ISSN : 2717 - 5022

JOURNAL ON GEOINFORMATICS

Nepal

Number: 20 **Jestha 2078 (June/July, 2021)**

8848.86M

Inauguration of Online Service Delivery "Mero Kitta" by Hon Prime Minister

Joint announcement of height of Sagarmatha from Nepal and China

Hon Minister Inagurating LiDAR Survey

Annual Publication of Survey Department, Government of Nepal

Director General of Survey Department, Mr. Prakash Joshi welcoming Rt. Hon. Prime Minister of Nepal Mr. K.P. Sharma Oli at the Department.

Rt. Hon. Prime Minister Mr. K.P. Sharma Oli handing over the cadastral map printed from the service received through the online system "MeroKitta" during its inauguration.

Hon. Foreign Minister Mr Pradeep Kumar Gyawali giving his speech during the joint announcement of the height of Mt Sagarmatha between Nepal and China

Director General Mr. Prakash Joshi presenting on the methodology of height measurement adopted by Nepal during the joint announcement of the height of Mt Sagarmatha between Nepal and China

Group of surveyors involved in height measurement program, felicitated from Survey Department in presence of Hon. Minister and Secretary of Ministry of Land Management, Cooperatives and Poverty Alleviation during joint announcement of height of Mt. Sagarmatha

Journal on Geoinformatics
Nepal

Number : 20

Jestha 2078 BS
June/July 2021 AD

Annual publication of Survey Department, Government of Nepal

The content and the ideas of the articles are solely of authors.

Published by:
Government of Nepal
Ministry of Land Management,
Cooperatives & Poverty Alleviation
Survey Department
Min Bhawan, Kathmandu
Nepal

No. of copies : 500

नेपाल सरकार
Government of Nepal
मा. डा. शिवमाया तुम्बाहाङफे
मन्त्री
भूमि व्यवस्था, सहकारी तथा गरिबी निवारण
फोन नं. : ४२००५७५
फ्याक्स नं. : ४२११६४५
सिंहदरवार, काठमाडौं, नेपाल
Hon.Dr. Shiva Maya Tumbahangphe
Minister
Land Management, Cooperatives and Poverty Alleviation
Website:www.shivamaya.com.np
Email: sm.tumbahangphe@nepal.gov.np
shivamaya2074@gmail.com

Message from the Minister

Survey Department, since its 64 years of establishment, has been working in the field of Surveying and Mapping activities, and also working as National Mapping Organization of Nepal. Department is working in the field of cadastral survey, topographical mapping, geodetic survey, establishment of geographic information infrastructure, technical support in international boundary survey and other surveying and mapping related activities. Since its establishment, it has come over from the very initial developments of technology in the field of surveying and mapping to the present advanced technologies. The department has gained experience in surveying & mapping from initial chain survey to present GNSS survey and working from lowest part of the country to the height part of the world. Besides these activities, the department is also publishing the journal since 19 years to share the information related to geo-information science, earth observation, surveying and mapping and today I am happy with the continuation of the publication of 20th issues of the Department's annual publication "Journal on Geo-informatics, Nepal" which is supporting in sharing information and research output in the aforementioned fields. The regular publication of this kind of enlightening production of the Department is commendable.

This year, Government of Nepal announced the height of Sagarmatha (Mt. Everest) jointly with China. Survey Department did the entire task from formulation of methodology, field survey, processing, and finalization of the height leading to the joint announcement. Strong technical teams for field activities were mobilized from the department. Group of expert surveyors were formed to conduct the processing of field data which was one of the most crucial part of whole measurement process. Finally, technical committee and steering committee were formed to conclude the measurement process and joint announcement. I would like to congratulate and thank entire team of Survey Department who were involved in the entire process.

Survey Department also started online service delivery from the survey offices at the district from this year. "Nepal Land Information System (NeLIS)" and "MeroKitta" lunched by the department for the first time which is a big step towards e-governance in the sector of land administration. The program was inaugurated by Prime Minister of Nepal, which shows the priority of the government and importance of the system to enhance the efficiency of the service delivery. I expect the replication of the system from the department in all the survey offices of the country.

I believe, this kind of publication will support in information sharing regarding surveying and mapping activities, geo-informatics and will be a platform for sharing the research output, information and hence hope for contribution from researchers, academicians, professionals and any other interested organization regarding articles on geo-information, surveying and mapping for the future issues as well.

Once again, I would like to thank and congratulate entire team of Survey Department for success in measurement of height of Sagarmatha and wish for the continuous publication of this annual publication.

....

Dr. Shiva Maya Tumbahangphe
Minister,
Ministry of Land Management, Cooperatives and Poverty Alleviation
Government of Nepal

Government of Nepal
Ministry of Land Management, Cooperatives and Poverty Alleviation
(..)

Phone No.: 4211666
4212632
4211843
Fax: 4232262
Singhadurbar, Kathmandu

Message from the Secretary

First of all, I would like to congratulate Survey Department for the continuation of its annual publication entitled "Journal on Geo-informatics, Nepal" and coming up with it's 20th issue. I feel privileged to have an opportunity to express my views on this professional annual journal being published by the national mapping agency under the ministry. I do believe that this kind of publication acts as a means to disseminate and propagate professional knowledge in the field of geo-informatics, surveying & mapping and other relevant disciplines.

I feel proud to see remarkable achievements from the department in the field of Surveying, Mapping and Geo-information system and contributing in the planning, policy making and execution of overall infrastructure development activities. I would like to acknowledge different commendable activities in geodetic infrastructure, geographical information production, landuse mapping, topographical base map update, technical support in international boundary and cadastral surveying conducted by the department. I am pleased to observe department is adopting advanced technologies in surveying and mapping field to provide efficient service delivery to the citizens. I feel enlightened that department has recently introduced the sophisticated LiDAR technology in surveying the western terai region for the first time in Nepal.

This year, Department has successfully accomplished the height measurement of the Mt. Sagarmatha and has announced jointly with People's Republic of China as an agreed height 8848.86m which is indeed a matter of huge professional pride and dignity. I feel very proud to be a part of this historical achievement by Survey Department and would like to congratulate and thank entire team of the Department. In addition, Hon. Prime Minister, K.P Sharma Oli inaugurated the 'Mero Kitta' and 'NeLIS' for the online service delivery from the survey offices. I feel so honoured to be part of this landmark event as well. I am confident that, this system will enhance the efficiency and transparency in the cadastral service delivery. I believe this online system will be implemented in all the survey offices of the country in earliest possible date. Meanwhile, I would like to assure my full support from the Ministry to all positive initiatives undertaken by the department in the capacity of Secretary of Ministry.

Finally, I would like to strongly recommend all professionals in the field of Surveying, Mapping and Geo-information to gain benefits from the articles of the journal. I honestly would like to appreciate the valuable efforts made by Advisory Council and Editorial Board of this journal to bring out this 20th issue of "Journal on Geo-informatics, Nepal" and wish every success for the continuation of this publication in future, as well.

Thank you and enjoy reading.

....
Tek Narayan Pandey
Secretary
Ministry of Land Management, Cooperatives and Poverty Alleviation
Government of Nepal

FOREWORDS

Survey Department has come with the 20th issues of its annual publication at this stage of sixty-four years of establishment of the Department. I would like to congratulate entire staffs of the department and personnel who have contributed for the betterment of the Department. I am delighted to put few words in this issue of the journal. To start with the major activities of the Department, it is continuously contributing in Land Administration services through its district level offices to the citizens, providing technical support in international boundary, generating geo-information services, geodetic control strengthening and other surveying & mapping activities. As a National Mapping Organization of Nepal, the Department is continuously contributing in the sector of Surveying, Mapping, Geo-information Science and Earth Observation, which are very much crucial for the planned development of the country.

Recently, Rt. Hon Prime Minister KP Sharma Oli inaugurated the online service delivery system named "MeroKitta" and Nepal Land Information System (NeLIS) developed by Survey Department to provide effective of efficient service to the citizens from the survey offices. This is the milestone and the turning point of the department in e-service delivery from Survey Offices at the district. Through this system, citizens can receive the service of map print, field book print, plot register print, request for field survey and online revenue payment and get the digital copy of map in hand without visiting the office. The service can also be received from the local level units which supports the E-land governance objective of the government. Another major achievement of the department is joint announcement of the height of Mt. Sagarmatha conducted from Kathmandu and Beijing. The jointly processed final snow height of Mt. Sagarmatha which was determined to be 8848.86m was jointly announced by Foreign ministers of both the countries by reciting the message from the president of respective countries. This has heightened the image of Survey Department in the world. I feel proud to be one of the parts of this historic event. I would like to congratulate and thank all the personnel who were involved in the height measurement program and who helped directly and indirectly to conduct the program successfully. Besides this historic task, the department has also started the LiDAR data capturing at the western Terai region of Nepal which will generate a very high resolution DEM useful for different development activities and disaster mitigation planning.

Being said that, I would like to express my sincere appreciation to the fellow colleagues, the members of Advisory Council and the Editorial Board for their invaluable contribution in this issue. The team deserves special thanks for their tireless efforts in bringing this issue in the stipulated time. More importantly, I extend sincere gratitude to all the authors for their resourceful professional contribution. I would like to request for such kind of support and professional contribution in the upcoming issues too. I am confident that this journal is proficient not only to the surveying and mapping professionals, but also to other scientific community and researchers as well.

Enjoy Reading!

Thank you!

