almost all areas of Mahabharat, Khani Khola and Bhumlu don't have good ecotourism sites. This is due to a lack of good infrastructure and roads.

The cause of ecotourism in marginalized areas is due to factors like dense forest land cover and poor accessibility to roads. Some areas like Maharabharat and Khani Khola have that problem. The criteria of slope, aspect, religious sites, attractions, land use land cover, highways, and village roads are taken into consideration so the result is based on these criteria.

3.4.2 Ecovillage Map

The ecovillage map has a highly suitable area of 0.020% of the total study area, 0.745% suitable, 10.11% marginalized and the remaining area is not suitable. The result shows that 49.26% of the study area is not suitable for ecotourism but 89% area is not suitable for ecovillage. It means that the aspect and road proximity have a great impact on ecovillage as our criteria. This results in the Phulchoki area not being suitable for ecovillage due to slope and aspect.

For the upliftment of local people, ecovillage can have a great impact in offering hospitality like a homestay, which is suitable in Bethanchowk due to the suitable slope and aspect but due to such factors, despite of presence of tourist attractions in Mahabharat, suitability of ecovillage is low. The Phulchoki area seems to have low suitability due to poor aspects. So, area-specific planning and preparation are necessary for ecovillage and ecotourism. However, the public voices, choices, and rights are essential to address rather than only preparing a criteria map and trying to implement it directly. A comprehensive study of individual parameters (for slope, aspect, road, religious sites, etc.) with social, and economic dimensions is required to get better results.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

In this study, GIS based MCDA and AHP methods have been used for ecotourism and ecovillage mapping. Data collection, preprocessing, rasterization, criteria map preparation and final layout were performed for ecotourism and ecovillage mapping as described in earlier sections. **Firstly**, many areas in different local levels like Dhulikhel, Banepa, Namobuddha, Panauti and Mandandeupur Municipalities have a good potential for ecotourism (2.5% of total study areas). However, most of the areas in Mahabharat, Khani Khola, Roshi, and Bhumlu Rural municipalities have the least potential for ecotourism despite the presence of major tourist attractions (visibility, spatial hiking point) present. **Secondly**, only Bethanchowk (0.020% of total study areas) seems to have very good potential for ecovillage. It means that the areas having high potential for ecotourism might not have good results for ecovillage and vice-versa due to important factors like the slope and aspect, cultural heritage sites, access to highways, and land cover. **Thirdly**, factors like road accessibility, slope, aspect, and religious site mostly determine the suitability regardless of good scenic beauty, geodiversity ecological diversity, and high elevation only.

4.2 Recommendations

This study can be very fruitful for the Ministry of Culture, Tourism and Civil Aviation to take necessary actions and preserve ecotourism and ecovillage in Kavrepalanchowk district.

Bethanchowk rural municipality needs to take appropriate action to develop a comprehensive model for ecovillages in their territory. By ensuring local participation, taking expert opinion, and developing a conservation plan, this result can be put into practice. Inter-governmental and multi-sectoral coordination and cooperation are also essential during the implementation of this result.

Furthermore, academic study focusing on the AHP techniques, and criteria selection approach would be more impactful. A similar study in other districts and throughout the country is recommended for creating baseline data and preparing plans accordingly. Future research on linking ecotourism and ecovillage for mitigating the effect of climate change and poverty reduction is interesting. Different sustainable development goals can be achieved through local-level plans and policies. To convert the local level agenda into action, this research can be taken as a valuable reference.

ACKNOWLEDGEMENTS

We would like to acknowledge the Director of the center Mr. Ramkumar Sapkota, for encouragement, continuous support, and valuable guidance to write and publish this paper. We would also like to acknowledge the reviewers, for their creative comments and valuable suggestions to make it better and possible for publication. We are thankful to all directors, instructors, senior, and junior trainees, and friends for their guidance and encouragement throughout this research.

REFERENCES

Zeybek, O., Zeybek, O., & Arslan,; (2017). *Ecovillages: The Place Where Ecotourism Turns Into Educational Tourism*. https://www.researchgate.net/publication /321223789

Koduvayur Venkitaraman, A., & Joshi, N. (2022). A critical examination of a community-led ecovillage initiative: a case of Auroville, India. *Climate Action*, *1*(1). https://doi.org/10.1007/s44168-022-00016-3

Samal, R., & Dash, M. (2023). Ecotourism, biodiversity conservation and livelihoods: Understanding the convergence and divergence. In *International Journal of Geoheritage and Parks* (Vol. 11, Issue 1, pp. 1–20). KeAi Communications Co. https://doi.org/10.1016/j.ijgeop.2022.11.001

Shang, Y., Bi, C., Wei, X., Jiang, D., Taghizadeh-Hesary, F., & Rasoulinezhad, E. (2023). Eco-tourism, climate change, and environmental policies: empirical evidence from developing economies. *Humanities and Social Sciences Communications*, *10*(1). https://doi.org/10.1057/s41599-023-01777-w

Poudel, D. P., & Shrestha, A. (2020). Review of local level policies. In *Southasia Institute of Advanced Studies (SIAS)*.

KC, A. (2017). Ecotourism in Nepal. *The Gaze: Journal of Tourism and Hospitality*, *8*, 1–19. https://doi.org/10.3126/gaze.v8i0.17827

Neupane, R., K C, A., Aryal, M., & Rijal, K. (2021). Status of ecotourism in Nepal: a case of Bhadaure-Tamagi village of Panchase area. *Environment, Development and Sustainability*, *23*(11), 15897–15920. https://doi.org/10.1007/s10668-021-01317-z

Anup, K. C., Ghimire, S., & Dhakal, A. (2021). Ecotourism and its impact on Indigenous people and their local environment: case of Ghalegaun and Golaghat of Nepal. *GeoJournal*, *86*(6), 2747–2765. https://doi.org/10.1007/s10708-020-10222-3

Yasin, K. H., & Woldemariam, G. W. (2023). GIS-based ecotourism potentiality mapping in the East Hararghe Zone, Ethiopia. *Heliyon*, *9*(8), e18567. https://doi.org/10.1016/J.HELIYON.2023.E18567

Withanage, N. C., Chanuwan Wijesinghe, D., Mishra, P. K., Abdelrahman, K., Mishra, V., & Fnais, M. S. (2024). An ecotourism suitability index for a world heritage city using GIS-multi criteria decision analysis techniques. *Heliyon*, *10*(11), e31585. https://doi.org/10.1016/j.heliyon.2024.e31585

AUTHOR INFORMATION

Name	:	**Prakash Ghimire**
Academic Qualification	:	Masters in GIS and Cartography
Organization	:	Land Management Training Center
Current Designation	:	Instructor
Work Experience	:	10 years
Published Article	:	3

CONCEPTS AND PRINCIPLES FOR IDENTIFICATION OF LOGICAL ERRORS IN CADASTRAL (PARCEL) DATABASE DEVELOPED BY DIGITIZATION OF ANALOGUE CADASTRAL (PARCEL) MAPS

Er. Mahesh Thapa

Survey Department, Nepal - *mahesh100thapa@gmail.com*

ABSTRACT

Cadastral databases created by digitization of analog cadastral maps are susceptible to errors, particularly when the original analogue maps are illegible mostly due to prolonged use. In addition to illegibility of analogue maps, missing digitization of certain parts of the cadastral maps or even entire map sheets leads to incomplete cadastral databases. In addition to introduction of errors during digitization, errors could infiltrate into cadastral database during regular cadastral operations. Errors in cadastral databases could have far reaching impacts. Hence, it is crucial to resolve these errors, starting with identification of the errors present in the cadastral database. However, identification of errors in cadastral database is not just time consuming but so cumbersome that the process often demotivates persons involved in the process of resolving errors leading to failure of such initiatives. This paper introduces concepts and principles for identification of logical errors in cadastral database leveraging the idea of consistency between plot-register and cadastral database, proposes taxonomy for classification of logical errors and provides formula for identification of different classes of logical errors. The principles, concepts and formula proposed in this paper can be utilized to develop automated system for identification of logical errors in cadastral database.

KEYWORDS: Analogue Cadastral Maps, Digitization, Cadastral Database, Plot Register, Inconsistencies, Errors

1. INTRODUCTION

1.1 Development of Cadastral Databases

Digital cadastral databases are either created alongside cadastral surveying or in cases where analog cadastral maps pre-exist, cadastral databases could be developed by digitization of these maps. Digitization of analog cadastral maps is a preferred method for creation of cadastral databases as cadastral databases can be developed swiftly and at a significantly lower cost compared to cadastral resurveys.

1.2 Errors in Digitization of Analogue Cadastral Maps

Cadastral databases developed from digitized analogue cadastral maps are susceptible to errors, particularly when the original analogue maps are illegible due to prolonged use. In addition to errors due to illegibility of maps, missing digitization of particular map sheets of portion of it can also lead to incompleteness of cadastral database. In general, ineffective quality control measures during digitization process potentially leads to introduction of errors in cadastral database. Also, errors can occur during regular cadastral operations such as parcel split and consolidation operations even after competition of digitization of cadastral maps.

In its simplest form, based solely on the constituents of cadastral maps, errors occurring in digitization of these maps can be categorized as follows:

a) Error in digitization of parcel lines

Errors in digitization parcel lines usually occur due to illegibility of analogue cadastral maps. The digitizer could wrongly digitize a line where it does not exist or the digitizer misses to digitize a line where it should have occurred. The digitizer could also misinterpret data in another layer and digitize it as part of different layer. E.g., Digitization of ward boundary as parcel boundary.

b) Errors in numbering of parcels

Errors can occur while providing numbers to parcels mostly due to illegible parcel numbers in analog cadastral maps.

1.3 Categorization of Errors in Cadastral Database based on Approach of Identification of Errors

Errors in cadastral databases can be identified based on comparison between digital cadastral database map and analogue cadastral map and also comparison between attribute table of digital cadastral database and plot-register. Hence, based on the approach of identification of errors, errors in cadastral database can be categorized as follows:

a) Errors of Graphical Nature

Errors such as shifting, missing, or creation of unnecessary parcel lines are graphical errors as these errors can be identified by rigorously comparing the graphical features of digital cadastral map and analogue cadastral maps. This is usually done by digital cadastral maps with scanned analogue cadastral maps.

b) Errors of Logical Nature

Errors in cadastral database which can be identified by making comparisons between attributes of cadastral database with entries made in plot-register are errors of logical nature. The process of identifying logical errors leverages relationship between two entities i.e., attributes of cadastral database and entries in plot-register.

This paper focuses on errors of logical nature introduced in cadastral databases which are developed by digitization of analogue cadastral maps. It discusses the current methods employed in identifying these errors of logical nature, theorizes taxonomy for classification of these errors and proposes formula for identifying these errors.

2. IDENTIFICATION OF ERRORS OF LOGICAL NATURE IN CADASTRAL DATABASE

2.1 Established Procedures in Identification of Errors of Logical Nature in Cadastral database

The current practices adopted in identification of errors of logical nature in cadastral database are manual. These processes are slow and tedious. Two approaches are generally followed in manual identification of errors in cadastral database.

a) Sporadic Identification of Errors (Manual)

Errors in cadastral databases are often identified during transactions related to specific parcels. This approach although helps in resolving issues at hand, it would take a very long time to ensure that the entire cadastral database is logically correct.

b) Systematic Identification of Errors (Manual)

Systematic manual approach for identification of errors in cadastral database involves comparing each parcel in plot-register with corresponding parcel in the cadastral database. Typically, this process is conducted in descending order, beginning with the largest parcel number in the plot register and proceeding to the smallest. Although, this approach ensures identification of logical errors, it is a very tedious and time-consuming.

2.2 Logical Consistency between Cadastral Database and Plot-register

Plot-register (Parcel subdivision and parcel consolidation register) maintains records of all cadastral operations such as parcel subdivision, parcel consolidation, etc. that causes changes in parcel database. Cadastral operations that causes changes in cadastral database are first booked in plot-register and only then changes are made in cadastral database. If any transactions are booked in plot-register, subsequent changes should be made in cadastral database. Hence, in theory, plot-register and cadastral database should be consistent to each other. This is an important concept which is utilized for identification of logical inconsistencies in cadastral database. All parcels in cadastral database which are not as per plot-register (i.e. inconsistent) signify logical inconsistencies. These inconsistencies need to be resolved for ensuring the consistency between cadastral database and plot-register.

2.3 Representing Plot-register as Tree Structure

Immediately after conduction of cadastral survey, all parcels surveyed in the field are registered in field-book and later to plot-register for conducting cadastral operations (parcel split, parcel consolidation, etc.). When parcels undergo parcel subdivision and/or parcel consolidation, new parcel numbers are created in plot-register and the parent parcels are cancelled (annulled). Accordingly, changes are made in cadastral database. These operations can be represented in a tree diagram, hereafter called Parcel Tree diagram as illustrated in Figure 1.

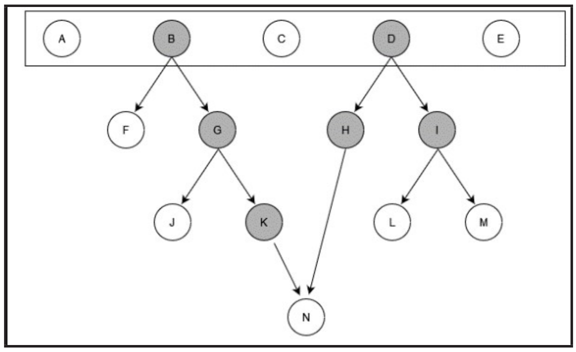


Figure 1: Parcel Tree Diagram

The tree diagram in Figure 1 represents the following parcel operations:

- Parcel [A, B, C, D, E] are created during cadastral field survey. These parcels are registered in field book and later to plot-register.
- Parcel B undergoes parcel subdivision creating parcels F AND G.
- Parcel G undergoes parcel subdivision creating parcels J and K.
- Parcel D undergoes parcel subdivision creating parcels H and I.
- Parcel I undergoes parcel subdivision creating parcels L and M.
- Parcel K and H undergoes parcel consolidation creating parcel N
- All parent parcels that underwent parcel subdivision and/or consolidation are annulled (cancelled). These are shaded grey in the tree diagram.

In terms of tree structure, the parcels in the tree diagram can be categorized as follows:

a. Root (Parcels) = [A, B, C, D, E]

These are the parcels created during cadastral survey.

b. Parent Nodes (Parcels) = [B, G, K, D, H, I]

All parent parcels are annulled and hence can no more exist in cadastral database.

c. Leaf Nodes (Parcels) = [A, F, J, N, C, L, M, E]

In the tree diagram, the shaded grey parcels are annulled due to parcel subdivision and parcel consolidation operations. Only leaf nodes (parcels) are not annulled and hence only these can exists in cadastral database. Hence, we can state that a cadastral database is logically consistent to plot-register if it has only the leaf node parcels.

2.4 Representing Plot-register as Tabular Structure

The above parcel operations can also be represented in a tabular form which is a standard practice while booking in plot-register. A minimalistic (not including owner, area, etc. information) tabular representation of parcel operations are shown in table1:

Table 1- Tabular Representation of Plot-register

Sn	Child Parcel	Parent Parcel	Remarks
1	A	0	Root Parcel
2	B	0	Root Parcel
3	C	0	Root Parcel
4	D	0	Root Parcel
5	E	0	Root Parcel
6	F	B	
7	G	B	
8	H	D	
9	I	D	
10	J	G	
11	K	G	
12	L	I	
13	M	I	
14	N	[K,H]	

In the above table, child parcel list all the parcels either created during cadastral survey or created later after cadastral operations such as parcel subdivision and/or parcel consolidation. Parent parcels are the mother parcels which are annulled when child parcels are created.

Child Parcel: List of all parcels that are generated during initial cadastral survey (i.e. records of which are made in Cadastral Field Book) and parcels which are created later either due to parcel subdivision or parcel consolidation.

Parent Parcel: Parcels which are subdivided or consolidated to form new parcels are parent parcels.

Root Parcel: Parcels which are created during cadastral survey are root parcel. The parent parcel of this is considered as 0.

2.5 Concept of Standing Parcels

Standing parcels is the set of parcels which should exist in cadastral database as per plot-register. It is equivalent to leaf node parcels as per tree diagram of cadastral operations of plot register. Set of standing parcels can be generated utilizing tabular entries of plot-register.

Standing Parcels = Child Parcels – Parent Parcels

In the above formula, all parent parcels are subtracted from the set of child parcels to give standing parcels. Standing parcels are equivalent to leaf node parcels in the tree diagram. A cadastral database consistent with the parcel register should have all and no more parcels other than the standing parcels.

2.6 Principle of Cadastral database Consistent with Plot-register

Consistency of a cadastral database can be expressed based on tree structure and tabular structure of plot-register.

In terms of tree structure of plot-register, a cadastral database is logically consistent with plot-register if and only if it contains exactly all parcels in leaf node of the plot-register tree diagram, without any additional ones.

In terms of tabular structure of plot register, a cadastral database is logically consistent with plot-register if and only if it contains exactly all parcels in the standing list, without any additional ones.

3. CATEGORIZATION AND FORMULAS FOR IDENTIFICATION OF LOGICAL INCONSISTENCIES

3.1 Types of Logical Inconsistencies

Logically inconsistent parcels are of different nature. In order to aid in correcting errors in cadastral database, logically inconsistent parcels can be categorized as follows:

a. Extra Parcels

All parcels that have neither been generated during cadastral survey nor created during any cadastral operations (parcel subdivision or consolidation) but exist in cadastral database are extra parcels. Extra parcels are typically mistakes when providing number to parcels. Although, these also can be special numbers used to flag parcels whose parcel number could not be identified while analogue maps are digitized.

b. Duplicate Parcels

All those parcels which have a greater number of occurrences in the cadastral database than recorded in the plot-register are duplicate parcels. Typically, these errors occur when mistakes are made in providing parcel numbers.

c. Missing Parcels

All those root parcels (parcels created during cadastral survey) that have not undergone parcel subdivision or consolidation, and thus should theoretically exist in cadastral database but are absent are missing parcels.

d. Dead Parcels

All those parcels which have gone parcel subdivision or consolidation, and thus should theoretically must not exist in cadastral database but still remain present are dead parcels. Dead parcel occurs when cadastral operations are booked in plot-register but not implemented in the cadastral databases.

3.2 Formulas for Identification of Logically Inconsistent Parcels in Cadastral Database

Formulas are prescribed for determination of logically inconsistent parcels in cadastral database in accordance to the type of logical inconsistencies discussed in section 3.1. To demonstrate the use of the formula, let us consider the following to be the parcels in cadastral database –

Database_parcels = [A, C, C, D, I, J, K, L, M, N, S]

And, let us also consider *Table 1 – Tabular Representation of Plot-register* to be the records of plot-register. Then we have,

Child_parcels = [A, B, C, D, E, F, G, H, I, J, K, L, M, N]

Parent_parcels = [0, B, D, G, I, K, H]

Root_parcels = [A, B, C, D, E]

a. Formula for determination of Standing Parcels

The following formula can be used to identify Standing Parcels.

Standing_parcels = Child_parcels – Parent_parcels

E.g. -

Standing_parcels

= [A, B, C, D, E, F, G, H, I, J, K, L, M, N] - [0, B, D, G, I, K, H]

= [A, C, E, F, H, J, L, M, N]

b. Formula for determination of Extra Parcels

The following formula can be used to determine Extra Parcels in cadastral database-

Extra_parcels = Database_parcels – Child_parcels

E.g. -

Extra_parcels

= [A, C, C, D, I, J, K, L, M, N, S] – [A, B, C, D, E, F, G, H, I, J, K, L, M, N]

= [S]

c. Duplicate Parcels

The following formula can be used to determine Duplicate Parcels in cadastral database-

Duplicate_parcels = for each parcel in Database_parcels if count of the parcel in Database_parcels is greater than 1 and also greater than count of the parcel in Child_parcels

E.g.

Duplicate_parcels = [C]

d. Missing Parcel

The following formula can be used to determine Missing Parcels

Missing_parcels = [Root_parcels] – [Database_parcels] – [Parent_parcels]

E.g. –

Missing_parcels = [A, B, C, D, E] - [A, C, C, D, I, J, K, L, M, N, S] - [0, B, D, G, I, K, H]

= [E]

e. Dead Parcels

The following formula can be used to identify Dead Parcels.

Dead_parcels = for each parcel in Standing_parcels if parent of Standing_parcels exist in Database_parcels

E.g. –

Dead_parcels = [D]

4. CONCLUSION AND RECOMMENDATION

This paper presents the concepts and principles for identification of logical errors in cadastral database leveraging the principle of logical consistency between cadastral database and plot-register. It provides taxonomy for classification of logical errors and formula for identification of these errors. Errors in cadastral databases have far-reaching impacts and hence needs to be identified and resolved. This paper provides way forward to identify logical errors which can be developed to build automated systems for identification of logical errors in cadastral databases.

AUTHOR INFORMATION

Name	:	**Er. Mahesh Thapa**
Organization	:	Survey Department
Position	:	Survey Officer
Academic qualification	:	Masters in Geospatial Technologies
Work Experience	:	12 years
Published Article	:	3

Modernizing Nepal's Height System: Leveraging GNSS and Gravity Observations for Global Compatibility

Sushmita Timilsina

Land Management Training Center-*qust04sharma@gmail.com*

ABSTRACT

Nepal's height-determination infrastructure faces unique challenges due to its diverse topography and landlocked geography. Traditional methods, primarily reliant on leveling techniques, are limited in their precision and coverage, hindering accurate height referencing across the country. However, advancements in Global Navigation Satellite System (GNSS) technology and gravity observations offer promising opportunities for modernizing Nepal's height system. This abstract explores the feasibility of transitioning Nepal's height system towards the International Height Reference System (IHRS) to achieve compatibility with global standards. It examines the potential benefits of integrating GNSS and gravity observations for precise height determination, addressing the challenges posed by Nepal's geographical constraints. The abstract outlines strategies for enhancing Nepal's geodetic infrastructure, including capacity building, international collaboration, and alignment with IHRS principles. By embracing modern geodetic techniques and adopting internationally recognized standards, Nepal can overcome its height determination challenges and contribute to the establishment of a unified vertical reference system on a global scale.

KEYWORDS: GNSS, IHRS, Gravity, Equipotential surface

1. INTRODUCTION

The height system of any country is a one-dimensional coordinate system to obtain the height of any point above a reference surface (Featherstone, 2006). This reference surface can be a reference ellipsoid, mean sea level determined from a tide gauge station, or any predetermined vertical datum. Depending upon the reference surface, the height system can be distinguished into physical height system and geometric height system. The height that links with the Earth's gravity field refers to the physical height and the height of a point relating to a mathematical model of Earth, such as ellipsoid, refers to the geometric height. Physical height accounts for the curvature of the Earth and variations in its gravitational field and is often measured using instruments such as leveling devices. The geometric height refers to the height of a point above a reference ellipsoid, ignoring variations in the Earth's gravitational field (Sanchez, GGOS, 2024).

The development and advancement in the Global Navigation Satellite System (GNSS) has made it possible to achieve horizontal and vertical coordinates of any point on Earth's surface. The horizontal accuracy being in about mm and vertical accuracy in about cm to sub cm level provided by satellite positioning system has created opportunities for many national and international agencies in different regions of the world to re-considering the determination of height and their vertical networks and datum(Jekeli, 2000). However, the reference ellipsoid is a smooth mathematical approximation of the physical Earth's surface, not its true figure. The ellipsoid height above any reference ellipsoid is a geometric height which is the height of a point in a geometric sense and not relate to the earth's real structure.

1.1 Physical Height

Physical heights are typically observed or transferred by using leveling, converting GNSS observations to physical heights

using a model, or a combination of both methods. Geodetic (spirit) leveling measures the geometric height difference between two leveling points located at two different equipotential (or level) surfaces of the Earth's gravity field. The relative height differences are referenced to a "known" height value at a benchmark or MSL at a tide gauge, which is an approximation of the geoid. Height corrections must be applied to observed height differences to account for the non-parallelism of the equipotential surfaces. Due to the non-parallelism of the equipotential surfaces, the sum of the level differences (dn) in a closed leveling loop at longer distances is not zero. Their correction requires gravity values along leveling traverses derived from gravity measurements to compute the leveling corrections. The surface gravity values can be obtained from Global Gravity Models (GGM) such as

EGM2008 or by interpolating the data from the existing gravity database.

1.1.1 Gravity Correction in Geodetic Leveling

To satisfy the loop closure condition of zero i.e. $\oint dn=0$ the leveled height differences must be converted to proper potential differences or physical height differences i.e. $\oint dw=0$. Therefore, to satisfy this condition we need

$$\oint dn + k = 0$$

Where k is known as the gravity correction of leveling. The potential differences or physical height differences are adjusted along vertical networks by the method of condition equations or by the method of parameter estimation.

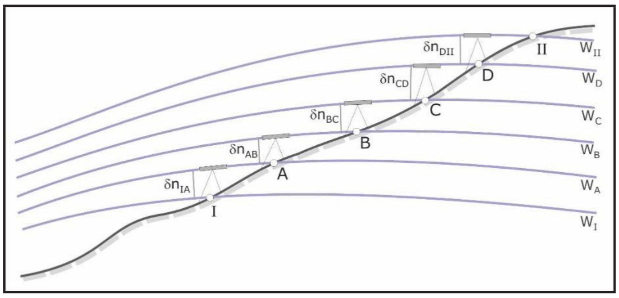


Figure 1: Equipotential Surfaces And Leveled Height Differences.

In practice, the potential difference from geometric (spirit) leveling between two benchmarks I and II is given by:

$$\Delta W_{II,I}=(g_{-IA}.\delta n_{IA})+(g_{AB}.\delta n_{AB})+(g_{BC}.\delta n_{BC})+\cdots..(g_{DII}.\delta n_{DII})$$

With $g_{AB}=(g_A+g_B)/2$

If the starting point (P_0) of a leveling line is on the geoid (W_0), the negative potential difference W is called geopotential number CP (Heiskanen and Moritz [1967, eq. 4-8]) and it is given by:

$$C_P = -\Delta W = W_o - W_P = \int_{P_o}^{P} g dn \cong \sum_{P_o}^{P} g\delta n$$

Where dn Corresponds to the leveled height differences using spirit leveling and g are the average of the gravity along the leveling line connecting P_0 and P. As geopotential numbers are given in [m^2/s^2], they are usually converted to heights (in m) by dividing the geopotential number by a gravity value.

Depending on the type of gravity values applied, different types of physical heights are distinguished: orthometric heights, normal heights, or dynamic heights.

1.1.2 GNSS Observation For Physical Height

A modern requirement of a height datum is for physical heights to be determined from GNSS observations. Ellipsoidal heights (h) derived from GNSS can be approximately transformed to a physical height (H) by subtracting either the: (i) modeled geoid value ($\boldsymbol{N}$) (i.e. $\boldsymbol{H_{orth}} = \boldsymbol{h} - \boldsymbol{N}$) or, (ii) modeled quasi-geoid value ($\boldsymbol{\zeta}$) for normal heights (i.e. $\boldsymbol{H_{norm}} = \boldsymbol{h} - \boldsymbol{\zeta}$). The huge progress made in the Global Navigation Satellite System (GNSS) to determine horizontal and vertical position on Earth's surface has provided an opportunity to determine the height of any point above the reference ellipsoid everywhere on the Earth. However, the reference ellipsoid is a smooth mathematical approximation of the physical Earth's surface, not its true figure. The Earth's surface/ topography, the geoid surface, and the ellipsoidal surface vary. The vertical distance between the geoid surface and the ellipsoid surface is known as geoid undulation. If proper determination of geoid undulation or geoid height is done then any ellipsoidal height measured on Earth's surface can be converted to the orthometric height simply following the following relation:

$$N = h - H$$

where N is geoid undulation or geoid height (height of geoid above ellipsoid) measured along ellipsoidal normal, H is orthometric height of Earth's surface at point P measured above geoid along the plumb line and h is the ellipsoid height measured at point P on Earth surface above the reference ellipsoid. To develop an appropriate geoid model for Nepal, the geographic characteristics must be taken into account along with accurate gravity data ensuring compatibility to use with different software.

2. COUNTRY'S CONTEXT

The height determination in Nepal is limited by the instrumentation and method used. Geodetic leveling is conducted to obtain the physical height. Generally, the precision of leveling is defined by $c\sqrt{k}$, where k is the length of the leveling traverse in kilometers and c is in millimeters. High-quality leveling is typically precise to $2\sqrt{k}$ mm along a traverse. These heights are used as the physical height for engineering purposes and fixing alignment all over Nepal. But these heights are rarely subjected to gravity correction. The gravity reductions are to be taken into account when leveling is done over a large area.

Nepal is a landlocked country broadly surrounded by India on the South, East, and West and China on the North. It does not have direct access to any sea/ocean; so it has adopted the Bay of Bengal connecting India as the reference for height determination. This height is carried over to the different parts of the country. It is not possible to run a leveling network throughout the country as a maximum percentage of Nepal has hills and mountains where it is difficult even for human survival. Therefore, it would be clever to develop the height reference for Nepal from GNSS observation and a precise geoid model requiring very little field work leaving behind the traditional method of leveling that demands massive field work. Furthermore, Precise GNSS observation along with sufficient surface gravity observations to produce an accurate geoid model can provide orthometric height with the desired accuracy.

To assess the strengths and weaknesses of the available height systems mainly three main criteria are: i) Compatibility with GNSS, ii) Ease of access/ use, and iii) Accuracy. The height system for Nepal with the application of GNSS and gravity observation is compatible with GNSS, easy to use, and can provide the desired accuracy. This was also demonstrated during the Everest height measurement project conducted by the Survey Department in 2020 A.D. The project used GNSS observations along with the surface and air-borne gravity data to develop a precise geoid model to compute the orthometric height of Everest. Thus, this meets the entire requirement aforementioned for considering the height system.

The practice of GNSS-RTK (Real Time Kinematics), LIDAR (Light Detection and Ranging), UAV (Unmanned Aerial Vehicle), and Gravimetry is thriving in government and private sectors of Nepal which demands geoid-based datum ensuring consistency in height measurements across different locations and regions. With the increasing need for precise vertical positioning especially in larger engineering projects running all over the country, modernization of the height system is seen as vital.

3. TOWARDS INTERNATIONAL HEIGHT REFERENCE SYSTEM (IHRS)

Moving another step further, the modern height system can be directed toward an International Height Reference System (IHRS). The IHRS is a global framework established by the International Association of Geodesy (IAG) to provide a consistent and unified reference for height measurements worldwide. The IHRS serves as a common reference surface for determining elevations and vertical positions across different regions and countries. Since the mean sea level defined by a country might not be on the same level as that defined by another country. The zero elevation as defined by one country differs up to ±2 meters from the zero elevation as defined by another country (Laura Sánchez, 2022). Landlocked countries like Nepal often in problems when determining their sea level. This becomes a great question when measuring the elevation of boundary points for example the measurement of height of the Mount Everest from Nepal and China side. It was very difficult to come to one conclusion and moving towards IHRS through the adoption of common global standards made it through.

If an alternative height reference frame were to be established for Nepal, precise GNSS observations along with a precise geoid model of Nepal are required which are refined over time with the availability of local gravity data. This system needs to be aligned with the internationally agreed (W_0=62,636,856.0 m^2/s^2) value and provides a seamless physical reference surface onshore and offshore (IAG Resolution 2015). By addressing these factors and actively participating in the global geodetic community, Nepal can move towards adopting an International Height Reference System that provides a consistent and accurate framework for height determination, aligning with international standards and best practices.

4. CONCLUSION

Nepal's height-determination infrastructure stands at a critical juncture, poised for transformation through the integration of modern geodetic techniques. The challenges posed by the country's diverse topography and landlocked geography necessitate innovative solutions to achieve accurate height referencing on a global scale. By embracing advancements in Global Navigation Satellite System (GNSS) technology and gravity observations, Nepal can modernize its height system and transition towards the International Height Reference System (IHRS). This transition not only facilitates compatibility with global standards but also enhances the accuracy and reliability of height determination across the country (Laura Sánchez, Unified Height System, 2022). Through international collaboration, capacity building, and alignment with IHRS principles, Nepal can overcome its height determination challenges and contribute significantly to the establishment of a unified vertical reference system on a global scale.