Prakash Joshi
Director General
prakash.joshi@nepal.gov.np

EDITORIAL

The annual publication of "Journal on Geo-informatics, Nepal" has been started since 2058 BS (2002 AD). This volume is continuation of the publication which has been an important asset of the Suvery Department and playing a remarkable role in sharing information on Surveying and Mapping, Geo-information and professional knowledge, skills & expertise in this field. The journal is a platform for researcher to publish their knowledge in the field of Surveying Mapping and Geospatial technologies. The coverage of more than 100 articles upto this 20th issues are in various topics dealing with historical to latest technologies emerging in geospatial field. The 20th issue is first issue, in which the published articles are reviewed by the experts.

I would like to express sincere thanks on behalf of the Editorial Board to all those incredible authors for their contributions in the journal publication. Special thank goes to members of Advisory Council and Editorial Board of the journal for their valuable contribution.

This issue of the journal contains variety of interesting and worth reading articles on different topics related to geospatial domain. The papers included in this volume are "Analyzing Trend and Pattern of Agricultural Drought: A Case Study Of Karnali And Sudurpashchim Provinces", "Analyzing Urban Growth Pattern and Driving Factors Using Remote Sensing and GIS: A Case Study of Banepa Municipality, Nepal", "Assessing the Accuracy of Remotely Sensed Forest Maps for Nepal", "Flood Modeling Assessment: A Case of Bishnumati River", "Fusion of Radar and Optical Data for Land Cover Classification Using Machine Learning Approach", "Geo-information modeling of soil erosion for sustainable agriculture land management in Sambhunath Municipality", "Measurement of Height of Mt. Sagarmatha", "Online Service Delivery in Survey Offices: Step towards e-Land Administration" and "Preparation of High-Resolution DTM and Orthophoto Using LiDAR in Nepal".

I am thankful to Survey Department for providing me the responsibility as the Editor-in-Chief for this 20th issue of the journal. With continuous guidance and advice of Advisory Council, this Editorial Board have been able to bring this issue of the journal for readers. On behalf of all the members of the Editorial Board, I would like to express sincere thanks to all contributing authors, paper reviewers, members of Advisory Council and all others persons who have contributed for the publication of this issue of the journal.

At last, not for the least, on behalf of Editorial Board, let me humbly request all of you to contribute your valuable articles, research papers, review papers for the upcoming issue of this journal.

Karuna K. C.,
Editor-in Chief,
Jestha, 2078 (June 2021)

Advisory Council

Editorial Board

Journal on
GEOINFORMATICS
Nepal

Jestha 2078, June 2021
Number 20

Features

Contents

List of Paper Reviewer
Sudip Shrestha
Bikash Kumar Karna
Prashant Ghimire
Hari Sharan Nepal
Sanjeevan Shrestha
Mahesh Thapa
Bigyan Banjara

Contents

Contents

Analyzing Trend and Pattern of Agricultural Drought: A Case Study Of Karnali And Sudurpashchim Provinces

Naresh Bista, Dikpal Mahat, Sachin Manandhar, Binayak Regmi, Uma Shankar Panday, Shashank Karki
nareshbista9@gmail.com, abinashmahat234@gmail.com, regmibinay56@gmail.com, sacheenmdr9@gmail.com, uspanday@ku.edu.np, Shashank.karki480@gmail.com

KEYWORDS

Agricultural Drought, Drought Severity Index, DSI Map, Monitoring, Climate Change

ABSTRACT

A drought is a period of time when an area or region experiences below-normal precipitation, with characteristics and impacts that can vary from region to region. Agricultural Drought analyzes and reflects the extent of the soil moisture and morphology of crop. Deficient rainfall in the winter of 2008 resulted in a severe drop in crop production right across the country. So, there is a necessity of assessment of drought events to make informed and timely decisions. The main focus of our study is to monitor the agricultural drought in Karnali and Sudurpashchim provinces of Nepal. The condition of drought in Karnali and Sudurpashchim provinces from 2001-2020 wereanalysed with the help of Drought Severity Index. MODIS NDVI (MOD13) and MODIS ET-PET (MOD16) datasets were used to monitor and analyze the trend and pattern of agricultural drought scenario. Both datasets were then normalized for DSI calculation and the DSI result was used to monitor and to analyze the trend and pattern in the agricultural drought scenario. Further, trend and pattern analyses were performed in terms of landcover, ecological zones, and the variation of DSI. After completion of this project, we can conclude that the Maximum dryness was found in March, it might be due to less NDVI and increase in evapotranspiration rate and maximum wetness in November. Agricultural area experienced more drought variation than other landcover zones

1. INTRODUCTION

A drought is a period of time when an area or region experiences below-normal precipitation, with characteristics and impacts that can vary from region to region (Cousteau, 2020).Drought is as low-onset natural hazard with effects that accumulate over a considerable period of time (weeks to months). The frequency and intensity of extreme climate events like drought have increased significantly(WMO, 2016).Since extreme climate events tend to be more abnormal, unexpected, unpredictable, and sensitive to climate change, they are considered the main source of terrestrial ecosystem instability and have a substantial impact on sustainable development of both ecosystems and human economy (LIU, 2016).

The absence of exact and widespread definition for dry drought prompts disarray about when a dry season starts and when it ends and the exact chance to execute crisis reaction activities or relief measures(WMO, 2016).Agricultural drought is mainly concerned with water deficit in crops because of a reduction in water supply in the soil, loss of soil moisture caused by decreases in precipitation (Wilhite & Glantz, 1985).It is associated with various subjects like agriculture, meteorology, hydrology, and plant physiology and consists of both natural and artificial systems (LIU, 2016).

Although, Agricultural drought is important for reducing disaster loss and impact, it is still poorly understood. Drought is recognized as a natural hazard which occurs with varying frequency in all climatic regimes due to climatic variability (NOAA, 2019). Concerns about drought, in terms of its frequency, intensity and duration, has grown world-wide, mainly in the countries like Nepal which are vulnerable to natural and human caused disasters. The country is highly reliant upon the regular availability of water for agricultural use. Drought is most significant in western part of Nepal, where the availability of water is limited and agriculture production is reliant on rainfall. Due to which, there is a drop in production of crops and might lead to risk of food insecurity.

1.1 Problem Statement

Nepal is one among the foremost the vulnerable countries with respect to climate change, due to greater warming in recent years than that of the global average (MoHA, 2009).These conditions have created a drought condition especially for the rain-fed hill farming system, where people depend on summer and winter rainfall for their major agricultural activities (Adhikari, 2018). Due to different causes like the lack of research on suitable index, inconsistency in precipitation and the rainfall pattern, lack of real time monitoring system etc. had caused the situation worst. So, there's a necessity of timely assessment of drought events for decision making.

2. STUDY AREA

Karnali Province is one of the seven federal Provinces of Nepal with the total area of 27,984 square kilometers (WIkipedia, 2020). It has some of the most remote and economically depressed areas of the country which are vulnerable to number of disasters including drought. Some regions (Mugu, Dolpa, Humla, Kalokot, Jajarkot) are permanently food deficit and despite food supply to these regions, it differs annual food deficit at least one-fourth requirement almost every year where crop yields are very poor.

Sudurpashchim Province is also one of the seven provinces of Nepal with the total area of 19,539 square kilometers lying within the region of latitude 28°12'to 30° 28'and longitude 80° 03' to 81° 50'.Most villages are very remote and inaccessible. Agriculture is the main source of livelihood where major crops are wheat, paddy, maize, garlic, mustard etc.

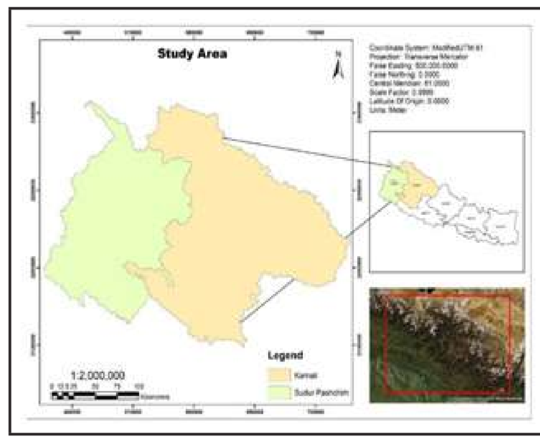

Figure 1: Study Area of Karnali and Sudurpashchim Province

3. METHODOLOGY

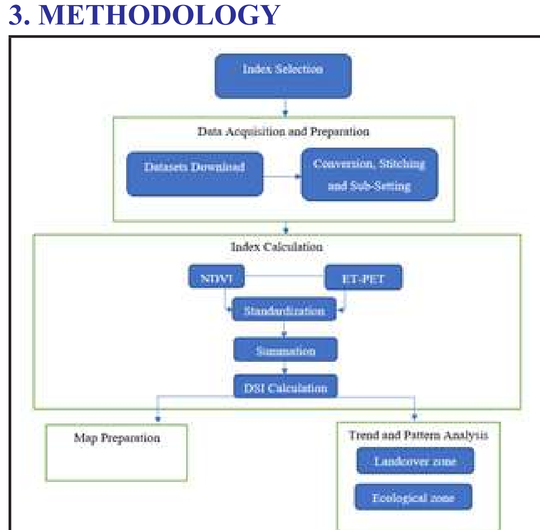

Figure 2: Workflow Diagram of Drought Monitoring

3.1 Index Selection

Drought index value is a number which is more useful than the raw information (Hayes, 2002).Drought Severity Index (DSI), which is the integration of NDVI and ET-PET was selected for the project because Drought Severity Index (DSI) can be produced at a 500m spatial resolution and can be used for a wide range of water-resource and ecological applications. DSI from NDVI and ET-PET is generally effective for characterizing moisture conditions at the province level, with better performance in rainfed-dominated than irrigation-dominated regions and it can be used for near-real-time drought monitoring with fine resolution across subtropical or other similar regions.

3.2 Data acquisition and Preparation

3.2 Datasets Download

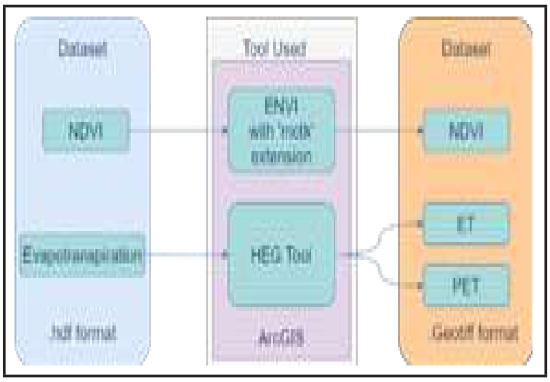

Figure 3: Data Preparation Chart

Two different datasets, MOD13 for NDVI and MOD16 for ET-PET were accessed from MODIS archives. MODIS NDVI is a global vegetation dataset for drought monitoring and trend analysis. Global monthly NDVI data was downloaded for five months (Nov- Mar) from 2000 for 20 years with Spatial and Temporal resolution of 500 m and 30 days respectively.

Similarly, MODIS ET-PET, a vegetation index, ratio of actual to potential evapotranspiration and useful for monitoring crop performance during the growing season and based upon availability of water for the crop. For MOD16, images were downloaded also with 500m and 30 days spatial and temporal resolution.

3.2.2 Data Conversion, Stitching and Sub-setting

The downloaded datasets from MODIS archives were in HDF file formats. ENVI software with MCTK extension tool was used for conversion of NDVI HDF file to Geotiff file format. Similarly, HEG tool was used to for conversion of ET-PET HDF file format to Geotiff file format. Similarly, ENVI was used for data stitching and ArcGIS was used for data sub-setting.

3.3 Index Calculation

Collected ET-PET and NDVI datasets were used to calculate a new DSI value as an index as given in chart below:

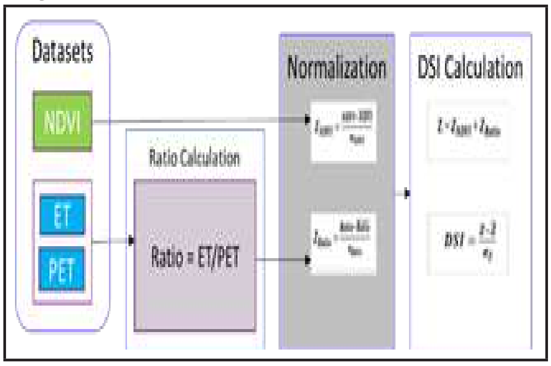

Figure 4: DSI Calculation Method

4. Trend and Pattern Analysis

Zonal statistics of DSI was calculated to get the trend and pattern with respect to landcover and ecological zones.

4.1 Landcover Zone

The obtained DSI value results were analyzed in terms of landcover change for 9-year time interval. Average DSI value were obtained for different landcover such as forest, grassland, wetland, agriculture, urban and barren land. The trend and pattern were analyzed with the help of bar plot.

4.2 Ecological zone

The obtained DSI value results were analyzed in terms of ecological study for 5-year time interval. Average DSI value were obtained for ecological zones as Mountain, Hilly and Terai. The trend and pattern were analyzed with the help of bar plot.

5. MAP PREPARATION

The output DSI was reclassified according to DSI classification referred by NASA as in table below and DSI maps of five months for 20 years were prepared.

Table 1: DSI Categorization

DSI range	Description	DSI range	Description
-1.5 or less	Extreme drought	0.3 to 0.6	Incipient Wet
-1.5 to -1.2	Severe Drought	0.6 to 0.9	Slightly Wet
-1.2 to -0.9	Moderate Drought	0.9 to 1.2	Moderately Wet
-0.9 to -0.6	Mild Drought	1.2 to 1.5	Very Wet
-0.6 to -0.3	Incipient Drought	1.5 or more	Extreme Wet
-0.3 to 0.3	Near-Normal		

Source:(US Department of Energy, 2013)

6. RESULT

6.1 DSI Map Preparation

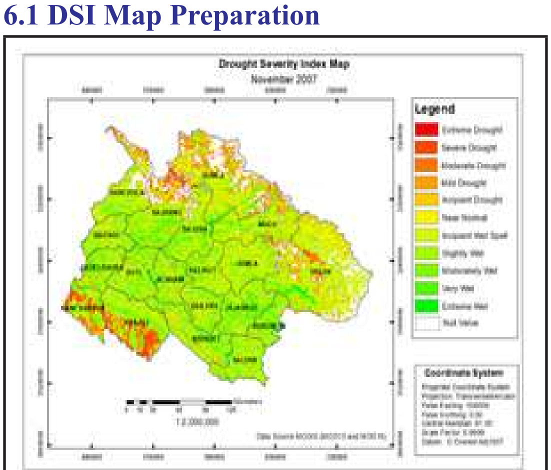

Figure 5: DSI Map of November 2007

Result shows, there is Moderate drought at some portions of Kanchanpur and Kailali. There is slightly wet condition in almost all hilly districts. Map shows some portions of Humla, Mugu and Dolpa had experienced Mild drought condition at the beginning of season. Also, the white portion on the map denotes no Value which represents snowy area.

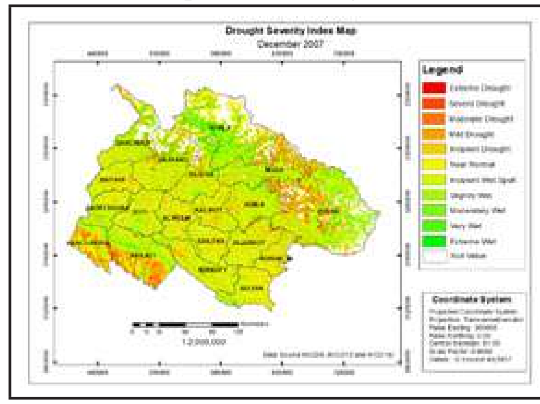

Figure 6: DSI Map of December 2007

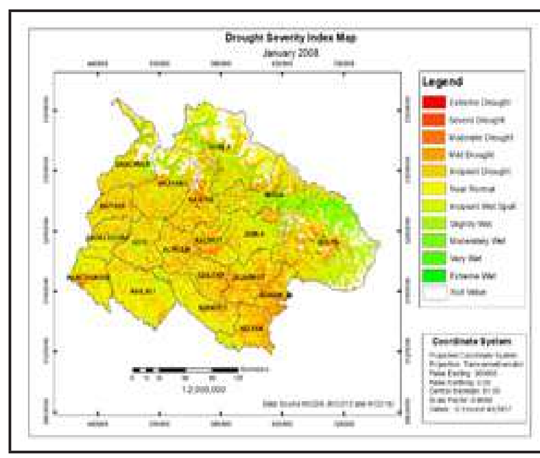

Figure 7: DSI Map of January 2008

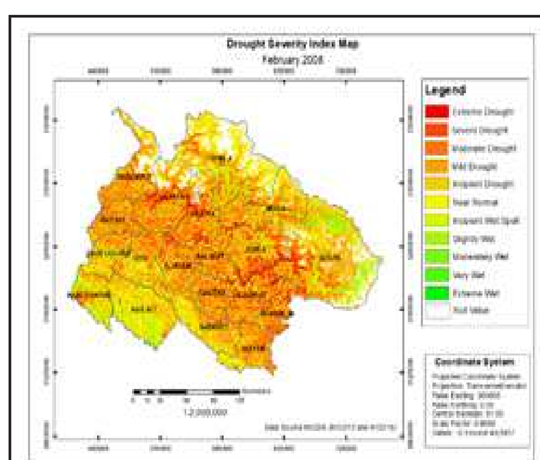

Figure 8: DSI Map of February 2008

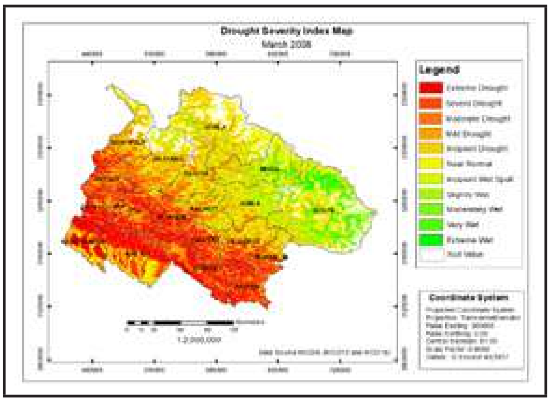

Figure 9:DSI Map of March 2008

Result shows, there was near-normal drought in almost all area in December and January. In February, there was moderate drought in hilly region and near-normal in some terai and mountain region. At the end of season, there was Extreme drought in terai area, Near-Normal in hilly region and slightly wet in Mugu and Dolpa District.

The trend of drought from November to March is decreasing from wet to extreme dry but the opposite trend in some portions of Kailali and Kanchanpur is due to wetlands where the availability of water is unpredictable.