REFERENCES

Drewes H, K. F. (2016). IAG Resolution 2015 for the Definition and Realisation of an International Height Reference System (IHRS). In *The Geodesist's Handbook.* J Geod 90.

Jekeli, C. (2000). *Heights, the geopotential, and vertical datums.* Columbus, USA: Department of Geodetic Science, The Ohio State University.

Laura Sánchez, M. C. (2024). *Global Geodetic Observing System*. Retrieved April 2024, from https://ggos.org/item/height-systems

Laura Sánchez, M. C. (2022). *Unified Height System.* Retrieved from Global Geodetic Observing System: https://ggos.org/item/height-systems/

Sánchez, L. W. (2023). Towards an integrated global geodetic reference frame: preface to the special issue on reference systems in physical geodesy. *Journal of Geodesy*.

W. E. Featherstone, a. M. (2006). Height systems and vertical datums: a review in the Australian context. *Journal of Spatial Science*, 21-41.

W.A Heiskanen, H. M. (1967). *Physical Geodesy.* San Francisco: Freeman and Co.

AUTHOR INFORMATION

Name	:	Sushmita Timilsina
Academic Qualification	:	MSc in Geodesy and Geoinformation
Organization	:	Land Management Training Center
Current Designation	:	Instructor
Work Experience	:	9 years
Published Paper/Article	:	4

DEPENDENCY OF ORIENTATION OF IMAGE CAPTURE ON VEGETATION INDICES

Sanjeev Kumar Raut[1], Dhurba Poudel[2], Umang Raj Dotel[1], Shree Krishna Adhikari[1]

[1]Land Management Training Center, Nepal

sanjeevraut.4@gmail.com, umang.dotel@gmail.com, shreek.ashikari@gmail.com

[2]Survey Department, Nepal-*poudeldhurba@gmail.com*

ABSTRACT

The concept of precision farming is increasing day by day through vegetation analysis. Vegetation indices are very important for finding out the condition of vegetation. The main theme of the research is the calculation of vegetation indices from images taken at different orientations. Digital cameras designed for the consumer market are increasingly being used as research instruments due to their low cost, compact size, and ease of use. It is quite time-consuming and costly to calculate the indices from the satellite imagery. Thus, from the camera with different sensors under different light conditions the vegetation indices are calculated so that we can predict the fertilizer, irrigation, and other disease control. The result shows that NDVI and SAVI at 270° are found to be higher than 0° followed by 90° and 180°.

KEYWORDS: Color, NDVI, SAVI, Matrix, Vegetation

1. INTRODUCTION

Crop growth monitoring has been one of the focus in the field of agronomy (Wenzhou et al. 2015). The study of vegetation is done through two methods using remote sensing: the first where satellite images or airborne images are studied and the second method through analysis of images taken from the camera. Being the sRGB and spectral values provided only for the Gretag Macbeth Color Checker 24 color patches, we preliminarily tested the possibility of calculating reference sRGB values for the other Color Checkers using spectral values (Danny P. 2006). Here, we tried to take the same scene from different orientations on correcting those images using Matlab for calculating the different vegetation indices. The Normalized Difference Vegetation Index (NDVI) is a versatile tool in remote sensing with applications ranging from agriculture and forestry to environmental monitoring and climate change research. Its ability to quantify vegetation dynamics makes it invaluable for understanding the Earth's ecosystems and their responses to natural and human-induced changes. NDVI is a key tool in remote sensing, especially for assessing vegetation health and monitoring changes in land cover over time. Soil Adjusted Vegetation Index (SAVI) is a vegetation index similar to NDVI but with a modification to account for soil brightness, which can cause distortions in NDVI values, particularly in areas with sparse vegetation or exposed soil. SAVI was developed to minimize these soil background effects and provide a more accurate measure of vegetation vigor(Huete, 1988). All those vegetation indices are calculated to determine how the indices are changed under different orientations.

2. OBJECTIVES

The main objective of this project is to

- To calculate vegetation index from color-corrected images.
- To compare the vegetation index at different orientations.

3. STUDY AREA

The images were captured of an area 1m2 on bare ground having grass and bare soil. Here 1m by 1m wooden frame was developed.

4. METHODOLOGY

The methodology is followed by image capturing, applying color correction, band extraction, and vegetation index calculation. The overall methodology is given below.

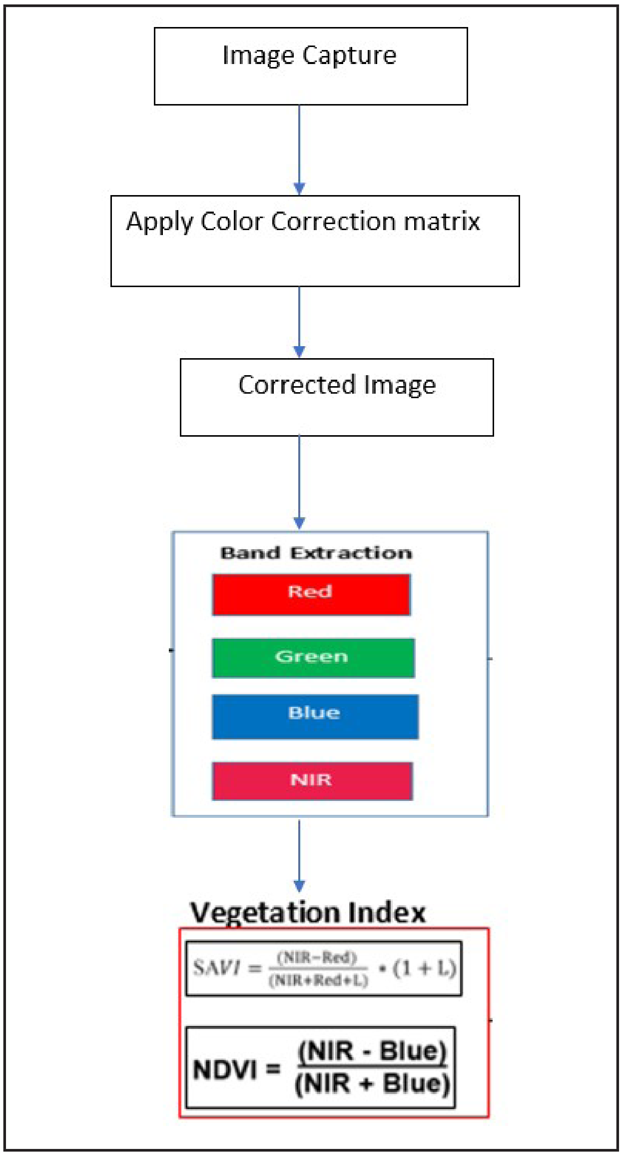


Figure 1. Overall Methodology

5. RESULTS & DISCUSSION

5.1 Image Capturing

In this stage, Canon DSLR having a camera resolution of 15.1 mega pixels was used to capture images. The images were captured at different angles making angle with vertical. Normally, angles of 00, 900, 1800, and 2700 were considered. The images were taken from the digital camera and stored as 24-bit color images. The image consists of Near infrared, Red, Green, and Blue Band.

5.2 Color Correction

Here two light conditions (Cloudy and Sunny) during capturing photos. At the same time, we captured the scene (study area) and image of the color checker passport. The given below figure 2 shows the photo capture from Canon DSLR.

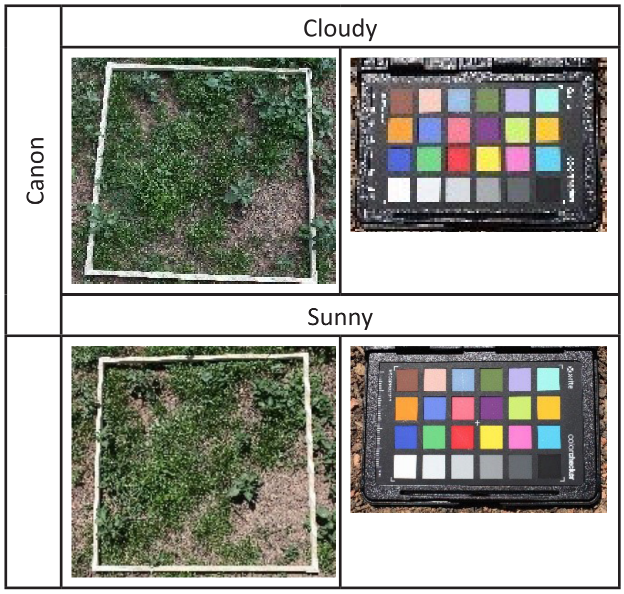


Figure 2. Image Capturing Mode

In MATLAB after reading 24 patches camera profile (Color Correction Matrix) code was generated. The 2nd step is the crop color checker passport, 3rd step is finding the centroid for each patch, 4th step is to calculate the RGB values for each patch, 5th. Step visualize the relationship between sRGB and observed RGB values and finally, save the observed RGB values in an excel file for further while images taken in the NIR band could not be color corrected.

Calculate the Color Correction Matrix (CCM) for each camera in different light conditions in order to correct the color in the images for the study area as shown in Table 3. Conceptually, the Color Correction Matrix is a (3*3) coefficient matrix based on the formulas below which is designed to eliminate the overlap in the color channels caused by the fact that blue light is seen by the Red and Green pixels on the imager, and vice versa.

$$R_{target} = a \times R_{source} + b \times G_{source} + c \times B_{source}$$
$$G_{target} = d \times R_{source} + e \times G_{source} + f \times B_{source}$$
$$B_{target} = g \times R_{source} + h \times G_{source} + i \times B_{source}$$

$$\begin{bmatrix} R_{T_1} & G_{T_1} & B_{T_1} \\ \vdots & \vdots & \vdots \\ R_{T_k} & G_{T_k} & B_{T} \end{bmatrix} = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix} \begin{bmatrix} R_{S_1} & G_{S_1} & B_{S_1} \\ \vdots & \vdots & \vdots \\ R_{S_k} & G_{S_k} & B_{S_k} \end{bmatrix}$$

Color Correction Matrix		
0.878114	0.021507	0.008038
0.016586	0.817229	-0.05672
-0.16143	-0.10477	0.756916

$$[T]_{kx3} = [CCM]_{3x3}[S]_{kx3}$$
$$[CCM] = [T][S^T][SS^T]^{-1}$$

Table 1 Color correction matrix

By analyzing the results, obviously, the corrected images look different than the original images because all photos were captured in different light conditions from the standard condition.

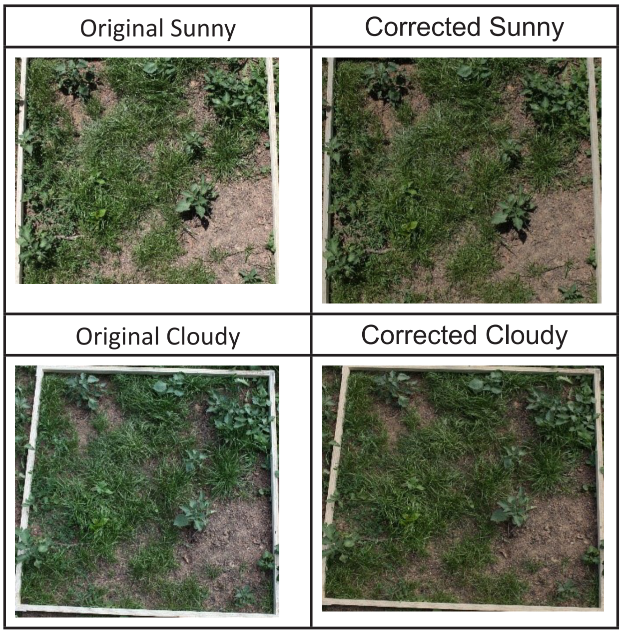


Figure 3. Image Showing After Correction

5.3 Band Extraction

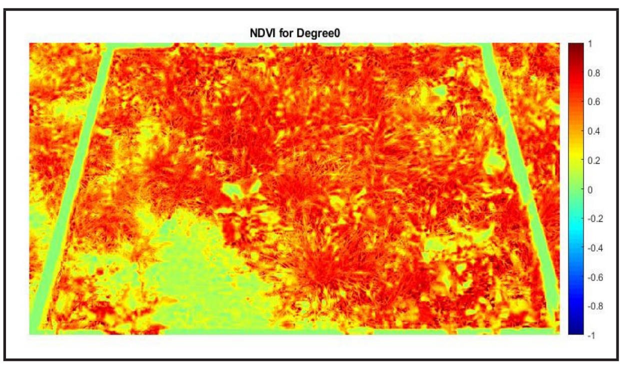
After color correction RGB images and Infra-red images then R, G, B & NIR bands were extracted.

5.4 Vegetation Index

Normalized Difference Vegetation Index (NDVI):

Under sunny condition,s the different camera orientations were considered. The orientations were determined by capturing images in the sun's direction. The different directions 00, 900, 2700, and 3600 were considered while taking the image. After extracting the NIR and R bands, NDVI is calculated and the result for different orientations is shown in Figure 4. The darker red shows the green area, and the orange to yellow color indicates the soil area. The NDVI is calculated from the reflectance measurement in the red and near-infrared spectrum(Verhulst & Govaerts, 2010)

$$NDVI = \frac{R_{NIR} - R_{Red}}{R_{NIR} - R_{Red}}$$



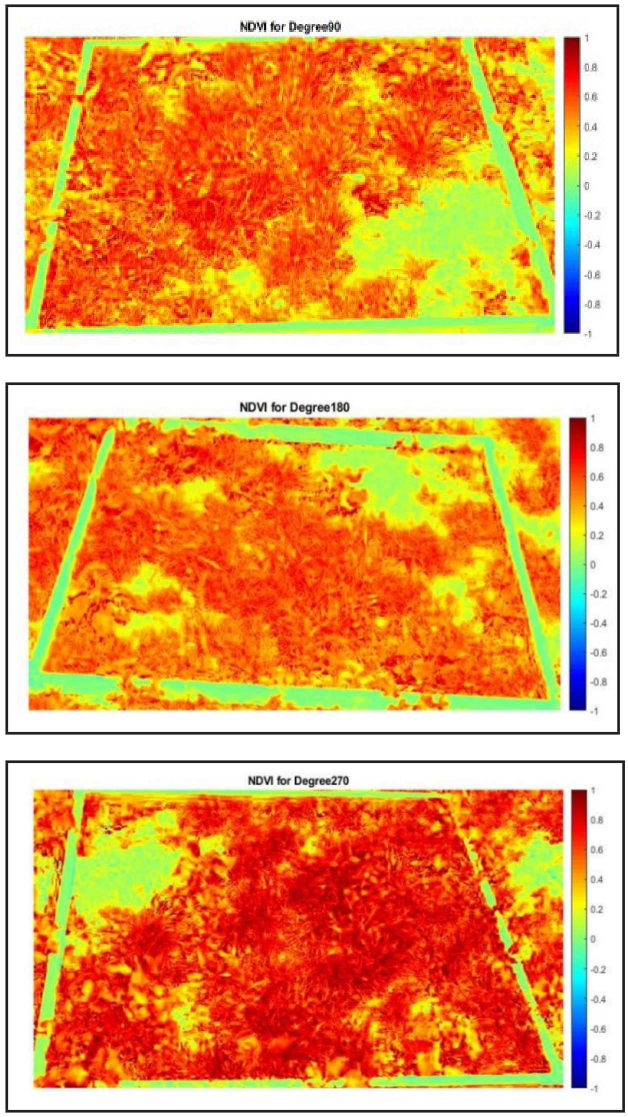


Figure 4. Showing NDVI at Different Orientations

Soil Adjusted Vegetation Index (SAVI):

The two conditions, orientation of image capturing and color correction were considered. To reduce the soil background effect, proposed using a soil-adjustment factor L to account for first-order soil background variations and obtained a soil-adjusted vegetation index (Huete A. 1988). The SAVI calculated at different orientations is shown in Figure 5. The index value ranges from -1 to 1. Compared to cloudy conditions sunny at 900 has more intensity in red color indicating a higher index value. The SAVI is calculated from the reflectance measurement in the red and near-infrared spectrum where L is a soil adjustment factor. (Zhang & Wang, 2022).