6.2 Yearly Drought Variation

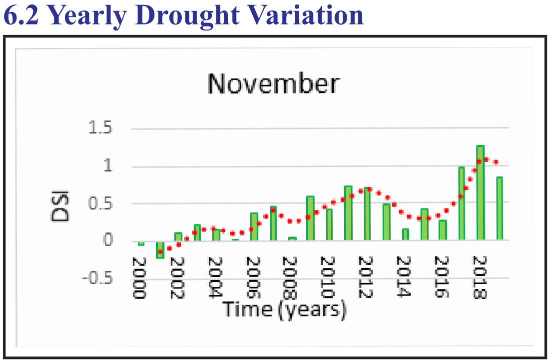

Figure 10: Bar plot of yearly variation of DSI in November

Result shows negative values in November of 2000-2001 which means there was dry condition then positive values from 2002, increasing DSI values and suddenly decreased at 2005 and 2008. From 2009, the drought condition in November at the beginning of season is wet till 2019.

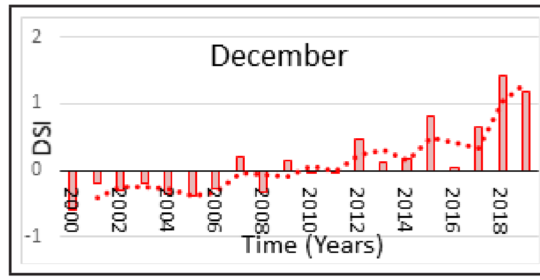

Figure 11: Bar plot of yearly variation of DSI in December

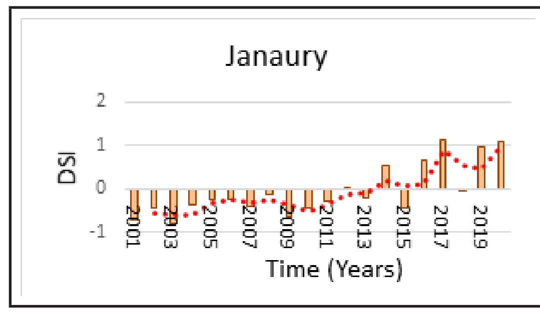

Figure 12: Bar plot of yearly variation of DSI in January

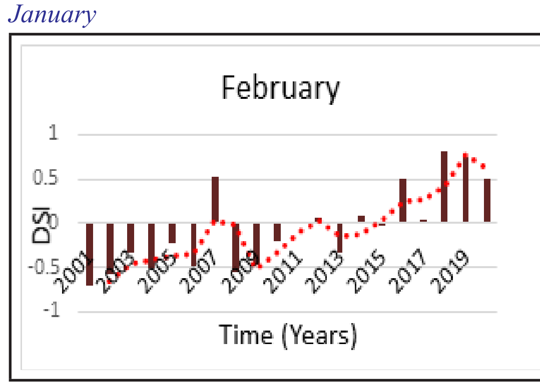

Figure 13: Bar plot of yearly variation of DSI in February

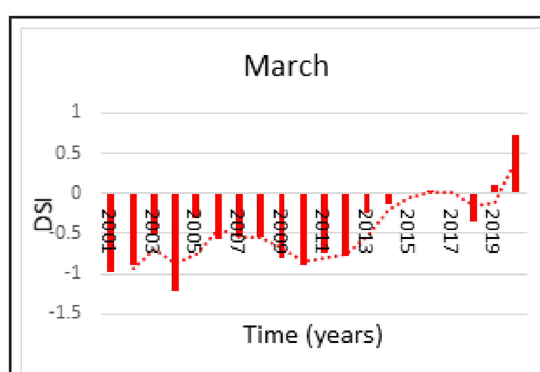

Figure 14: Bar plot of yearly variation of DSI in March

In December, there was dry condition from 2001 to 2008 and wet condition from 2009 to 2020 and the highest value was in 2018. Results show negative values from 2001 to 2010 and positive values from 2011 to 2020 in January and in February, there are negative values from 2001 to 2011 and positive values from 2012 to 2020. In March, all year except 2015, 2016, 2017, 2019 and 2020 have negative values and there is highest value in 2020.

Results show Minimum DSI value in March 2004 (Severe Drought), Maximum DSI value in December 2018 (Very Wet) and November experiences wetness in average and March experiences dryness in average.

There are great deviations in the drought in the season of the year 2004, 2006, 2008, and 2009 from 2000-2020 in which the drought condition was worse than in other year. The result coincides with the fact that the season of year 2006, 2008 and 2009 was the worst of all seasons.

6.3. Trend and Pattern Analysis

6.3.1 Landcover Study

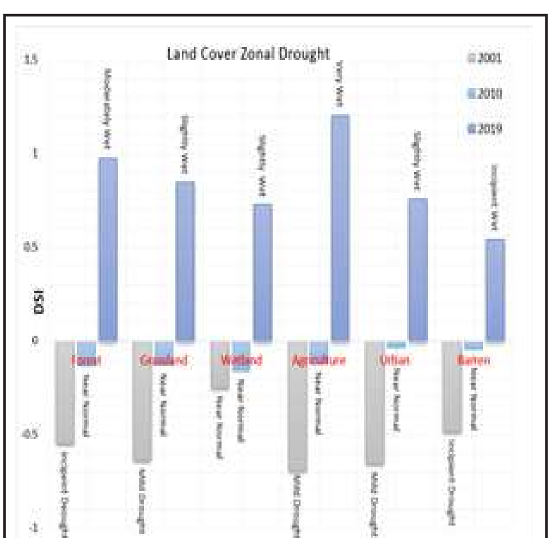

Figure 15: Bar plot of DSI with Landcover zones

The map results show that in year 2001, the lowest drought index value is in agricultural lands that is agricultural lands had experienced high drought conditions than other lands. Comparatively, forest and Barren lands had experienced low drought than urban and grasslands. The result show there is low drought in wetlands than other lands.

The result shows the lowest DSI value in wetlands which means wetlands had experienced extreme drought. After wetlands, the high drought condition is in forest, grasslands and agricultural lands respectively. In the season of 2019, DSI value is in agricultural lands which means agricultural lands had experienced severe wet condition in 2019 due to decrease in mean surface temperature causing wetness after 2010.

In year 2001 and 2010, average DSI value is negative but in the season of 2019 average DSI value is positive which is due to the availability of water resources, lower temperature. The maximum change in DSI value is in Agricultural area (From -0.6926 in 2001 to 1.2065 in 2020).

6.3.2 Ecological study

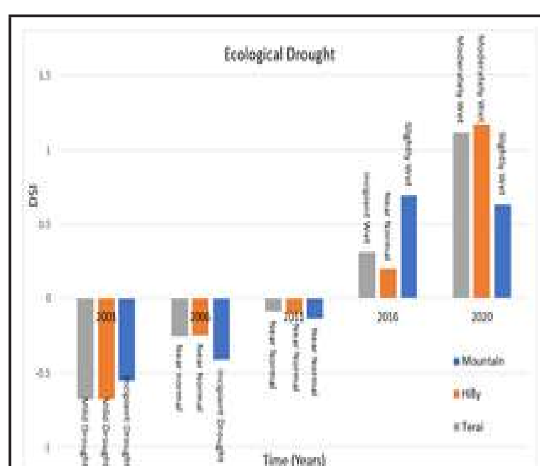

Figure 16: Bar plot of DSI with Ecological zones

As result shows, in 2001 lowest mean DSI value is in hilly region and Mountain region has the highest mean DSI value which means comparatively better condition in mountain region than others. As shown, in 2006 mountain region has the lowest negative and hilly region has the highest negative DSI value than other regions.

Result shows in the season of 2011 lowest negative DSI value is in mountain region and highest in terai region that means terai region experienced better drought condition than other regions. Also, in the season of 2016, highest positive DSI value in mountain region and lowest positive in hilly region which means hilly region had experienced worst drought condition than other regions. Similarly, in the year of 2019, lowest DSI value is in mountain region and highest in hilly region which means mountain region had experienced worst drought condition.

7. CONCLUSION

This study discussed the condition of drought in of Karnali province and Sudurpashchim province from 2001- 2020 with the help of Drought Severity Index.

Result shows the maximum change in DSI value from Land Cover study in Agricultural area (-0.692632 (2001) to 1.206597 (2020)). Since land use in Agricultural area changes in different time of year according to the stage of the plant from vegetation to cutting stage which changes the NDVI value of the given region. From ecological study, results showed the highest positive DSI value in mountain region and lowest positive in hilly region which means hilly region had experienced worst drought condition than other regions. Furthermore, result showed that year 2008 had faced the worst drought in given 20 years.

REFERENCES

Adhikari, S. (2018). Drought Impact and Adaptation strategies in the Mid-Hill Farming system of Western Nepal.

Cousteau, A. (2020). *Education*. Retrieved from National Geographic: https://www.nationalgeographic.org/encyclopedia/drought/

Hayes, M. (2002). Drought Indices. *International Journal of Climatology*, p. 18.

LIU, X. (2016). Agricultural drought monitoring: Progress, challenges, and. *Journal of Geographical Sciences* .

MoHA, M. o. (2009). Nepal Disaster Report.

NOAA. (2019). *Climate Monitoring*. Retrieved from National Centres For Environmental Information : https://www.ncdc.noaa.gov/monitoring-references/dyk/drought-definition

US Department of Energy. (2013). A Remotely Sensed Global Drought Severity Index. 361. Retrieved from http://digitalcommons.unl.edu/usdoepub/361

WIkipedia. (2020). *Economy of Nepal*. Retrieved from Wikipedia, the free encyclopedia: https://en.wikipedia.org/wiki/Economy_of_Nepal#:~:text=Agriculture%20remains%20Nepal's%20principal%20economic,and%20providing%2031.7%25%20of%20GDP.

Wilhite, D., & Glantz, M. (1985). Understanding the Drought Phenomenon: The Role of Definitions. *Water International*, 111-120. Retrieved from National Drougght Mitigation Center.

WMO, W. M. (2016). National Drought Policies.

ACKNOWLEDGEMENT

We, Sachin Manandhar, Naresh Bista, Binayak Regmi, Abinash Mahat would like to express our great gratitude towards the Survey Department of Nepal for considering our paper to publish in the Journal of Survey Department. Furthermore we are grateful towards our supervisor Asst.Prof. Uma Shankar Panday and Er. Shashank Karki, Department of Geomatics Engineering, Kathmandu University for their constant guidance, advice and every possible help. Without them this project had not been possible to be completed. Furthermore we are also grateful towards our Mr. Shangharsha Thapa for suggesting and providing insights during our project.

Nevertheless, we would like to thank our colleagues, family and everyone who helped us to their maximum extent for making this project a success. Their support and guidance played a vital role. We convey our finals thanks to all our friends with whom, we had privilege of interacting and working for the completion of the project.

Author's Information

Name	:	Sachin Manandhar
Academic Qualification	:	BE in Geomatics Engineering
Organization	:	Kathmandu University
Current Designation	:	Web GIS Developer at Pathway Technologies and Services
E-mail	:	sacheenmdr9@gmail.com

Analyzing Urban Growth Pattern and Driving Factors Using Remote Sensing and GIS: A Case Study of Banepa Municipality, Nepal

Rabina Twayana, Sijan Bhandari, Reshma Shrestha
rabinatwayana123@gmail.com, sijanbhandari12@gmail.com, reshma@ku.edu.np

KEYWORDS

Urban Growth, Driving Factors, Analytical Hierarchy Process (AHP)

ABSTRACT

Nepal is considered one of the rapidly urbanizing countries in south Asia. Most of the urbanization is dominated in large and medium cities i.e., metropolitan, sub-metropolitan, and municipalities. Remote Sensing and Geographic Information System (GIS) technologies in the sector of urban land governance are growing day by day due to their capability of mapping, analyzing, detecting changes, etc. The main aim of this paper is to analyze the urban growth pattern in Banepa Municipality during three decades (1992-2020) using freely available Landsat imageries and explore driving factors for change in the urban landscape using the AHP model. The Banepa municipality is taken as a study area as it is one of the growing urban municipalities in the context of Nepal. The supervised image classification was applied to classify the acquired satellite image data. The generated results from this study illustrate that urbanization is gradually increasing from 1992 to 2012 while, majority of the urban expansion happened during 2012-2020, and it is still growing rapidly along the major roads in a concentric pattern. This study also demonstrates the responsible driving factors for continuous urban growth during the study period. Analytical Hierarchy Process (AHP) was adopted to analyze the impact of drivers which reveals that, Internal migration (57%) is major drivers for change in urban dynamics whereas, commercialization (25%), population density (16%), and real estate business (5%) are other respective drivers for alteration of urban land inside the municipality. To prevent rapid urbanization in this municipality, the concerned authorities must take initiative for proper land use planning and its implementation on time. Recently, Nepal Government has endorsed Land Use Act 2019 for preventing the conversion of agricultural land into haphazard urban growth.

1. INTRODUCTION

1.1 Background

Urban growth is defined as the physical and functional changes in the urban landscape (Thapa & Murayama, 2010). Nepal is considered one of the rapidly urbanizing countries in south Asia (Devkota, 2018). According to Muzzini & Aparicio (2013), the average urban population growth rate of Nepal is about 6 % per annum since the 1970s. Most of the urbanization is dominated in large cities i.e., metropolitan and sub-metropolitan cities, and medium cities i.e. municipalities (Bakrania, 2015). Various factors are responsible for the rapid urbanization in Nepal. According to Thapa and Murayama (2010), physical topography, services accessibility, economic opportunities, land market, bombing in real estate market, population growth, existing plans and policies related to the urban governance, etc. are the major driving factors for urban landscape change in Nepal. Growing urbanization in Nepal has also affected the social, economic, environmental, cultural aspects of various regions of Nepal (Ishtiaque, Shrestha, & Chhetri, 2017). In addition to this, growing urbanization has caused various problems in urban regions such as; overcrowding, housing problems, unemployment, development of slums, water and sanitation, poor health and spread of diseases, traffic congestion, urban crime, etc. (Rinkesh, 2019). Thus, proper urban planning and implementation approaches/ technologies must be adopted to eradicate the negative impacts of urbanization.

With the development of advanced geospatial technologies, it has fetched huge applications in the domain of Urban land governance. The use of Remote Sensing and Geographic Information System (GIS) technologies in the sector of urban land governance is growing day by day due to its capability of mapping, analyzing, detecting changes, etc. Using the spatial multi-temporal remotely sensed satellite images, provides a unique perspective to analyze how urban cities are evolving (Stefanova & Ramseyc, 2001). In addition to this, remote sensing is specifically used for classifying the various urban regions such as; agriculture, built-up, barren, water bodies, etc. Furthermore, GIS is specifically used for data spatial and non-spatial data management, mapping, surveying, etc.

The study on urban growth patterns is important to understand to control hazard and unplanned growth. Using the latest geospatial technologies helps in analyzing the urban dynamics pattern spatially and temporally which supports the formulation and implementation of urban planning model to achieve sustainable urban land governance.

1.2 Objectives

The main objective of this paper is to analyze the urban growth pattern in Banepa Municipality from the past three decades (1992-2020) using Landsat imageries and explore driving factors for change in the urban landscape using the AHP model.

1.3 Study Area

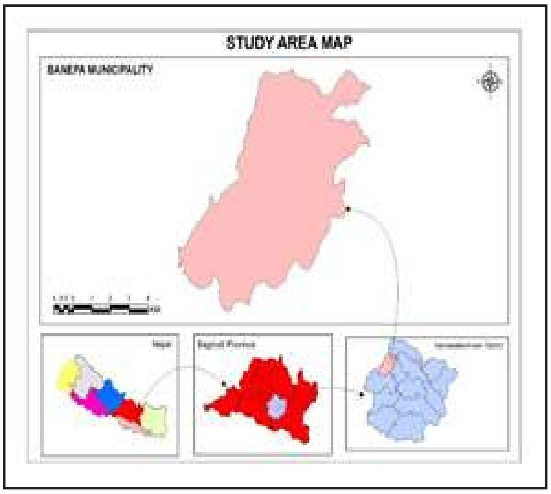

Figure 1: Study Area Map

The Banepa municipality is considered as one of the growing urban municipality in the context of Nepal due to commercial hub, accessibility of highways and urban roads, the attraction of tourists to religious and historical sites, hospital services, educational facilities, etc. It is located at 27°38′ N and 85°31′ E and lies at 1500m above the sea level. It has an area of approximately 55 km2 which consists of 14 administrative wards (Ministry of Federal Affairs and General Administration, 2017). According to the Central Bureau of Statistics, the population of this municipality was 55, 628 having a population density of 10,000/ km2. based on the 2011 census.

1.4 Data Used

Table 1: Characteristics of Acquired Image Data

Data Type	Acquisition Date	Band	Resolution	Source
LandSat5 TM	29 Mar 1992	Multispectral	30m	USGS
LandSat7 TM	02 Apr 2002	Multispectral	30m	
LandSat7 ETM+	12 Apr 2012	Multispectral	30m	
LandSat8 OLI	4 Apr 2020	Multispectral	30m	

Table 1 describes the characteristics of acquired satellite imagery data from the USGS website. The main reason for choosing this acquisition date is due to the availability of the google earth imageries (2002, 2012, 2020) and Topo-Sheets data (1992) of the study area to perform an accuracy assessment of the classified images.

2. METHODOLOGY

2.1 Satellite Images Acquisition and Pre-processing:

Initially, freely available satellite images were acquired from the United States of Geological Survey (USGS) website of the respective year; 1992,2002,2012, and 2020. Then, consecutive operations i.e., Radiometric calibration, FLASH atmospheric correction, and geometric correction were carried out in ENVI software. In radiometric calibration, DN's of acquired satellite imageries are converted into radiance and then obtained radiance values are again converted into Top of Atmosphere (TOA).
FLASH is the atmospheric correction method that corrects wavelength in the visible through near-infrared and short-wave infrared regions to decrease the influence of scattering and absorption of an atmospheric molecule on object reflectance. FLASH was selected over other methods since it considers different atmospheric parameters such as visibility, aerosol types, zenith angles, azimuthal angles, etc. and can reduce atmospheric effects more effectively (Schläpfer et al., 2018). According to (Felde et al., 2003), mathematically this model can be represented as;

$$L = \left(\frac{A\rho}{1-\rho_e S}\right) + \left(\frac{B\rho}{1-\rho_e S}\right)$$

where, r=pixel surface reflectance
P_e= average surface reflectance for the pixel and surrounding region
S= spherical albedo of the atmosphere
L_a= radiance backscattered by the atmosphere

A and B = coefficients that depend on the atmospheric and geometric conditions but not a surface.