$$SAVI = \frac{(B_{NR} - B_{RED})\,(1 + L)}{B_{NIR} + B_{RED} + L}$$

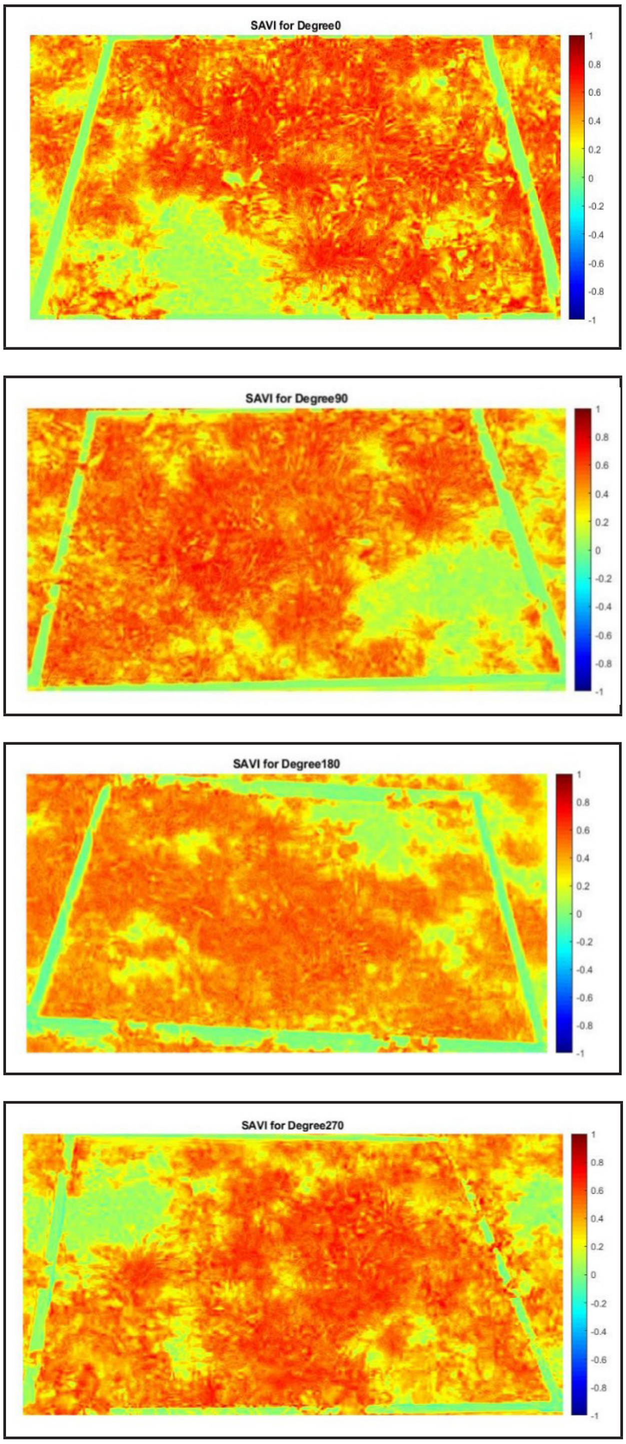


Figure 5. Showing SAVI at Different Orientations

6. RESULTS & DISCUSSION

Talking about the NDVI and SAVI range lies between -1 to +1. Within the different orientations of sunny taking the 0.1 as threshold value then NDVI and SAVI at 2700 is found to be highest than 00 followed by 900 and 1800. It concludes that sun direction affects the result of NDVI and the same applies to SAVI. For SAVI this is due to introducing the soil brightness factor (L=0.5). The average values for NDVI and SAVI are 0.4 and 0.36 respectively.

In comparison to all sunny conditions cloudy conditions are found to be less. This may be over illumination in sunny which affects the overall index value. Comparing at glance for NDVI and SAVI in the same region in the same condition the NDVI value is greater than the SAVI value as shown in Figure 6. It illustrates there are fewer differences after the threshold 0.1 value.

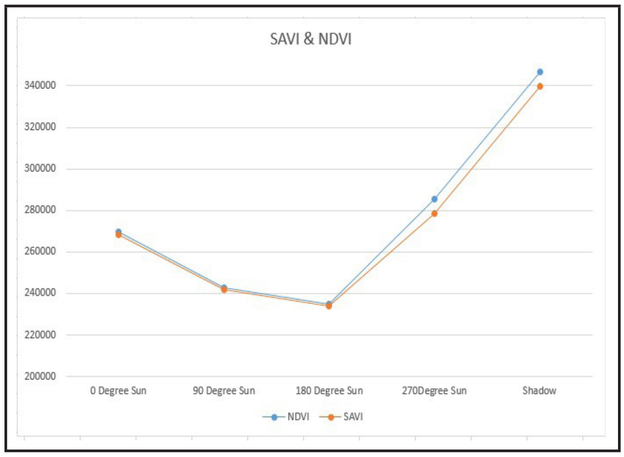


Figure 6. Comparing Between SAVI and NDVI

7. CONCLUSION

The mobile phones from the different vendors have different quality and specifications thus, need a correction. A small correction of color after a simple theory gives the proper result. The color correction must be applied as the different sensors have different properties for storing the scenes. The image capturing from the different orientations result from the variation in vegetation indices. A particular orientation is always mandatory while taking the image. It concluded that certain direction of orientation affects the analysis result of particular indices. The use of normal cameras from different mobile phones is very useful in remote sensing technologylike in agriculture and archaeology. Hence low-cost mobile can be very useful in smart and precision farming.

REFERENCES

Bunkei M, Wei Y., Jin C, Yuyichi O. and Guoyu Q. (2007). Sensitivity of the Enhanced Vegetation Index (EVI) and Normalized Difference Vegetation Index (NDVI) to Topographic Effects: A Case Study in High-Density Cypress Forest. Journal of Mdpi. http://www.mdpi.com/1424-8220/7/11/2636.

Farrell M., Gili A. & Noellemeyer E. (2018). Spectral indices from aerial images and their relationship with properties of a corn crop. Journal of Springer https://doi.org/10.1007/s11119-018-9570-9·

George E. M, Joao C. N. Verification of color vegetation indices for automated crop imaging applications. Journal of Elsevier.

Huete, A.R. A soil adjusted vegetation index (SAVI). Remote sensing of Environment 1988, 25, 295-309.

J. Hamlyn G. & V. Robin A. Remote sensing of vegetation, Oxford University Press, U.K.

Koch M and Mather P. M. (2012) Computer Processing of Remotely- Sensed Images, John Wiley & Sons Ltd Press, West Sussex.

Levin, N., E. Ben-Dor, and A. Singer. 2005. A digital camera as a tool to measure color indices and related properties of sandy soils in semi-arid environments. Int. J. Remote Sens. 26(24): 5475-5492.

Martínez L., Arbiol R., Palà V.& Pérez F (2008). Digital Metric Camera radiometric and colorimetric calibration with simultaneous CASI imagery to a CIE Standard Observer-based color space. Journal of IEEE. https://ieeexplore.ieee.org/document/4423761.

Schmittmann O. and Lammers P. S. (2017). A True-Color Sensor and Suitable Evaluation Algorithm for Plant Recognition, Journal of NCBI .https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5579884/.

Takeshi M, Kenlo N. N., Hiroyuki O and Satoshi T. (2010) Applicability of Green-Red Vegetation Index for Remote Sensing of Vegetation Phenology. Journal of Mdpi.

Wenzhu Y, Sile W, Xiaolan Z, Jingsi Z and Jiaqi F(2015). Greenness identification based on HSV decision tree. Journal of Elsevier.

Huete, A. R. (1988). A soil-adjusted vegetation index (SAVI). Remote Sensing of Environment, 25(3), 295–309. https://doi.org/10.1016/0034-4257(88)90106-X

Verhulst, N., & Govaerts, B. (2010). The normalized difference vegetation index (NDVI) GreenSeeker TM handheld sensor: Toward the integrated evaluation of crop management Part A: Concepts and case studies. 16. https://repository.cimmyt.org/bitstream/handle/10883/550/94192.pdf?sequence=1&isAllowed=y

Zhang, Y., & Wang, R. (2022). Estimation of aboveground biomass of vegetation based on Landsat 8 OLI images. Heliyon, 8(11), e11099. https://doi.org/10.1016/j.heliyon.2022.e11099

AUTHOR INFORMATION

Name	:	Sanjeev Kumar Raut
Academic Qualification	:	M.Sc. in Photogrammetry and Geoinformatics
Organization	:	Land Management Training Center
Current Designation	:	Instructor
Work Experience	:	12 years
Published Paper	:	5

LAND MANAGEMENT TRAINING CENTER: THE CENTER OF EXCELLENCE IN LAND MANAGEMENT AND GEOMATICS EDUCATION

Tina Baidar[1], Ram Kumar Sapkota[1]

tina.baidar13@gmail.com, ramksap1@gmail.com

[1]Land Management Training Center

ABSTRACT

Land Management Training Center, being the oldest and only government institution to develop over 10,000 land professionals through various training programs, has been pivotal since its inception. Certified with ISO 9001:2015 for Quality Management in 2022, LMTC offers extensive long and short-term training courses. Long-term training courses such as Senior Survey Training and Junior Survey Training provide in-depth knowledge of surveying, mapping, geo-information, and land administration using traditional to modern tools and technologies. Adhering to the principle of Continuing Professional Development, LMTC also provides diverse short-term training courses such as training on land administration and management, informal land tenure, land, instrumental handling, GIS, Remote Sensing, UAV, GNSS, etc. The target group of short-term training is not only from in-service survey professionals but also covers a wide range of sectors such as the Department of Land Management and Archive, Department of Hydrology and Meteorology, Central Bureau of Statistics, Nepal army, Nepal Police, Courts, and many more. Furthermore, the Center has also collaborated with Kathmandu University from bachelor's degree courses to PhD programs and provided government scholarships to over 400 students. LMTC has a variety of features and facilities such as library service, lab, transportation, hostel, canteen, museum, etc. that foster and sustain an ideal learning atmosphere. The Center is committed to enhancing new and existing capacities, upgrading its scope and services, and extending its outreach locally and globally.

KEYWORDS: LMTC, Land Management, Training, Land Administration, Geomatics, Geoinformatics, CPD

1. INTRODUCTION

Land and Management Training Center (LMTC), under the Ministry of Land Management, Cooperatives and Poverty Alleviation, Government of Nepal was established in 1968 A.D. The Center is located about 30 kilometers east of Kathmandu in Dhulikhel Municipality. Figure 1 shows orthophoto of LMTC premises.

Figure 1: Orthophoto of LMTC Premises

LMTC is the oldest and the only governmental institution continually and significantly producing human resources and enhancing the capacity of government personnel in the field of Surveying, Mapping, and Land Management since its establishment. The Center was initially named Napi Talim Kendra (Survey Training Center) and was renamed as Land Management Training Center on July 10, 2000. The Center has already produced more than 10,000 land professionals at different levels through various types of training courses.

LMTC is certified with ISO 9001:2015 for Quality Management on 29 June 2022 A.D. The Center has been conducting a wide range of long and short-term training incorporating state-of-the-art modern technologies. Along with this, LMTC has collaborated to run academic courses with Kathmandu University (KU). Additionally, the Center contributes to the capacity building of Provincial and Local Governments.

2. VISION, MISSION, AND GOAL OF THE CENTER

The vision of LMTC is to develop as 'The Center of Excellence in Land Management and Geomatics Education'.

The mission of LMTC is 'To Build and Enhance Institutional Capacity in Land Management and Geomatics'

The goal of the Center is 'To produce qualified and skilled human resources in the field of Land Management and Geomatics'

3. OBJECTIVES OF THE CENTER

To achieve the abovementioned vision, mission, and goal, the following objectives have been devised:

- To conduct different levels of professional courses.
- To carry out Pre-service and In-service Training, Refresher courses, and Orientation programs.
- To collaborate with national & international academia and professional organizations.
- To promote Research and Development.
- To support provincial and local governments in developing qualified human resources.

4. STRATEGIC GOALS OF THE CENTER

The strategic goals of the Center are listed below:

Goal 1: STRENGTHEN- Strengthen the existing capacity of the Center through proper resource management

Goal 2: UPGRADE- Improvise in several aspects to enhance/improve its current scope/services.

Goal3: OUTREACH- Collaboration with provincial & local governments as well as national and international professional organizations

5. ORGANIZATIONAL STRUCTURE

Land Management Training Centre is the department level organization under the Ministry of Land Management, Cooperatives, and Poverty Alleviation led by the Executive Director (Gazetted First Class Officer). It comprises four different sections headed by four respective directors. Each section has several units assigned with different tasks and responsibilities. Centre has a dedicated team of 57 staff including permanent and on contract. The organizational structure of the Training Center is shown in Figure 2.

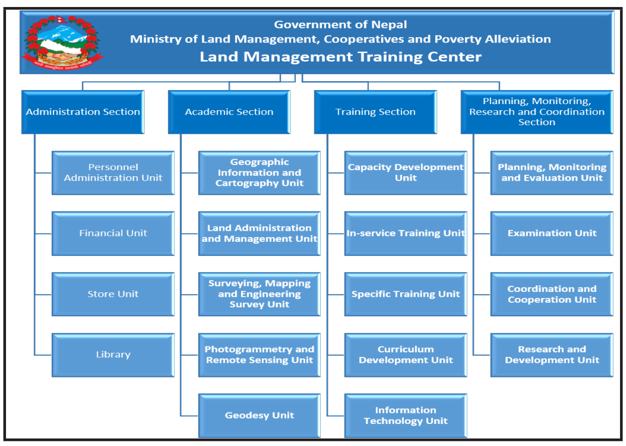


Figure 2. Organizational Structure of Land Management Training Center

6. COURSES OFFERED AT THE CENTER

LMTC has been organizing several long-term and short-term training courses to build the capacity in Surveying and Mapping, Geoinformation, and Land management. The long-term trainings are focused on producing professionals in these sectors and contributing to their professional growth whereas, the short-term trainings are focused on Continuing Professional Development (CPD) of staffs from various government organizations.

6.1 Long-Term Training

The long-term training is designed to provide in-depth knowledge of surveying, mapping, geo-information, and land administration. The Center conducts two types of long-term training courses: Senior Survey Training (for in-service candidates) and Junior Survey Training (for in-service and fresh candidates). The courses are delivered by providing theoretical lectures supported by tutorials and assignments, indoor practical sessions, outdoor practical sessions including field camp of 2-3 months, study visits to contextualize learning, demonstrations for hands-on understanding, and a final independent project for culminating overall learning throughout the course.

Senior Survey Training

Senior Survey Training is conducted for in-service candidates for a one-year duration with a maximum of 24 trainees in each batch to produce senior surveyors and to enhance their professional knowledge.

Table 1: Course Structure of Senior Survey Training

S.N.	Course Structure	Duration
1	Module I: Administration and General Awareness	3 Weeks
2	Module II: Fundamentals of Surveying and Mapping	3 Weeks
3	Module III: Applied Mathematics and Physics	3 Weeks
4	Module IV: Elementary Geodesy & Geodetic Positioning	2 Weeks
5	Module V: Astronomy and Satellite Geodesy	3 Weeks
6	Module VI: Geographic Information System and Cartography	4.5 Weeks
7	Module VII: Photogrammetry	3 Weeks
8	Module VIII: Remote Sensing	3 Weeks
9	Module IX: Cadastral Survey and Land Administration	4 Weeks
10	Module X: Topographical and Engineering Survey	3 Weeks
11	Module XI: Field Survey I (Geodetic Survey Methods)	25 days
12	Module XII: Field Survey II (Topographical and Cadastral Survey)	25 days

13	Module XIII: Field Survey III (Engineering Survey)	25 days
14	Module XIV: Final Independent Project	30 days

By the end of the Senior Survey Training, the successful candidates get acquainted with adequate theoretical as well as practical knowledge in the field of spatial data acquisition using traditional and modern tools and techniques, processing, visualization, analysis, and dissemination techniques and technologies. They also gain a comprehensive understanding of land administration and geo-information management and become competent in delivering services in a digital environment using modern technologies. Most importantly, this training contributes to their professional growth.

Junior Survey Training (In-Service)

Junior Survey Training (In-service) is conducted for government employees (non-gazetted) under engineering service, survey group, or equivalent for a one-year duration with a maximum of 24 trainees in each batch to enhance their knowledge and skills.

Table 2: Course Structure of Junior Survey Training (In-service)

S.N	Course Structure (14 modules)	Duration
1	Module I: Public Administration and Organizational Management	3 Weeks
2	Module II: Fundamentals of Surveying and Geoinformation Technology	3 Weeks
3	Module III: Applied Mathematics and Physics	3 Weeks
4	Module IV: Basic computer and Computer Aided Drafting	3 Weeks
5	Module V: Geodetic Control Survey	3 Weeks
6	Module VI: Geographic Information System and Cartography	4 Weeks
7	Module VII: Photogrammetry and Remote Sensing	4 Weeks
8	Module VIII: Cadastral Survey	3 Weeks
9	Module IX: Land Administration	3 Weeks
10	Module X: Engineering and Topographical Survey	3 Weeks
11	Module XI: Field Survey I (Geodetic Survey Methods)	25 Days
12	Module XII: Field Survey II (Topographical and Cadastral Survey)	25 Days
13	Module XIII: Field Survey III (Engineering Survey)	25 Days
14	Module XIV: Final Independent Project	30 Days

Junior Survey Training (Fresh)

Junior Survey Training (Fresh) is intended for students who have completed their 10+2 education with a background in science (with Physics and Mathematics) or completed I.Sc program (with Physics and Mathematics) with a duration of one year for a maximum of 24 trainees in each batch to produce a surveyor.

Table 3: Course Structure of Junior Survey Training (Fresh)

S.N	Course Structure (14 modules)	Duration
1	Module I: Public Administration and Organizational Management	3 Weeks
2	Module II: Field Survey I (Survey Instruments and Concept)	3 Weeks
3	Module III: Fundamentals of Surveying and Mapping	3 Weeks
4	Module IV: Applied Mathematics, Physics, and Computer Application	3 Weeks
5	Module V: Geodetic Control Survey	3 Weeks
6	Module VI: Geographic Information System and Cartography	4 Weeks
7	Module VII: Photogrammetry and Remote Sensing	4 Weeks
8	Module VIII: Cadastral Survey	3 Weeks
9	Module IX: Land Administration	3 Weeks
10	Module X: Engineering and Topographical Survey	3 Weeks
11	Module XI: Field Survey II (Geodetic Survey Methods)	25 days
12	Module XII: Field Survey II (Topographical and Cadastral Survey)	25 days
13	Module XIII: Field Survey III (Engineering Survey)	25 days
14	Module XIV: Final Independent Project	30 Days

By the end of the Junior Survey Training, successful candidates will have acquired both theoretical and practical knowledge in spatial data acquisition, processing, analysis, and dissemination techniques and technologies. They also develop a comprehensive understanding of land administration and geo-information management, becoming proficient in delivering services in a digital environment using modern technologies

Short-Term Training

Land Management Training Center has been conducting short-term training to meet specific needs in the field of geo-information science and land administration. Short-term training courses are focused on the specific subject matter and are generally of 2 to 5 weeks span. Different short-term training provided by the Center has been clustered and shown in the following table with target groups and Institutions

Table 3: Courses and Target Groups of Short-Term Training

S. N	Courses	Duration	Target Group and Institution
1.	Geographic Information System (GIS) Training: Basic, Advanced, and Web	15 Days	Employees from Government and Public Sector
2.	Remote Sensing Training (RS): Basic, Advanced	15 Days	Employees from the Government and Public Sector.
3.	GNSS And UAV Training	2 Weeks	Employees from Government and Public sector
4.	Digital Cadastral Survey and Office Management Training	2 weeks to 30 Working Days	Permanent employees of the Nepal Government working in positions of non-gazetted first or second class or equivalent.
5.	Professional Course on Geomatics and Land Administration	30 Working days	Gazetted officer of Government of Nepal Engineering service, Survey group having permanent service of at least two years.
6.	Pre-Service: Training for Newly Recruited Survey Officers, Orientation Training on LA and Management (Officer Level)	1 week to 3 Months	Newly recruited Revenue and Survey Officers (Gazette Class III Level)
7.	Instrument Handling Training	2 Weeks	Local level, non-Gazette fresh employees of the Survey Department and Court's Amins/ Surveyors
8.	Training in Land Administration (LA)/Land Management	2 days to 2 Weeks	Newly recruited (Amin/Surveyor/ Survey officer) of local level, High-level officials working in the field of Land Administration for Non-Gazetted officials working in Land Revenue Offices.
9.	Open-Source Software-QGIS Training	2 Weeks	An employee of the Government of Nepal, having basic computer skills and basic knowledge of Surveying and Mapping.
10.	Training on Informal Land Tenure	3 Days - 2 Weeks	Members of the National Land Commission, District Committee, Survey Officer, Surveyor, and Assistant Surveyor
11.	Orientation Training for Honourable District Judges	3 Days	Judges from different district courts of Nepal
12.	Training on Land Use/Land Management for Local Level	2 Days-1 Week	Mayor, Deputy Mayor or Vice-chairperson, Ward Chair-persons of Local Level, Officer level or equivalent working in the field of land NGO

The overall objectives of these short-term training programs are to acquire theoretical, and practical knowledge and skills, and get familiar with the current situation in the respective theme of courses such as Instrument handling, Office (Digital) Cadastre, Land Administration and Management, Informal Land Tenure, (Web) GIS (Geographic Information System), Remote Sensing, GNSS (Global Navigation Satellite System), and UAV (Unmanned Aerial Vehicle). The target group of these trainings covers a wide range of participants from in-service employees to our stakeholders such as the Ministry of Forest and Environment, Election Commission, District courts, National Land Commission, Department of Mines and Technologies, etc. of the Federal Government, and also covers Provincial and Local Governments.

7. COLLABORATION WITH ACADEMIC INSTITUTIONS

LMTC has been collaborating with academic institutions to produce academic human resources in the field of Geomatics and Land Administration from Bachelor's degrees to PhD. Since 2007 A.D. it has been collaborating with Kathmandu University and is on the way of collaborating with other academic institutions shortly.

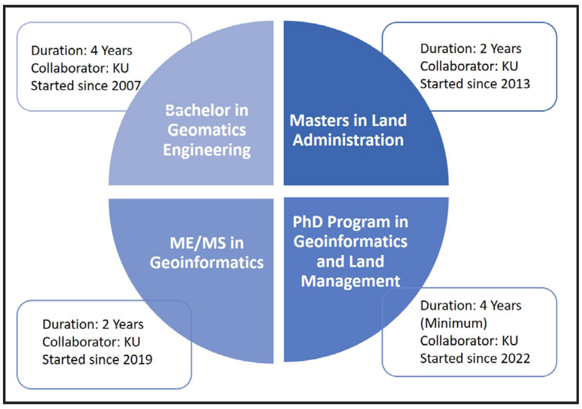


Figure 3: Academic Collaboration with Kathmandu University

As shown in Figure 3, LMTC has collaborated with Kathmandu University since 2007 in the Bachelor in Geomatics Engineering Course which is a 4 years course. In this period, 267 students (until 2018), with government scholarships have graduated and the studies of 98 students (until 2022) with scholarships are ongoing (Figure 4).

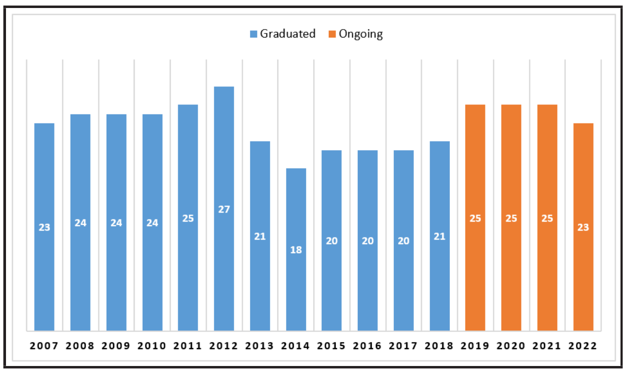


Figure 4: Total Yearly Scholarship Recipients: Bachelor's Degree in Geomatics Engineering

Besides this, LMTC has also collaborated with Kathmandu University in two years of master's Degree Courses in Land Administration since 2013 and a Master of Engineering or Master of Science Course in Geoinformatics since 2019. A combined total of 56 students from both Master's degree courses have received government scholarships in academic collaboration. Furthermore, LMTC has also extended its academic collaboration with KU in the program in Geoinformatics and Land Management since 2022. The PhD program is of a minimum four years duration.

Additionally, LMTC also collaborated with KU and CTEVT from 2015 to 2018 in a three-year Diploma in Geomatics Engineering course. During these years of collaboration, 180 graduates received scholarships.

8. WHAT MAKES US DIFFERENT?

Land Management Training Center is the only governmental institution continually producing human resources and enhancing the individual and institutional capacity in the field of Surveying, Mapping, and Land Management for more than 5 decades. The following list of features demonstrates how the Center stands different from others with some collection of pictures as shown in Figure 5.

Figure 5: Unique Features of LMTC

- More than 10,000 human resources produced
- ISO 9001:2015 Certified Institution
- Academic Member of the International Federation of Surveyors (FIG)
- Highly qualified instruction from renowned national and international universities
- Dedicated and capable workforce
- Availability of sufficient physical infrastructure
- Adequate surveying technologies from traditional to state-of-art technologies
- Furnished Library and lab facilities
- Peaceful and motivating environment
- Equipped with calibration lab
- Intensive fieldwork with closed Survey camp
- Collaboration with various Universities for academic degrees

- Competent and proficient products contributing outstandingly to a wide range of national and international institutions

9. WHAT HAVE WE ACHIEVED SO FAR?

Land Management Training Center has been continuously and significantly producing human resources in the fields of Surveying and Mapping, Land Management, and Geoinformation. This section graphically shows the achievements of the Center until fiscal year 2079/80.

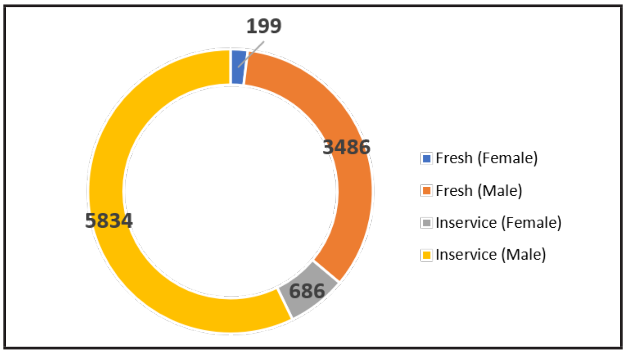


Figure 6: An Overview of Total Graduates by Intake and Gender" (FY 2079/80)

A total of 10,205 human resources (Figure 6) have already been trained or graduated through a wide range of long and short-term training comprising fresh and in-service candidates. Out of this total, 3685 graduates were fresh intakes including 199 female and 3486 male, and 6520 graduates were from in-service with 686 female and 6834 male.

Figure 7 shows the cumulative long-term training graduates from Basic Survey Training, Junior Survey Training, and Senior Survey Training which totals 2614, 680, and 2106 respectively by the end of fiscal year 2079/80. At present, the Center only offers Senior and Junior Survey Training

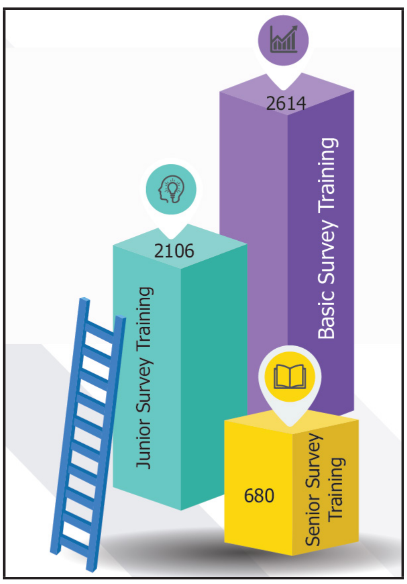


Figure: Cumulative Long-Term Training Graduates (FY 2079/80)

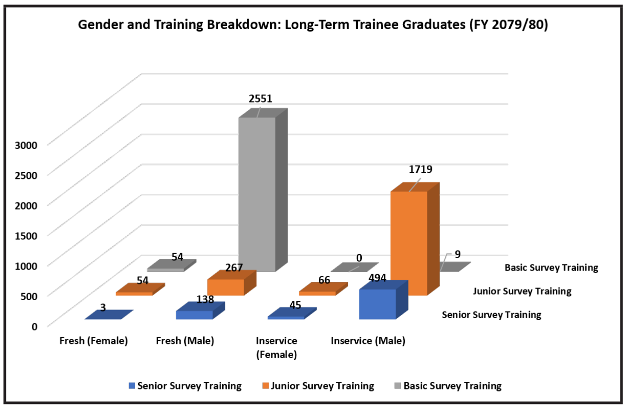


Figure 8: Gender and Training Breakdown: Long-Term Trainee Graduates (FY 2079/80)

Similarly, Figure 8 shows the gender and training breakdown of long-term training graduates to demonstrate statistics of gender-wise graduates from each long-term training together with the information in categories of fresh or in-service.

Figure 9 reveals the statistics of short-term training graduates with a total of 562 female graduates (513- In-service, 52- Fresh) and 3775 male graduates (3468- In-service and 307-Fresh)

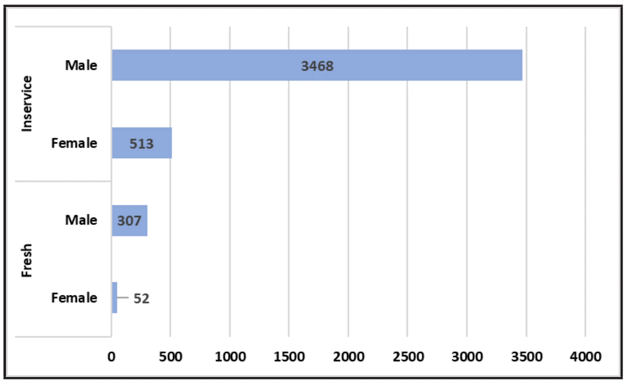


Figure 9: Short-term Training Graduates (FY 2079/80)

In addition, figure 10 shows a course-wise breakdown of 32 short-term trainings with total graduates in the respective trainings.

Besides this, LMTC has also produced a large number of human resources in the field of Geomatics (Bachelor's and Master's degrees) in collaboration with Kathmandu University as discussed in Section 7. In summary, the achievements of the Center since its establishment till the date is huge covering a wide range of sectors from all three levels of government. During this time, the Center also has developed its physical infrastructures and facilities to enhance the teaching and learning process.