The topography of the selected study area is very undulating which may result in geometrical distortion of acquired satellite images. Thus, to carry out change detection and multi-temporal analysis the acquired satellite imageries need to co-registered with each other. Using the image registration module and topographic map sheets (1:25000) published by Survey Department, Nepal geometric distortion was reduced sequentially.

2.2 Image Classification

Supervised Image classification with Maximum Likelihood Classifier (MLC), available in ENVI software was carried out to perform image classification. Initially, the image was planned to be classified into four land cover categories i.e., Built-up, Barren, Agriculture, and Forest land. To perform a maximum likelihood method classifier sufficient amount of training data should be available in the form of ground-referenced data for various land cover types (Karna, et al.). In this study minimum of 30 samples for each category were extracted to perform the image classification.

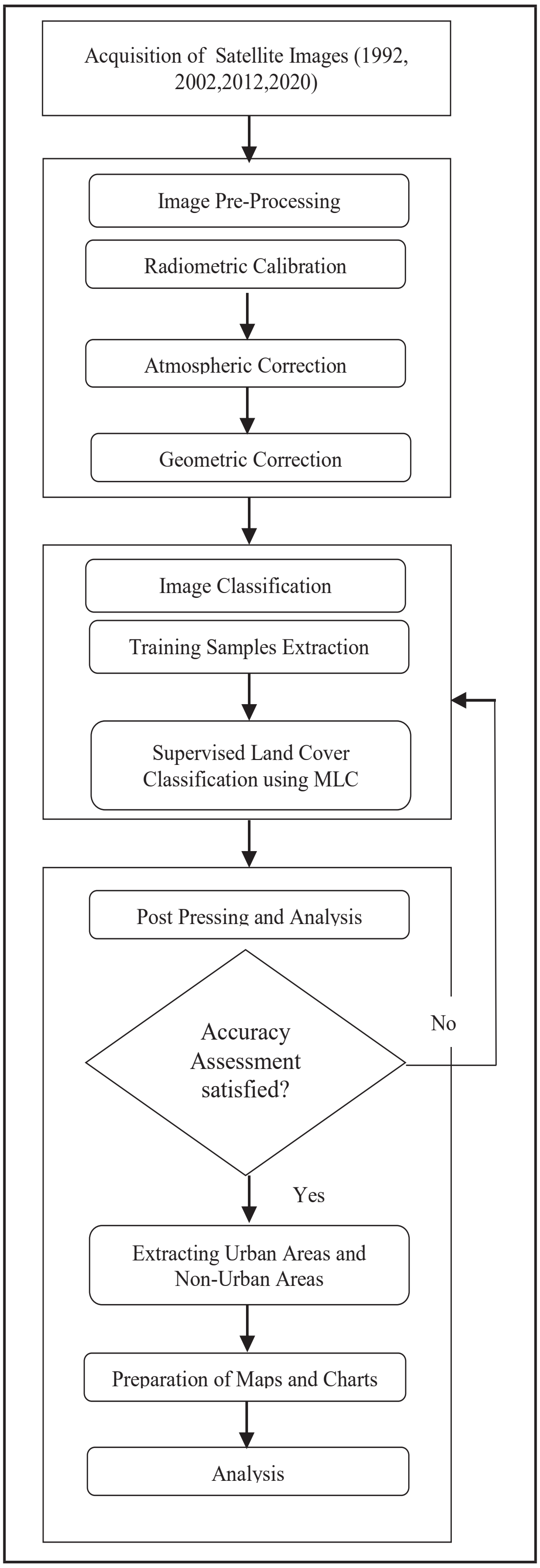

Figure 2: Methodological Flowchart

2.3 Post-processing and Analysis

Ground truth samples were collected from Google Earth Pro for year 2002,2012 and 2020 and samples were collected from georeferenced topo sheets for the year 1992 since google earth imagery were not found in this year. The accuracy assessment of prepared land cover maps was done via Confusion Matrix using Ground Truth ROIs under the post processing of ENVI. Minimum 30 samples were collected for each land cover class and tested over the classified image. 84.35%, 83.70%, 85.71% and 86.82% of overall accuracy and 0.788, 0.778, 0.806 and 0.821 kappa statistics were obtained for year 1992,2002,2012 and 2020 respectively.

After obtaining the desirable accuracy of image classification, they were further classified into binary classification (Urban and Non-Urban areas). The main aim of binary classification is to precisely distinguish the urban and non-urban lands inside the study area. The binary classification was carried out by merging agriculture, forest, and barren categories as non-urban areas and remained builtup areas as it is.

According to (As-syakur et al., 2012), built-up and barren land has a similar reflectance value in satellite images thus, there is a high probability for misclassification which ultimately affects the overall results. In addition to this, agriculture and forest are highly dominant in the study area due to which the urban areas would be suppressed during image classification. Thus, to minimize suppression of urban areas and the misclassification, initially, images were classified into four categories and further in binary classification.

At last, respective binary maps along with necessary charts and graphs were prepared to disseminate and carrying out for further analysis.

2.4 Analyzing Impacts of Driving Factors Using AHP Model

To analyze the responsible driving factors for change in urban growth patterns, at first desk study was performed to identify, select and define the major drivers as per necessity. Then using the framework in figure 3 analysis was proceed further. At first, subjective judgment and pair wise matrix of the selected drivers were prepared based on scale range as illustrated in the table 2 developed by (Saaty, 1986).

Internal Migration(D1), population density (D2), Commercialization(D3), Real estate business (D4) were four drivers used in this study. To check the consistency of the subjective judgment, the consistency ratio (CR) needs to be evaluated significantly.

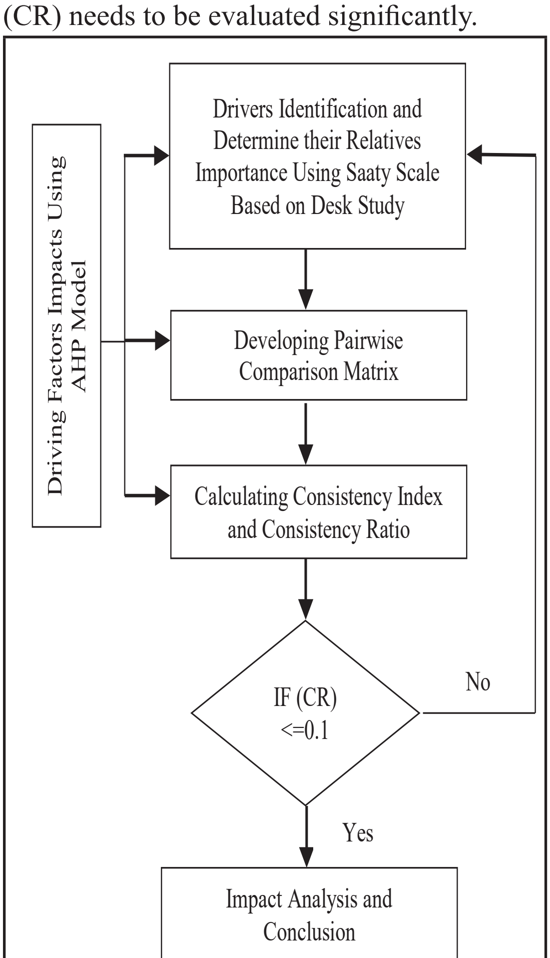

Figure 3: AHP Framework

Table 2: Saatty rating scale

Saatty Rating Scale	
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extreme Importance
2,4,6,8	Intermediate Importance
1/3,1/5,1/7,1/9	Values for inverse comparison

For evaluating the CR, firstly; the sum of a column of each driver was calculated using the pairwise matrix as illustrated in table3.

Table 3: Pairwise matrix

D1	**D2**	**D3**	**D4**
1	5	4	7
0.200	1	3	6
0.250	0.333	1	5
0.143	0.167	0.200	1
1.593	**6.500**	**8.200**	**19**

Then, each element of the pairwise matrix was normalized by, dividing each element of the matrix with its respective column summation value. The individual normalized elements (D11 to D44) and weights of each driver are illustrated in table 4. The weight of the driver is also referred to as the priority vector/normalized principal eigen vector. The weight of each driver was calculated using the following formula.

$$Weight \quad \frac{\Sigma sum\ of\ all\ row\ elements\ of pairwise matrix}{number of drivers}$$

Accordingly, for calculating the principal eigenvalue, the weighted sum (A) of each driver were calculated which is illustrated in the table 5.

Table 4: calculation of priority vector

D1	D2	D3	D4	Priority Vector (P)
0.628	0.765	0.480	0.438	0.578
0.126	0.153	0.360	0.375	0.253
0.157	0.051	0.120	0.313	0.160
0.090	0.026	0.024	0.063	0.050

Table 5: Calculation of weighted sum

D1” (D1*P)	D2” (D1*P)	D3’’’ (D1*P)	D4’’’’ (D1*P)	A (D1*P)
0.363	0.194	0.077	0.022	0.164
0.073	0.039	0.058	0.019	0.047
0.091	0.013	0.019	0.016	0.035
0.052	0.006	0.004	0.003	0.016

Furthermore, using the formula as mentioned below the principal eigen value (λmax) was calculated and obtained as 4.161.

$$\lambda max = \frac{weighted\ \Sigma\ of\ each\ criteria\ (A)}{weight\ of\ each\ criteria\ (Priority Vector)}$$

After, determining the value of λmax Consistency Index (CI) was calculated using the mentioned below formula. The CI value was obtained as 0.054.

$$CI = \frac{\lambda max^{-n}}{n - 1}$$

n = number of drivers used.