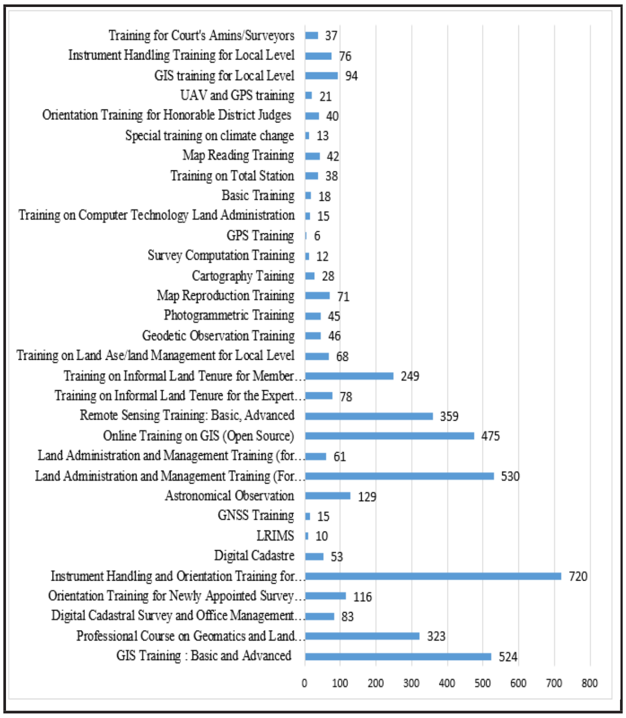


Figure 10: Course-Wise Breakdown of Short-Term Training Graduates

10. MAJOR STAKEHOLDERS

Land Management Training Centre has been providing different types and levels of training for capacity building and professional development to the officials of several government institutions in the field of Geoinformation and land management. The major stakeholders organizations are:

1. Ministry of Federal Affairs and General Administration
2. Ministry of Energy, Water Resources and Irrigation
3. Ministry of Forests and Environment
4. Department of Survey
5. Election Commission
6. Department of Land Management and Archive
7. National Land Commission
8. Department of Mines and Geology
9. Department of Roads
10. Department of Urban Development and Building Construction
11. Department of Hydrology and Meteorology
12. Office of Nepal Trust
13. Kathmandu Valley Development Authority
14. National Disaster Risk Reduction and Management Authority
15. Provincial and Local Governments
16. Courts
17. Nepal Army
18. Nepal Police
19. Armed Police Force
20. Central Bureau of Statistics

11. CAREER OPPORTUNITIES

The successful graduates from the long-term training of the Land Management Training Centre and the collaborative programs of Universities have a wide range of career opportunities within and outside the country, in government, non-government, and private sectors. They are exhibiting the excellent professional performance in the national and international organizations such as:

1. Federal Government
   a. Ministry of Land Management, Cooperatives, and Poverty Alleviation
   b. Department of Mines and Geology
   c. Department of Forest
   d. Department of Urban Development and Building Construction
   e. Nepal Army
   f. Nepal Police
   g. Armed Police Force
2. Provincial & Local Government
3. National and International Universities
4. Non-Governmental Organizations
5. Private Companies (National & International)
   a. Consulting Firms
   b. Construction Companies
   c. Engineering Consultancies
   d. Hydropower Companies etc.

12. FEATURES AND FACILITIES

The Land Management Training Center offers a variety of features and facilities that foster and sustain an ideal learning atmosphere. The Center has training blocks with classrooms and labs to smoothly conduct the long-term training and event halls for organizing the short-term training. It is well equipped with analog surveying and mapping equipment such as theodolites, levels, planes, tables, telescopic alidade, etc., and modern equipment like total stations, digital levels, GPS, UAV, etc.

The library service provides a comprehensive collection of resources, including books, journals, and research articles, and a quiet study environment, to enhance learning and research activities. There is also a survey museum in the Center with a collection of analog and modern instruments and a demonstration of analog photogrammetry and cartographic techniques.

Similarly, the Center's lab facilities are equipped with computers with required software installed to provide hands-on learning experiences and practical training. Moreover, LMTC has also started taking competitive and fair computer-based entrance examinations for long-term training in this lab. Furthermore, LMTC has a calibration lab equipped with the necessary equipment to calibrate the axis of the surveying instrument.

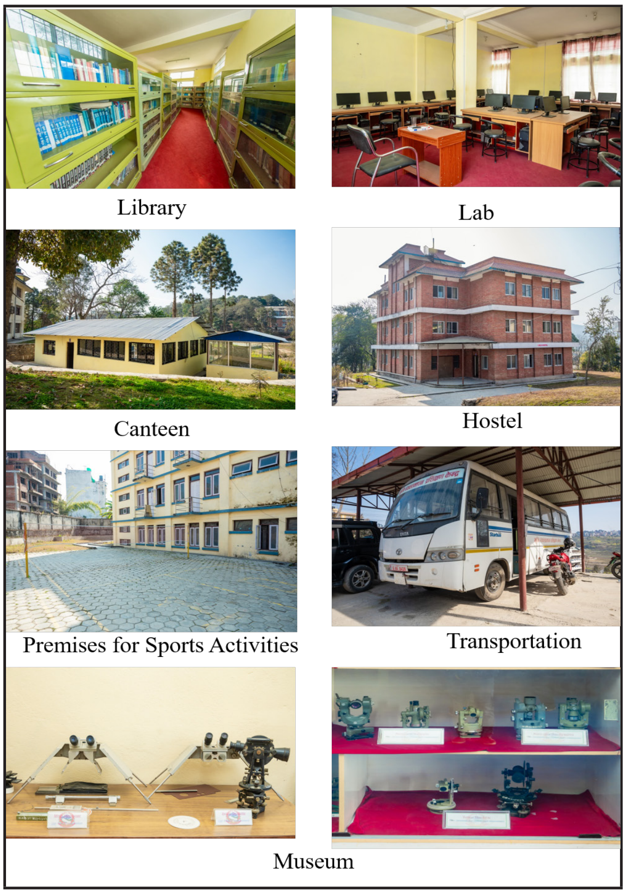


Figure 11: Features and Facilities of LMTC

The Center also has hostel facilities that offer comfortable and secure accommodations to long-term as well as short-term trainees. This facility aims to create a supportive and focused atmosphere for trainees to maximize their learning experience.

In addition, LMTC has a canteen service to provide hygienic and nutritious food at an affordable price, a convenient transportation facility from Kathmandu to ensure easy and hassle-free commuting for students, faculty, and staff, and premises to support sports activities and ensure physical fitness of staff and trainees.

13. FUTURE PLANS

Land Management Training Center is envisioned to be the Center of excellence in Geomatics Education and Land Management with the upcoming plans to persistently build and enhance individual and institutional capacity building and a vivacious contribution to policy research in the sector of Land Management and Geomatics along with the national and international collaboration for professional growth and development. The plans for the Center as listed below:

- To conduct research and innovation in the sector of Land Management and Geomatics.
- To contribute to capacity building in three tiers of Government in the sector of Land Management and Geomatics.
- To extend collaboration with academia and regional training institutions

14. CONCLUSION

Land Management and Geoinformatics are the crucial sectors in modern society that facilitate land administration, land use planning, land valuation, land taxation, resolution of land-related conflicts, infrastructure development, social equity, environment conservation, and sustainable development. In this context, the Land Management Training Center has been playing a vital role in these sectors by developing skilled and qualified professionals who contribute to effective land administration and expanding the horizon of the Geoinformatics sector. The scope of the training courses offered by the Center covers from traditional surveying and mapping courses to start-of-art technologies in these fields such as (Web) GIS, Remote Sensing, GNSS, UAV, LiDAR, and so on. By providing a theoretical base, hands-on training, and access to the latest technology, the Land Management Training Center ensures that its graduates are well-prepared to tackle the challenges of land administration and geoinformatics along with significant contributions to the continuing professional development of the in-service trainees. As stated in the Strategic Goals of the Center, it has not only dedicated its activities to strengthening the new and existing capacity but is also continually working on upgrading its scope and services and increasing its outreach to provincial and local governments as well as national and international professional organizations together with its focus on professional development, capacity enhancement, and research and development.

ACKNOWLEDGMENT

The authors would like to acknowledge Janak Raj Joshi, Executive Director of Land Management Training Center for suggesting the concept of this paper and providing crucial inputs feedback, and guidance throughout. Most of the information and data used in this paper are based on the documents published by the Center which include Brochures, Leaflets, and Strategic Plans. Therefore, the authors are also grateful to Sudip Shrestha, Lekhnath

Dahal, Shristi Poudel, Binita Shahi, and Payal Shrestha for their additional inputs in the leaflet and brochure of the Center and also to Bigyan Banjara and Sushmita Timilsina for helping in the compilation of data of trainees in various long and short-term training course.

REFERENCES

Bhatta, G.P., Dahal, T.P., Dahal. L.N., Ranjit, B., Shrestha, S., & Shahi, R., (2013). An Introduction to Land Management Training Center, *Journal of Land Management and Geomatics Education*, 60-65.

AUTHOR INFORMATION

Name	:	Tina Baidar
Academic Qualification	:	MSc. in Geospatial Technologies
Organization	:	Land Management Training Center
Current Designation	:	Instructor
Work Experience	:	9 years
Published Article	:	7

GUIDELINES FOR AUTHORS PREPARING MANUSCRIPTS FOR PUBLICATION IN THE JOURNAL GOING TO BE PUBLISHED BY LMTC

Author Name [1], Author Name[2]

[1] *Author Affiliation and Email Address*

[2] *Author Affiliation and Email Address*

ABSTRACT

These guidelines are provided for preparation of papers for publications in the journal going to be prepared by Land Management Training Centre. These guidelines are issued to ensure a uniform style throughout the journal. All papers that are accepted by the editorial board of this journal will be published provided they arrive by the due date and they correspond to these guidelines. Reproduction is made directly from author-prepared manuscripts, in electronic or hardcopy form, in A4 paper size 297 mm x 210 mm (11.69 x 8.27 inches). To assure timely and efficient production of the journal with a consistent and easy to read format, authors must submit their manuscripts in strict conformance with these guidelines. The editorial board may omit any paper that does not conform to the specified requirements.

KEYWORDS: Manuscripts, Journals, LMTC, Guidelines for Authors, StyleGuide

1. MANUSCRIPT

1.1 General Instructions

The maximum paper length is restricted to 8 pages. The paper should have the following structure:

1. Title of the paper
2. Authors and affiliation
3. Keywords (6-8 words)
4. Abstract (100 – 250 words)
5. Introduction
6. Main body
7. Conclusions
8. Acknowledgements (if applicable)
9. References
10. Appendix (if applicable)

1.2 Page Layout, Spacing and Margins

The paper must be compiled in one column for the Title and Abstract and in two columns for all subsequent text. All text should be single-spaced, unless otherwise stated. Left and right justified typing is preferred.

1.3 Length and Font

All manuscripts are limited to a size of no more than eight (8) single-spaced pages (A4 size), including abstracts, figures, tables and references. ISPRS Invited Papers are limited to 12 pages. The font type Times New Roman with a size of nine (9) points is to be used.

Setting	A4 size paper	
	mm	inches
Top	25	1.0
Bottom	25	1.0
Left	20	0.8
Right	20	0.8
Column Width	82	3.2
Column Spacing	6	0.25

Table 1. Margin settings for A4 size paper

2. TITLE AND ABSTRACT BLOCK

2.1 Title

The title should appear centered in bold capital letters, at the top of the first page of the paper with a size of twelve (12) points and single-spacing. After one blank line, type the author(s) name(s), affiliation and mailing address (including e-mail) in upper and lower case letters, centred under the title. In the case of multi-authorship, group them by firm or organization as shown in the title of these Guidelines.

2.2 KEYWORDS

Leave two lines blank, then type "**KEYWORDS:**" in bold capital letters, followed by 5-8 KEYWORDS. Note that ISPRS does not provide a set list of KEYWORDS any longer. Therefore, include those KEYWORDS which you would use to find a paper with content you are preparing.

2.3 Abstract

Leave two blank lines under the KEYWORDS. Type "**ABSTRACT:**" flush left in bold Capitals followed by one blank line. Start now with a concise Abstract (100 - 250 words) which presents briefly the content and very importantly, the news and results of the paper in words understandable also to non-specialists.

3. MAIN BODY OF TEXT

Type text single-spaced, **with** one blank line between paragraphs and following headings. Start paragraphs flush with left margin.

3.1 Headings

Major headings are to be centered, in bold capitals without underlining, after two blank lines and followed by a one blank line.

Type subheadings flush with the left margin in bold upper case and lowercase letters. Subheadings are on a separate line between two single blank lines.

Subsubheadings are to be typed in bold upper case and lower case letters after one blank line flush with the left margin of the page, with text following on the same line. Subsubheadings may be followed by a period or colon, they may also be the first word of the paragraph's sentence.

Use decimal numbering for headings and subheadings

3.2 Footnotes

Mark footnotes in the text with a number (1); use the same number for a second footnote of the paper and so on. Place footnotes at the bottom of the page, separated from the text above it by a horizontal line.

3.3 Illustrations and Tables

3.3.1 Placement: Figures must be placed in the appropriate location in the document, as close as practicable to the reference of the figure in the text. While figures and tables are usually aligned horizontally on the page, large figures and tables some- times need to be turned on their sides. If you must turn a figure or table sideways, please be sure that the top is always on the left-hand side of the page.

3.3.2 Captions: All captions should be typed in upper and lower case letters, centered directly beneath the illustration. Use single spacing if they use more than one line. All captions are to be numbered consecutively, e.g. Figure 1, Table 2, Figure 3.

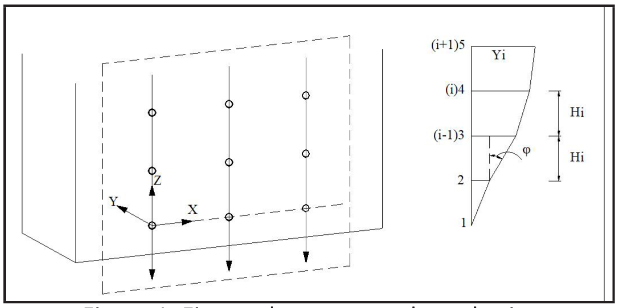


Figure 1. Figure placement and numbering

3.4 Equations, Symbols and Units

3.4.1 Equations: Equations should be numbered consecutively throughout the paper. The equation number is enclosed in parentheses and placed flush right. Leave one blank lines before and after equations:

$$x = x_0 - c\frac{X - X_0}{Z - Z_0} \; ; \; y = y_0 - c\frac{Y - Y_0}{Z - Z_0} \quad (1)$$

where c = focal length

x, y = image coordinates

X_0, Y_0, Z_0 = coordinates of projection center

X, Y, Z = object coordinates

3.4.2 Symbols and Units: Use the SI (Système Internationale) Units and Symbols. Unusual characters or symbols should be explained in a list of nomenclature.

3.5 References

References should be cited in the text, thus (Smith, 1987a), and listed in alphabetical order in the reference section. The following arrangements should be used:

3.5.1 References from Journals: Journals should be cited like (Smith, 1987a). Names of journals can be abbreviated according to the "International List of Periodical Title Word Abbreviations". In case of doubt, write names in full.

3.5.2 References from Books: Books should be cited like (Smith, 1989).

3.5.3 References from Other Literature: Other literature should be cited like (Smith, 1987b) and (Smith, 2000).

3.5.4 References from websites: References from the internet should be cited like (Maas et al. 2017). Use of persistent identifiers such as the Digital Object Identifier or (DOI) rather than a URLs is strongly advised. In this case last date of visiting the web site can be omitted, as the identifier will not change.

3.5.5 References from Research Data: References from internet resources should be cited like (Dubaya et al., 2017).

3.5.6 References from Software Projects: References to a software project as a high level container including multiple versions of the software should be cited like (GRASS Development Team, 2017).

3.5.7 References from Software Versions: References to a specific software version should be cited like (GRASS Development Team, 2015).

3.5.8 References from Software Project Add-ons: References to a specific software add-on to a software project should be cited like (Lennert and GRASS Development Team, 2017).

3.5.9 References from Software Repository: References from internet resources should be cited like (Gago-Silva, 2016).

ACKNOWLEDGEMENTS (optional)

Acknowledgements of support for the project/paper/ author are welcome.

REFERENCES

Dubayah, R.O., Swatantran, A., Huang, W., Duncanson, L., Tang, H.,Johnson, K.,Dunne, J.O., and Hurtt, G.C., 2017. CMS: LiDAR-derived Biomass, Canopy Height and Cover, Sonoma County, California, 2013. ORNL DAAC, Oak Ridge, Tennessee, USA https://doi.org/10.3334/ORNLDAAC/1523.

Gago-Silva, A., 2016. GRASS GIS in Grid Environment. Figshare https://doi.org/10.6084/m9.figshare.3188950.

GRASS Development Team, 2017. Geographic Resources Analysis Support System (GRASS) Software, Open Source Geospatial Foundation http://grass.osgeo.org (20 September 2017).

GRASS Development Team, 2015. Geographic Resources Analysis Support System (GRASS) Software, Version 6.4. Open Source Geospatial Foundation http://grass.osgeo.org (1 June 2017).