Finally, the CR value needs to be calculated to evaluate the consistency of the judgment. In this study, CI was obtained as 0.060 (acceptable) using the formula as mentioned below. According to Saaty (1986), the value of RI depends upon the number of drivers used, thus, RI=0.89 for n=4.

$$CR = \frac{CI(Consistency\ Index)}{RI(Random\ Consistency\ Index)}$$

3. RESULTS AND DISCUSSION

3.1 Urban Growth Pattern

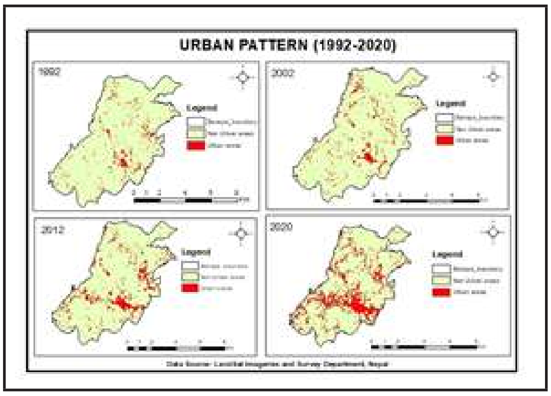

Figure 4: Map Showing Urban Pattern

Figure 4 demonstrates the urban growth pattern in each decade of the study area. It can be observed that the urbanization of the study area is gradually increasing since, 1992 to 2012 but has suddenly risen from 2012 to 2020. Highway and major roads network can be visualized in the given figure 4 which is extracted from toposheets of the year 1992 published by Survey Department, Nepal. It depicts that urbanization is growing rapidly along the roads in a concentric pattern till days. In addition to this, figure 4 also illustrates that the urbanization is mostly in the core area of the city (Banepa Bazzar) whereas scattered urban patterns can be depicted in upper regions from Araniko highway.

3.2 Status of Urban Growth

Table 6: Statistics of Land Cover

Year	1992	2002	2012	2020
Urban areas (ha)	273.96	361.98	558.54	983.16
Urban areas (%)	5.03	6.65	10.25	18.04
Non-Urban areas (ha)	5173.20	5085.18	4888.62	983.16
Non-Urban areas (%)	94.97	93.35	89.74	81.95

Figure 5 shows the trend of urban and non-urban areas from 1992 to 2020. It depicts that in 1992 total municipality was covered with

273.96 ha of urban areas with 5.03 % of its total land. Similarly, in 2002, 361.98 ha of land was covered with urban which occupies 6.65 % of the total land of a municipality. Correspondingly, in 2012, urban areas slightly rose and cover an area of 558.54 ha which occupies 10.25 % of the total land of Banepa. The municipality faced the highest urban growth in 2020 with an area of 983. 16 ha occupying 18.04 % of the total land.

The comparative analysis between built-up and non-built-up areas in each decadal interval can be depicted from the illustrated table 6. It shows most of the land is covered with non-urban areas where only a few were covered with urban areas in the year 1992. Similarly, in 2002 and 2012 there was still dominancy of non-urban areas. Non-urban areas covered almost similar to that of 1992 with little diminutions. In 2020, large amount of non-urban areas was converted to urban areas which has ultimately raise urban growth of municipality in highest amount.

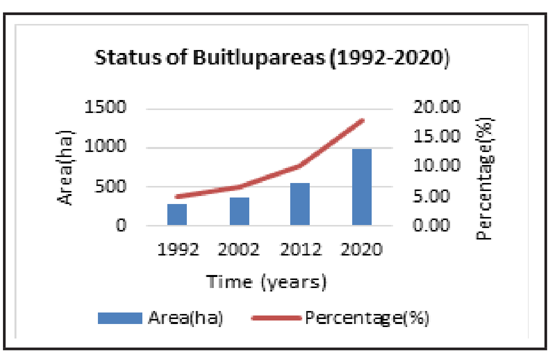

Figure 5: Graph Showing Status of Built-up Areas

3.3 Change analysis of Urban areas

Table 7: Statistics Showing Change in Urban Areas

From-To	1992-2002		2002-2012		2012-2020	
Time period	10		10		8	
Change	Area (ha)	%	Area (ha)	%	Area (ha)	%
	88.02	1.62	196.56	3.60	424.62	7.79
Annual Rate of Change	8.80	0.16	19.65	0.36	53.07	0.97

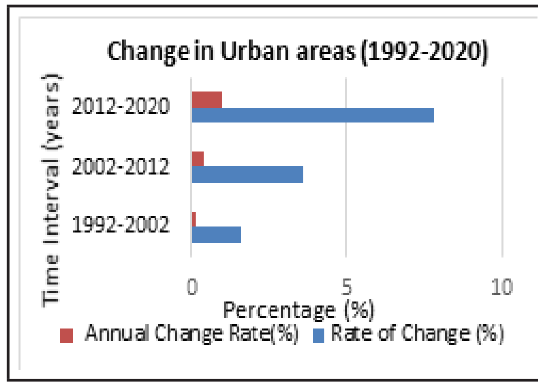

Figure 6: Graph Showing Rate of Change in Urban Areas

Table 7 illustrates the change in urban areas between each decade interval i.e., 1992-2002, 2002-2012, 2012-2020. It shows that between 1992 to 2002, urban areas grew at a rate of 0.16 % (8.08 ha) per year, accumulating 1.62 % (88.02 ha) over this decade. Similarly, in the case of 2002-2012 urban areas were increased at a rate of 0.36 % (19.65 ha) per year and cumulate an area of 196.56 ha (3.60 %) between 2002-2012. Also, in the case of 2012-2020, the urban areas were continuously increased at a rate of 0.97 % (53.07 ha) per annum which accumulate 7.79 % (424.62 ha) of total land by end of this period.

3.4 Driving factors

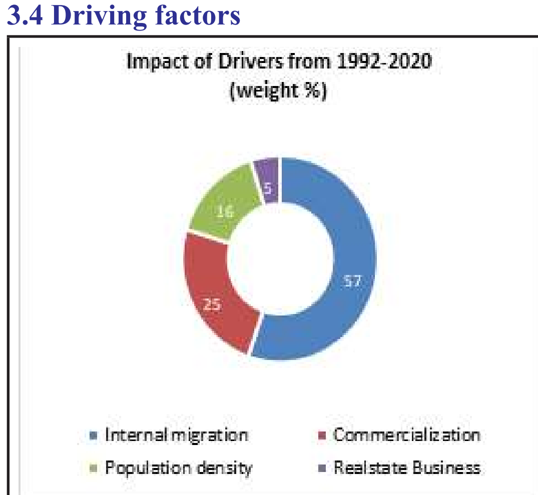

Figure 7: Chart Showing Impact of Driving Factors

The selected driving factors; Internal Migration, Commercialization, Population density, and Real estate business, and their impact on urbanization was analyzed using the AHP model which is shown in figure 7. It confirms that internal migration with a weight of 57 % is found to be a major responsible factor for urbanization inside the municipality. Based on Tiwari (2008), internal migration and urbanization are highly correlated to each other. The high flow rate of internal migration from a place to another place proportionally increases the urbanization of the drifted area. A document published by Thapa & Murayama (2010), reveals that flow of migration from rural areas to urban areas since the 90's to the present date, is considered as one of the major drivers for rapid urbanization over various parts of Nepal. Accordingly, based on the data published by Kc (2004), internal migrant flow from rural areas to urban areas is continuously increasing in Kathmandu city and nearer urban cities of Nepal such as; bhaktapur, banepa, dhulikhel, etc. In the case of Banepa, individuals are migrated from rural areas of kavre district (Dohalghat, Roshi, Bethanchowk, Khanikhoa etc) for better physical infrastructure facilities, education and health facilities, employment opportunities, commercial business because, a major highway of our nation (Araniko Highway) passes through this municipality, a leading university (Kathmandu University) and well-renowned hospital (Dhulikhel Hospital) are situated near to this municipality. In addition to this, it is also found that this municipality is a vital commercial hub of care district due to which people are also migrating in high flow rate from rural areas to core area (banepa bazzar) which has resulted the enormous urban growth across core area.

Commercialization with a weight 25% is found to be another responsible factor after internal migration for rapid urban changes of a municipality. According to Tiwari (2008) commercialization is highly interlinked to urbanization. It involves; transactions, modern marketing, and exchange methods which enormously give rise to the growth of urban cities.