Lennert, M. and GRASS Development Team, 2017. Addon i.segment.stats. Geographic Resources Analysis Support System (GRASS) Software, Version 7.2, Open Source Geospatial Foundation https://grass.osgeo.org/grass7/manuals/addons/i.segment.stats.html (1 June 2017).

Maas, A., Rottensteiner, F., Heipke, C., 2017. Classification under label noise using outdated maps. In: *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. IV-1/W1, pp. 215-222,

doi.org/10.5194/isprs-annals-IV-1-W1-215-2017

Smith, J., 1987a. Close range photogrammetry for analyzing distressed trees. *Photogrammetria*, 42(1), pp. 47-56.

Smith, J., 1987b. Economic printing of color orthophotos. Report KRL-01234, Kennedy Research Laboratories, Arlington, VA, USA.

Smith, J., 1989. *Space Data from Earth Sciences*. Elsevier, Amsterdam, pp. 321-332.

APPENDIX (OPTIONAL)

Any additional supporting data may be appended, provided the paper does not exceed the limits given above.

Note: The format for the journal is taken and modified from the format of ISPRS archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences

Effective Land Administration in Nepal: Navigating Governance, Legal and Financial Pathways within the Climate Change- Land Nexus: Summary Report

(27-29 February 2024, Land Management Training Center, Dhulikhel, Nepal)

Umang Raj Dotel[1], Sushmita Timilsina[1]

umangdotel@gmail.com, qust04sharma@gmail.com

[1]Land Management Training Center

Kadaster, UN-Habitat, Global Land Tool Network, and Land Management Training Center collaborated to organize a workshop titled "Effective Land Administration in Nepal: Navigating Governance, Legal, and Financial Pathways within the Climate Change-Land Nexus" from February 27-29, 2024, at Land Management Training Center, Dhulikhel, Nepal.

The primary goal of this workshop is to investigate the positive effects of effective land administration on climate preservation. Bringing together 20 participants from federal and provincial land ministries, NGOs, UN-Habitat, and academic institutions, discussion was made on climate change, its issues, and how effective land administration and their policy leads to minimize the risk related to the climate change.

Key highlights of the workshop include:

- Relation between Land and Climate Change, and how legal and financial issues can be addressed.
- Highlighting the policies related to land use, value and development and how existing land policies are implemented for effective land administration.
- Sustainable models for land management and administration.

The three-day workshop began with a key-note by Clarissa Augustinus and Roshni Sharma on "The Land & Climate Change Nexus: How Do We Navigate It and Address Legal and Financial Issues?" The discussion included an overview of nine planetary boundaries (climate change, land use change, biodiversity loss, freshwater use, nitrogen and phosphorus cycles, ocean acidification, chemical pollution, atmospheric loading, and ozone depletion), as well as a safe operating space for humanity with inclusive and sustainable development to meet socioeconomic needs for food, water, income, education, resilience, voice, jobs, energy, equity, gender, and health. According to the scientists, four of these planetary boundaries have already been crossed: climate change, biodiversity loss, changes to land systems, and altered biogeochemical cycles (phosphorus and nitrogen). Tenure security encourages land users to be more secure and to incorporate land management for long-term protection of the land, reducing land degradation and restoration.

Followed by a discussion from Dr. Eva-Maria Unger, on "EU Green Deal and its impact on Land Administration" where the European Green Deal and its objectives of tackling climate change, promote sustainability, and boosting economic growth were highlighted.

Claudia Lindner gave a talk on The Rio Conventions, which include national policies and land as a common factor among the United Nations Framework Convention on Climate Change, United Nations Conventions to Combat Desertification, and United Nations Convention on Biological Diversity. To improve climate resilience and adaptation, cross-sectoral cooperation is needed. Nepal's commitment to implementing inclusive and transparent policies for transitioning its economy to carbon-neutral, climate-resilient, and sustainable development was focused along with effective land administration as a strategic enabler to achieve national level climate goals, as stated in the country's policies, which include the Nepal Adaptation Plan, 2020, National Climate Change Policy, 2019, Long Term Strategy for Net-zero Emissions, 2021.

Ganesh Prasad Bhatta, Joint Secretary/Speaker of the Ministry of Land Management, Cooperatives, and Poverty Alleviation, Nepal, gave a presentation on the country's perspective on policy, governance, and accountability. The Framework of Effective Land Administration (FELA), which has nine pathways (Governance, Institutions and Accountability, Policy and Legal, Financial, Data, Innovation, Standards, Partnerships, Capacity and Education, Advocacy and Awareness), was discussed, along with its objectives and prerequisites. The discussion included current land use, land value and development policies, the existence of an efficient land administration system, and how policy and legal pathways are thought to be moving in the right direction. However, more work is required to achieve the characteristics of "Governance Pathways" as envisioned by the FELA.

Janak Raj Joshi, Executive Director of Land Management Training Center presented on Latest developments especially on government sector. He started by addressing the presence of legal pathway of FELA enlightening its significance. Primarily, he focused on the provisions of government related to land in constitutions, Land Use Act 2019, Land Survey Acts and Regulation, Land Revenue Act and Regulation, later he talked about the prominent aspects of legal framework and issues under discussion. He concluded with the new major initiatives taken by government.

Among other discussions were a project on support to reducing the landlessness and scaling up climate-smart land use and farming practices to improve livelihoods of marginalized and poor communities in four target municipalities of Nepal whose expected results were land tenure security, climate smart land use, sustainable livelihoods, by Bishnu Paudel and Raja Ram Chhatkuli, EU Supply Chain and Regulations by Claudia Lindner, Land Pooling and its example in Nepal by Gangalal Pokharel, Curricula adaptations due to amendments by Sudip Shrestha, Climate Change-Land Nexus: Overview on Curriculum Adaptation at Geomatics Education at Kathmandu University by Dr. Reshma Shrestha, Current Business Model in Nepal and the Business Process Reengineering by Janak Raj Joshi, Sustainable Financial Models: Land Market and Land Valuation in Nepal with a demo of GIS based land valuation on Changunarayan Municipality-4, Nepal by Harisharan Nepal and Land Administration in Nepal: A sustainable resource of Revenue by Roshan Shankar Ghimire.

Summary of the workshop: Workshop statistics

1. The number of organizers of the workshop was four.
2. The workshop was of 3 days which had nearly 18 hours of technical presentations, seminar and discussions, that is 5 hours 45 minutes hours each day excluding breaks.
3. There was one key-note presentation and 22 presentations and three group discussions.
4. The list of presentations and respective presenters are illustrated in Table 1.
5. The workshop started with inaugural session chaired by Mr. Janak Raj Joshi, Executive Director, Land Management Training Center, Dhulikhel and chief guest was Mr. Ganesh Prasad Bhatta, Joint Secretary, Ministry of Land Management, Cooperatives and Poverty Alleviation, Nepal.
6. The Workshop ended with a closing ceremony chaired by Mr. Janak Raj Joshi.

Table 1. List of Presentations and Presenters

SN	Presentations	Presenter
1	UN-Habitat Nepal/GLTN	Raja Ram Chhatkuli
2	GLTN/Kadaster	Eva-Maria Unger
3	The land & Climate Change Nexus: How do we Navigate it and Address Legal and Financial Issues?	Clarissa Augustinus and Roshni Sharma
4	EU Green Deal and its impact on Land Administration	Dr. Eva-Maria Unger
5	EU Supply Chain regulations	Claudia Lindner
6	STDM application in Nepal	Raja Ram Chhatkuli
7	Policy, Governance and Accountability: Nepal's perspective	Ganesh Prasad Bhatta
8	Latest developments in Nepal I / Government Perspective	Janak Raj Joshi
9	Latest developments in Nepal II /Civil Society Perspective	Jagat Deuja
10	Curricula adaptations due to amendments	Sudip Shrestha
11	Overview on Curriculum Adaptation at Geomatics Education at Kathmandu University	Dr. Reshma Shrestha
12	Example from ongoing MAFRA funded project on land tenure, land use and Climate Change	Bishnu Paudel and Raja Ram Chhatkuli
13	SDGs Data Hub	Eva-Maria Unger
14	The Rio Conventions and National Policies	Claudia Lindner
15	Examples from the Netherlands	Jacques Vos
16	Land Administration Scenarios	Claudia Lindner
17	Identifying Appropriate Technology Investments for Land Records and Transaction Systems	Kate Fairlie
18	Current Business Model in Nepal and the Business Process Reengineering	Janak Raj Joshi
19	Land Pooling	Gangalal Pokharel
20	Sustainable Financial Models: Land Market and Land Valuation in Nepal	Harisharan Nepal
21	Land administration in Nepal: A sustainable resource of Revenue	Roshan Shankar Ghimire
22	Financing Land Administration and Climate Action	Eva-Maria Unger
23	The Current Business Model in the Netherlands	Dick Eertink

Land Literacy Program: A Joint Effort of the Government and Non-Governmental Organizations Towards Land Issues Awareness on Communities

Dharm Raj Joshi
DRJoshi@habitatnepal.org
Habitat for Humanity International - Nepal

Awareness on land related issues and services is the key for the effective land governance. It is more vital to the disadvantaged and marginalized groups of the community. Lack of understanding on land related polices, institutional and legal framework, government programs, mode of service delivery and practical issues among communities, people are facing different hurdles and inconvenience in land related issues and services.

To address or narrow down knowledge gap and to create land awareness in community level, Land Management Training Centre (LMTC), a specialized training institution of the government of Nepal under Ministry of Land Management, Cooperatives and Poverty Alleviation for land management and surveying & mapping; Community Self-reliance Centre (CSRC), a national level NGO working on land rights sector, and Habitat for Humanity Nepal, an international organization specialized on adequate and equitable housing jointly signed MoU to implement Land Literacy Program in Nepal for the first time in Nepal. Memorandum of Understanding (MoU) to conduct Land Literacy Program has been signed as per the Ministerial level decision made on November 24, 2023.

The overarching objective of 'Land Literacy' program is to build the knowledge base at community level on land and housing related policies, programs and systems and enables community people to access land and housing rights and related services informing them about policy and practicalities of land tenure security and its rational use. After its successful implementation, it may widen the way for people to proactively involve in related decision-making processes and influence the policy decisions and facilitate in identifying alternatives for practical solutions, to make policies, practices, and decisions work for people in the ground.

A number of significant activities executed for the effective implementation of Land Literacy Program after signing the MoU.

- **Land Literacy Module** is developed and is rolled-out for piloting in 13 communities from 6 local governments from Koshi, Madhesh, Lumbini and Sudurpaschim Provinces.
- **Training of Trainers** (ToT) for land literacy program was organized for 3 days, from 22 – 24 February 2024, which was a first of its kind in Nepal to equip resource persons/facilitators for land literacy trainings at community in collaboration with the government. This Training created the first cohort of 23 land literacy trainers. The participants of ToT training included land focal persons of the local governments, staffs of the partner NGOs and Habitat Nepal staffs coming from Koshi, Madhesh, Lumbini and Sudurpaschim Provinces, where land and housing issues have been intrenched and local governments are willing to join hands to address these problems.
- **Land Literacy Program Piloted** in the selected 6 local governments between March – May 2024 in 13 communities from 6 districts of Koshi, Madhesh, Lumbini and Sudurpaschim, where 6 local governments are supporting this initiative of educating communities about policies and practicalities in securing their land tenure rights and adequate housing. Summary of the program is provided in Table 1.

Table 1. Land Literacy Training : Program Summary

S.N.	Name of Local Levels/District	Number of Communities	Number of Land Literacy Participants
	Sudurpaschim Province		
1	Bedkot Municipality, Kanchanpur District	2	50
	Madhesh Province		
2	Ganeshman Charnath Municipality, Dhanusha District	3	79
3	Saptakoshi Municipality, Saptari	2	51
4	Gujara Municipality, Rauthat	2	51
	Lumbini Province		
5	Dangisharan Rural Municipality, Dang District	2	51
	Koshi Province		
6	Gadhi Rural Municipality, Sunsari	2	56
	Total number of Communities and ToT participants	13	338

In a nutshell, 338 individuals/families have participated in Land Literacy program from 13 communities of 6 local levels in 6 districts across 4 provinces.

The piloting program was concluded on 17th May 2024. To assess and evaluate the program, a review and reflection program has been conducted in Land Management Training Center, Dhulikhel on 17-21 June, 2024

List of Short-Term Trainings Conducted in Fiscal Year 2080-81

SN	Training Name	Place	Number of Trainees
1	Refreshment Training for High Level Officials Related to Land Management	LMTC	28
2	Land Administration and Management Training (Assistant Level)	LMTC	27
3	Refreshment Training on Land Administration and Management (Officer Level)	Online	430
4	Training of Trainers (TOT)	LMTC	49
5	Training on Informal Land Tenure for the Expert Member and Member Secretary of National Land Commission District Committee	LMTC	26
6	Training on Informal Land Tenure for Member Secretaries of National Land Commission District Committee	LMTC	23
7	Digital Cadastral Survey and Office Management Training (In-service Training for Amin)	LMTC	21
8	Digital Cadastral Survey and Office Management Training (In-service Training for Surveyors)	LMTC	22
9	Professional Course on Geomatics and Land Administration (In-service Training for Survey Officers)	LMTC	13
10	Orientation Training for Newly Appointed Survey Officers	LMTC	8
11	Refreshment Training for Senior Officers	LMTC	15
12	Instrument Handling and Orientation Training for Newly Appointed Assistant Level Employees	LMTC	8
13	Instrument Handling Training for Local Level	Banke	31
14	Land Administration and Instrument Handling Training (Amin/ Surveyors Working in Court and Local Level)	LMTC	22
15	Orientation training for Honorable District Judges	Bhaktapur	19
16	GIS Training for Local Level	Dang	22
17	GIS Training for Local Level	Lamjung	13
18	GIS Training for Local Level	Panchthar	21
19	Basic GIS Training	LMTC	23
20	Advanced GIS Training	LMTC	22
21	Digital Cadastre / NeLIS Training	LMTC	13
22	Basic Remote Sensing Training	LMTC	20
23	Land Use/Land Management Training for Local Level	Makwanpur	23
24	Land Use/Land Management Training for Local Level	Sunsari	22
25	Land Use/Land Management Training for Local Level	Jhapa	24
26	Land Use/Land Management Training for Local Level	Baglung	20

Calendar of Major Geoinformatics Events

1 **FIG Working Week 2024**
Date: 19-24 May, 2024
Place: Accra, Ghana
Website: https://www.fig.net/fig2024/

2 **ISPRS TC II Mid-term Symposium on 'The Role of Photogrammetry for a Sustainable World'**
Date: 11-14 June, 2024
Place: Las Vegas, Nevada, USA
Website: https://www.isprs.org/tc2-symposium2024/index.html

3 **BUCEA International Summer School on Smart Cities 2024**
Date: 14-22 July, 2024
Place: Beijing, China
Website: https://english.bucea.edu.cn/Admission/SummerSchool/

4 **ESRI User Conference**
Date: 15-19 July, 2024
Place: San Diego, California
Website: https://www.esri.com/en-us/about/events/uc/

5 **ESA-JRC International Summer School on GNSS 2024**
Date: 15-26 July, 2024
Place: Novo Mesto, Slovenia
Website: https://www.esa-jrc-summerschool.org/

6 **ISPRS TC V Mid-term Symposium on 'Insight to Foresight via Geospatial Technologies'**
Date: 6-8 August, 2024
Place: Manila, Philippines
Website: https://philsa.gov.ph/news/philippines-set-to-host-isprs-in-2024/

7 **ION GNSS+ 2024**
Date: 16-20 Septermber, 2024
Place: Baltimore, USA
Website: https://www.ion.org/gnss/

8 **12th International FIG Workshop on the Land Administration Domain Model & 3D Land Administration**
Date: 24-26 September, 2024
Place: Kuching, Malaysia
Website: https://gdmc.nl/3DCadastres/workshop2024/

9 **InterGEO Conference**
Date: 24-26 September, 2024
Place: Stuttgart, Germany
Website: https://www.intergeo.de/en/

10 **ISPRS WG III/7: International Symposium on Geomatics, Remote Sensing, and Climate Change in the Arctic, Antarctica, and High Mountain Asia**
Date: 25-27 September, 2024
Place: Shanghai, China
Website: https://tripolar-rs.tongji.edu.cn/

11 **ISPRS WG II/8: International Workshop on "Photogrammetric Data Analysis"**
Date: 07-09 October, 2024
Place: Moscow, Russia
Website: http://technicalvision.ru/ISPRS/PDA24

12 **ISPRS TC IV Mid-term Symposium on 'Spatial Information to Empower the Metaverse'**
Date: 22-25 October, 2024
Place: Perth, Australia
Website: https://www.isprs.org/tc4-symposium2024/index.html

13 **International Association of Geodesy Workshop on Asia Pacific Gravity, Geoid, and Vertical Datums**
Date: 06-08 November, 2024
Place: Manila, Philippines
Website: https://iagworkshop2024.dge.upd.edu.ph/

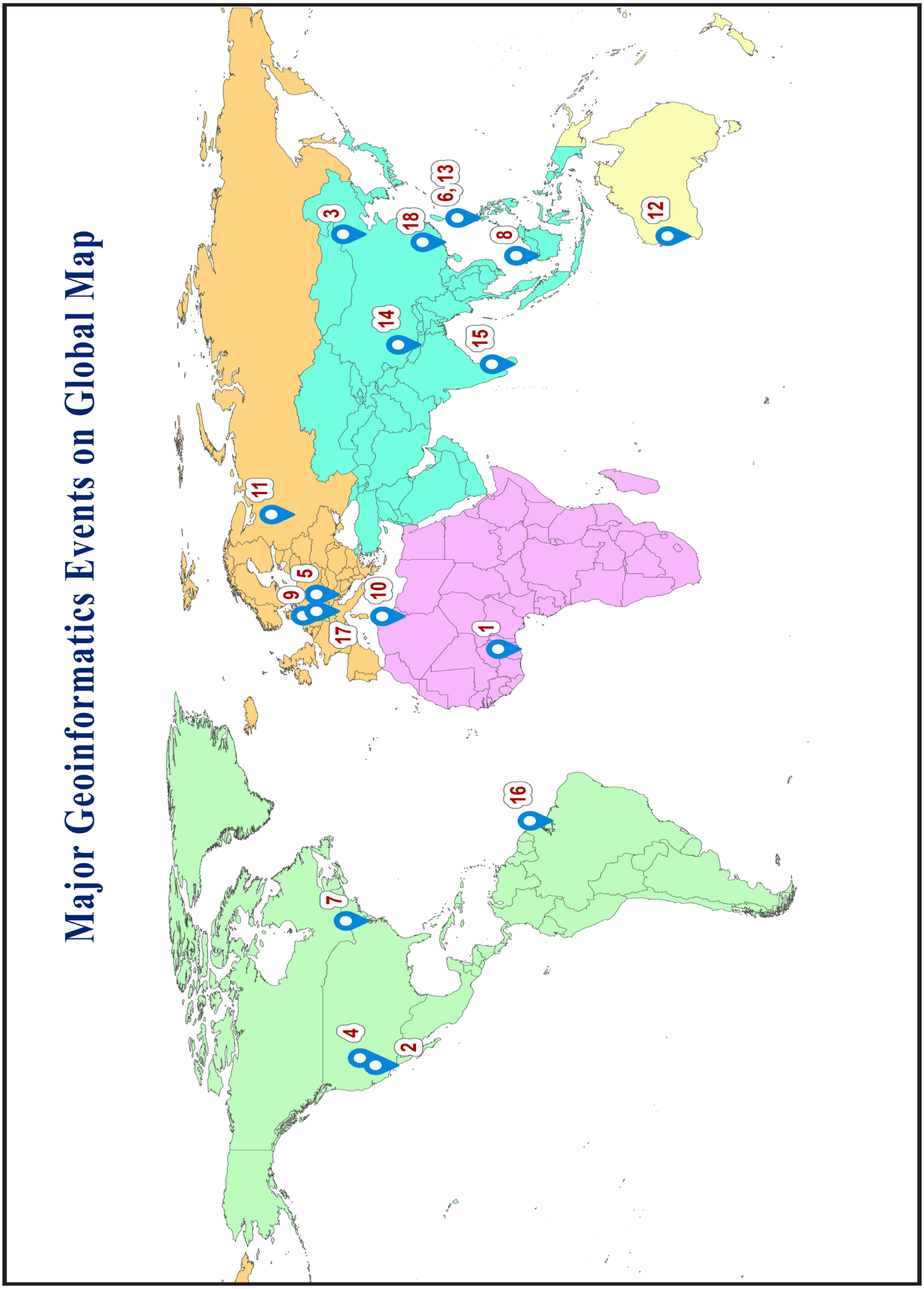
14 **FIG Regional Conference 2024**
Date: 14-16 November, 2024
Place: Kathmandu, Nepal
Website: www.fig.net/nepal2024/

15 **45th Asian Conference on Remote Sensing**
Date: 17-21 November, 2024
Place: Colombo, Sri Lanka
Website: https://www.survey.gov.lk/acrs2024/

16 **FOSS4G 2024**
Date: 01-08 December, 2024
Place: Belém, Brazil
Website: https://www.osgeo.org/events/foss4g-2024-belem-brazil/

17 **ISPRS WG II/3: 8th International ISPRS Workshop on LowCost 3D - Sensors, Algorithms, Applications**
Date: 12-13 December, 2024
Place: Brescia, Italy
Website: https://lc3d.fbk.eu/

18 **First Asian Cartographic Conference AsiaCarto 2024**
Date: 8-10 December, 2024
Place: Hong Kong, China
Website: https://asiacarto.org/2024/


Major Geoinformatics Events on Global Map
1
2
3
4
5
6, 13
7
8
9
10
11
12
14
15
16
17
18

Major Programs Planned for Year 2081/82

SN	Program	Planned Month	Venue
1.	Training of Trainers	Shrawan	LMTC Premises
2.	Refreshment Training for High-Level Officials Related to Land Management	Shrawan	LMTC Premises
3.	Orientation Training for Newly Recruited Survey Officers	Bhadra-Mangsir	LMTC Premises
4.	Professional Course on Geomatics and Land Administration (In-service Training for Survey Officers)	Bhadra	LMTC Premises
5.	Digital Cadastral Survey and Office Management Training (In-service Training for Amin)	Bhadra	LMTC Premises
6.	Digital Cadastral Survey and Office Management Training (In-service Training for Surveyors)	Bhadra	LMTC Premises
7.	Total Station Calibration Training for Team Leaders of Survey Team	Bhadra	LMTC Premises
8.	Training on Cadastral Surveying and Mapping and Land Registration for Technical Employees Working in Survey Offices	Bhadra	LMTC Premises
9.	Basic Map Reading Training for Employees of Kavrepalanchok District	Ashwin	LMTC Premises
10.	Land Use/Land Management Training for Local Level	Ashwin	Local Level
11.	Basic Remote Sensing Training	Ashwin	LMTC Premises
12.	GIS Training for Local Level	Ashwin	Local Level
13.	Orientation Training on Informal Land Tenure for Officials of the National Land Commission	Ashwin	LMTC Premises
14.	Basic Map Reading Training for School-Level	Ashwin	Schools
15.	Training on Cadastral Survey and Land Registration for Technical Employees Working in Informal Land Tenure Management	Kartik	LMTC Premises
16.	Orientation Program for District Judges	Kartik	LMTC Premises
17.	Training on Cadastral Surveying and Mapping and Land Registration for Technical Employees Working in Survey Offices	Mangsir	LMTC Premises
18.	Land Use/Land Management Training for Local Level	Poush	Local Level
19.	GIS Training for Local Level	Poush	Local Level
20.	Training on Cadastral Survey and Land Registration for Technical Employees Working in Informal Land Tenure Management	Poush	LMTC Premises
21.	Orientation Training on Informal Land Tenure for Officials of the National Land Commission	Magh	LMTC Premises
22.	GIS Training for Local Level	Falgun	Local Level
23.	Instrument Handling and Orientation Training for Newly Recruited Assistant-Level Employees of Survey Group	Falgun	LMTC Premises
24.	Training on Surveying and Mapping/Land Administration for Employees Working in Court	Falgun	LMTC Premises
25.	Advanced Remote Sensing Training	Chaitra	LMTC Premises
26.	Instrument Handling Training for Local Level	Chaitra	LMTC Premises
27.	NeLIS Training	Chaitra	LMTC Premises
28.	Land Administration and Management Training for officer-level Employees Working in Land Revenue Offices	Chaitra	
29.	Training on Cadastral Surveying and Mapping Using GNSS and UAV	Baisakh	LMTC Premises
30.	Land Administration and Management Training for Assistant-level employees Working in Land Revenue Offices	Baisakh	LMTC Premises
31.	Basic Land Literacy Training for Local Level	Baisakh	LMTC Premises
32.	Basic GIS Training	Baisakh	LMTC Premises
33.	Training on the Application and Processing of LiDAR Data	Jestha	LMTC Premises
34.	NeLIS Training	Jestha	LMTC Premises
35.	Basic Map Reading Training for School-Level	Jestha	Schools

Articles Published in Previous Editions

Volume IV (Published in 2079 B.S)

Volume V (Published in 2080 B.S.)

GOVERNMENT OF NEPAL

MINISTRY OF LAND MANAGEMENT, COOPERATIVES AND POVERTY ALLEVIATION

LAND MANAGEMENT TRAINING CENTER

Dhulikhel, Kavrepalanchok

INTRODUCTION

Land Management Training Center (LMTC), under the Ministry of Land Management, Cooperatives and Poverty Alleviation, Government of Nepal was established in 1968. LMTC is the oldest and the only governmental institution continually and significantly producing human resources and enhancing the capacity of government personnel in the field of Surveying Mapping, and Land Management since its establishment. The center has already produced more than 10,000 land professionals at different levels through various types of training courses.

LMTC is certified with ISO 9001:2015 for Quality Management on 29 June 2022 A.D. The center has been conducting a wide range of long and short-term training incorporating state-of-the-art modern technologies. Along with this, LMTC has collaborated to run academic courses with Kathmandu University (KU). Additionally, the Center contributes to the capacity building of Provincial and Local Governments.

VISION

To be the Center of Excellence in Land Management and Geomatics Education.

MISSION

Building and Enhancing Individual and Institutional Capacity in Land Management and Geomatics Sector.

GOAL

To produce qualified and skilled human resources in the field of Land Management and Geomatics.

OBJECTIVES

- To conduct various professional courses.
- To carry out Pre-service and In-service Training, Refresher courses, and Orientation programs.
- To collaborate with national and international academia and professional organizations.
- To promote Research and Development
- To support provincial and local governments in developing qualified human resources.

OUR FACULTIES/TRAINERS

Our courses are delivered by passionate and dedicated faculties/trainers who possess wealth of national and international experiences, and high qualification obtained from renowned national and international universities.

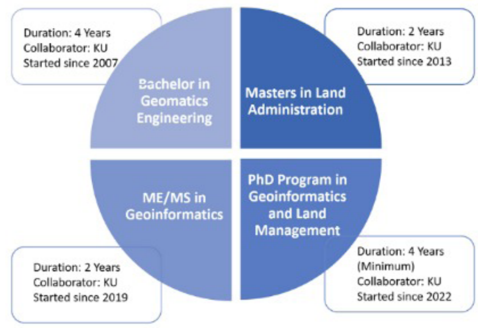
ANNUAL PUBLICATION

JOURNAL OF LAND MANAGEMENT AND GEOMATICS EDUCATION

OFFICIAL WEBSITE

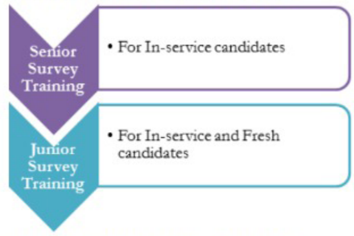
www.lmtc.gov.np

ACADEMIC COURSES (In Collaboration)



TRAINING COURSES

LONG TERM TRAININGS



SHORT TERM TRAININGS

FUTURE PLANS

- To contribute in Policy Research in the sector of Geomatics and Land Management
- To contribute to capacity Building of Local Governments in the sector of Geomatics and Land Management
- To extend collaboration with academia and regional training institutions

Government of Nepal

Ministry of Land Management, Cooperatives and Poverty Alleviation

LAND MANAGEMENT TRAINING CENTER

ACHIEVEMENT OF FY 2080/81

NOVEL SUCCESSES

Achievements of 2080/81

- Successfully conducted 4 Episodes of Lecture of the Month Series
- Conducted Computer Based Entrance Exam for Junior Survey Training (Inservice) for the First Time
- Residential Training of Trainers (TOT) for capacity building of LMTC Staff
- Refresher Course for High Level Officials Working in the field of Land Management
- Conducted Three days' Workshop on "Effective Land Administration in Nepal: Navigating Governance, Legal and Financial Pathways within the Climate Change - Land Nexus" in Collaboration with UN Habitat, and Global Land Tool Network and Kadaster (The Netherlands)
- Conducted Training of Trainers for Land Literacy in Collaboration with Community Self-reliance Centre, and Habitat for Humanity International Nepal

TRAININGS LAUNCHED THIS FISCAL YEAR

GIS Training for Local Level	56
Training for District Judges	19
Instrument Handling & Orientation	61
Land Use/Land Management	89
Informal Land Tenure Training	49

ADDITIONAL CAPACITY BUILDING SHORT TRAININGS

- Digital Cadastre (13)
- Orientation Training for New Officers (8)
- Remote Sensing (20)
- Land Administration & Management Gazetted Class III (430)
- Land Administration & Management Non-Gazetted (27)

LONG TERM TRAININGS

- Senior Survey Training Inservice (23)
- Junior Survey Training Fresh (24)
- Junior Survey Training Inservice (24)

INSERVICE TRAINING GRANTING 2 POINTS

Professional course on Geomatics & Land Administration (Gazetted Class III)	13
Digital Cadastre & Office Management Training (Non-Gazetted Class I)	22
Digital Cadastre & Office management Training (Non-Gazetted Class II)	21

SALIENT FEATURES

MOU with Community Self-reliance Centre and Habitat for Humanity International Nepal for conducting Land Literacy Trainings

The figures in the parenthesis are the numbers of trainees

Photo Gallery

55th Anniversary of LMTC

Inaguration of International Workshop on Effective Land Administration in Nepal Navigating Governance, Legal and Financial Pathways within the Climate Change-Land Nexus

Executive Director Mr. Janak Raj Joshi and Former Executive Director Mr. Ganesh Prasad Bhatta on Welcome and Farewell Ceremony of Each Other

Survey Literature Assembly - 2080

Junior Survey Training (Fresh) Batch 2080-81 with Executive Director, Coordinator and Assisstant Coordinator

Junior Survey Training (Inservice) Batch 2079-80 with Executive Director, Coordinator and Assisstant Coordinator

Honourable Minister Mr. Balram Adhikari with LMTC Family

Participants of GIS Training for Local Level-Dang

Participants of Informal Land Tenure Training for Member Secretaries of District Committee

Senior Survey Training Batch 2080-81 with Executive Director, Coordinator and Assisstant Coordinator

Participants of Inservice Training for Survey Officers

Participants of Basic Remote Sensing Training

Participants of Advanced GIS Training

Participants of NeLIS-Digital Cadastre Training

Participants of Orientation Training for Honourable District Judges

LMTC Visit of Senior Executive Development Program along with High Level Officials from Nepal Administrative Staff College

Participants of Land Use-Land Management Training for Local Level at Makwanpur

Participants of Land Administration and Instrument Handling Training

Graduate Students of University of Southern Queensland Conducting Field Survey at LMTC Premises

Graduation Cremony of Junior Survey Training (Inservice) Batch 2079-80

Junior Survey Training (Inservice) Computer Based Entrance Examination - 2081

Trainees of Junior Survey Training (Fresh) Conducting Plane Table Survey at Lumsalbesi

High Level Officials from Ministry, Executive Director, Directors and Instructors at Field Camp

Executive Director Mr. Janak Raj Joshi During Field Inspection and Viva

Participants of Lecture of The Month Episode 2

LMTC Ladies Staff Team Celebrating Victory After Winning Ladies Futsal Competition in Sports Event 2081

LMTC Staff on Sports Event 2081

LMTC Family