Based on the information retrieved from the municipal official website; https:// banepamun.gov.np reveals most of the Newari communities are attracted to commercial business since the historical development of the city. Thus, most of the peoples are found to be engaged in a commercial business which has ultimately rise urbanization inside the city since 90s to 2020. Population density with a weight of 16 % is found to be the third driver which is responsible for the urban growth inside the municipality. According to the Salas (1986), population dynamics and change in the urban landscape are positively correlated to each other which states that with an increase in population density urbanization will be ultimately increased in any specific region. Various studies were already accomplished to analyze the trend of population dynamics in urban areas and its impact on the urbanization of Nepal. A report published by (Nepal Urban Population 1960-2021, 2021), demonstrates a significant increase in the population throughout major cities of Nepal since 90s to 2020, with has increased in new settlements. Thus, being an urban city of Nepal since the late 90's banepa municipality is also experiencing an additional expansion of settlements from 90s to 2020 resulting in enormous urban growth

The real estate business has also impacted the urban dynamics of banepa municipality. The AHP model used in this study reveals it weighs 5%, which is comparatively less than that of three drivers (Internal migration, Commercialization, Population density). Since 2000, the real estate business found to be introduced due to the high demand of the land for the construction of buildings, houses, apartments, etc mainly in various city areas of Nepal (Ishtiaque, Shrestha, & Chhetri, 2017). From a paper published by (Thapa & Murayama, 2010), it is found that since 2000, the real estate business inside Kathmandu city was not only originated but was found to be boomed which has caused rapid urbanization. In addition to this, the paper also suggests that the influence of the real estate business can be also seen in nearer cities such as bhaktapur,banepa, dhulikhel etc. Thus, due to the attraction of real estate business from Kathmandu, many local people of banepa municipality seems to be found fragmenting their arable land for housing and industrialization to construct modern groceries, restaurants, private parking, etc. which has ultimately created the rapid urbanization inside municipality during 2002-2020

4. CONCLUSION

This study has shown the capability of the latest geospatial technologies such as Geographic Information System (GIS), Remote Sensing (RS), etc. for analyzing urban growth patterns taking the case of Banepa Municipality. It also demonstrates the use of the Analytical Hierarchy Process (AHP) model to analyze the impact of drivers for continuous urban growth from 1992 to 2020 inside Banepa municipality. This study depicts that urbanization in the study area is gradually increasing from 1992 to 2012 and has risen suddenly and cover 18% of land until coming to 2020. Analytical Hierarchy Process (AHP) was adopted to analyze the impact of drivers which reveals that, Internal migration (57%) is major drivers for change in urban dynamics whereas, commercialization (25%), population density (16%), and real estate business (5%) are other respective drivers for alteration of urban land inside the municipality. In addition, the result obtained from this demonstrates that if this pattern continues, there will be rapid urban growth with a quick loss of agricultural land and other existing natural resources. Hence, to prevent rapid urbanization, the concerned authorities must take initiative for implementing land management related policies like Land Use Policy 2015, Land Use Act 2019.

REFERENCE

Stefanova, W. L., & Ramseyc, M. S. (2001, March 1). Monitoring urban land cover change:An expert system approach to land cover classification of semiarid to arid urban centers. *Remote Sensing of Environment*.

Bakrania, S. (2015, 10 29). Urbanization and Urban Growth in Nepal. *GSDRC*.

Banepa Municipality. (n.d.). Retrieved from Banepa Municipality: https://banepamun.gov.np/ne/node/3

Devkota, K. (2018). Challenges of Inclusive Urbanization in the Face of Political Transition in Nepal. In J. Mugambwa, & M. W. Katusiimeh, *Handbook of Research on Urban Governance and Managemnet in the Developing World.* IGI GLOBAL.

Eddin, B. (n.d.). The Application of Remote Sensing and GIS in Urban Planning.

Ishtiaque, A., Shrestha, M., & Chhetri, N. (2017, 10 8). Rapid Urban Growth in the Kathmandu Valley,. *MDPI*.

Joshua, M., & Katusiimeh, M. (n.d.). Urban Governance and Management in the Developing World. *IGI GLOBAL* .

Karna, K. B., Shrestha, S., Sainju, S., Sigdel, G. P., Shrestha, S., & Karmacharya, A. (n.d.). *Introduction to Remote Sensing: An Introductory Book.* Land Management Training Center, Government of Nepal .

Ministry of Federal Affairs and General Administration. (2017). *MOFAGA.* Retrieved from https://www.sthaniya.gov.np/gis/

Muzzini, E., & Aparicio, G. (2013). Urban Growth and Spatial Transition in Nepal. The World Bank.

Neill, A. (2021, March 31). Urbanization in Nepal 2019. Statista.

Nepal Urban Population 1960-2021. (2021). Retrieved from Macrotrends: https://www.macrotrends.net/countries/NPL/nepal/urban-population#:~:text=Nepal%20urban%20population%20for%202019,a%203%25%20increase%20from%202015

Rinkesh. (2019). *Cause, Effects and Solution of Urbanization*. Retrieved from https://www.conserve-energy-future.com/causes-effects-solutions-urbanization.php

Saaty, R. (1986). The analytic Hierarchy Process -What it is and How it is used. *Mathematical Modelling of Socio Economic Plant Sciences, 20*.

Salas, R. M. (1986). Urban Population Dynamics. *Asia-Pacific Population Journal, 1*(1).

Schlapfer, D., Hueni, A., & Richter, R. (2018 , Januray 29). Cast Shadow Detection to Quantify the aerosol optical thickess for atmospheric correction of high spatia resolution optical Imagery. *Remote Sensing* . doi:10.3390/rs10020200

Thapa, R. B., & Murayama, Y. (2010). Drivers of Urban Growth of Kathmandu Valley,Nepal:Examining the Efficacy of the Analytical Hierarchy Process. *Applied Geography*.

Author's Information

Name	:	Rabina Twayana
Academic Qualification	:	Bachleor's Degree in Geomatics Engineering from Kathmandu University
Organizatioin	:	Naxa Pvt. Ltd., Kathmandu
Current Designation	:	WebGIS Developer
Work Experience	:	Six-month
Published paper/article	:	2
E-mail	:	rabinatwayana123@gmail.com

Assessing the Accuracy of Remotely Sensed Forest Maps for Nepal

Menaka Hamal, Rajesh Bahadur Thapa
menakahamal@gmail.com, rajesh.thapa@icimod.org

KEYWORDS

Remotely Sensed Maps, Point Sampling, Accuracy Assessment, Province wise Forest Coverage

ABSTRACT

The accuracy assessment is vital to validate the remotely sensed thematic output before being front to the users. The statistical accuracy measures and modeling have been using widely for the accuracy assessment of the remote sensing product. This study uses six open-access land cover products - Land Cover of Nepal 2010, GlobeLand30, Treecover2010, Global PALSAR-2 forest/Non-Forest, Tree Canopy Cover (TCC), and ESACCI Land Cover 2010, to find out the most reliable forest product for Nepal. The forest/non-forest data were extracted from each product. The stratified random sampling was used to create test points and verified ground truth in Google Earth (GE) by visual interpretation. The overall accuracy (OA), producer's accuracy (PA), user's accuracy (UA), Kappa statistics, and the Nash-Sutcliffe model efficiency coefficient (NSE) were measured for each forest/non-forest map. The OA and UA were found to be highest by 94%; the Kappa statistics showed an 89% level of agreement and NSE showed 77 % performance level for Nepal Land Cover 2010 which is the highest among six datasets. Whereas ESACCI land Cover 2010 was found to be the least performer - OA and UA are 53% and 66% respectively, Kappa shows a 53% level of agreement and NSE shows 4%.. The ESACCI land Cover 2010 was found to be the highest coverage whereas Tree Canopy Cover (TCC) has the least one for each province. This study gives the methodological insight to compare remotely sensed datasets and help the user in the selection of the most reliable open-source forest map for Nepal.

1. INTRODUCTION

Forest resources play a vital role for the people and the planet by providing various goods and services (FAO 2018). However, according to Food and Agriculture Organization (FAO), 31.6% of the global forest area in 1990 reduced to 30.6 % in 2015 mainly due to excessive use of fossil fuels and deforestation. With the access of satellite imageries and availability of image processing and interpretation tools, FAO started Global Forest Assessment to monitor forest resources using remote sensing since 1990 to maintain forest status and its change record at global, regional, and biome level. Likewise, different initiatives have developed land cover and thematic maps using satellite imageries that capture from different sensors, following scientific and methodological processes and techniques, and made them available to the public. To select and use the most reliable products in a specific area, the remotely sensed maps are compared.

The various studies regarding the comparison of remotely sensed maps have been conducted globally. However, limited to some of the countries. (Estoque et al., 2018) assessed and compared eight remotely sensed forest maps for Philippine and concluded that NAMRIA30 had the lowest overall dis-agreement with the reference data whereas GLOBELAND30 had the highest. Similarly, (Yang et al., 2017) compared eight forest products with a medium resolution (30–50 m) imagery for China and found that the forest areas of OU-FDL and JAXA forest maps had a high correlation with that of GlobeLand30. Likewise, (Bai et al., 2014) compared five global land cover datasets for China to look into the consistencies and discrepancies among those datasets. (Giri, Zhu, & Reed 2005) compared the Global Land Cover 2000 and MODIS global land cover data to evaluate the similarities and differences in methodologies, and identified the areas of spatial agreement and disagreement among datasets. This comparison makes users be informed before the selection of land cover data required for the specific applications.

In Nepal, forest occupies 5.96 million ha (40.36%), forest including woodland covers 44.74% of the total area of the country (DFRS 2015).. So, Department of Forest and Research Survey (DFRS) has been generated forest and land cover datasets as a part of the forest inventories, but those are closed source. The national-level open-source land cover dataset for the year 2010 acquired from the International Center for Integrated Mountain Development (ICIMOD).

The global land cover and thematic datasets are also available free from the web such as **GlobeLand30-** land cover global raster dataset developed by the National Geomatics Center of China, **Global tree cover data (treecover2010)** developed by University of Maryland, **Global 25m resolutions PALSAR-2/PALSAR** mosaic and forest/non-forest map prepared by Earth Observation Research Center (EORC) of Japan Aerospace Exploration Agency (JAXA**), Tree Canopy Cover (TCC)** layers by the USA, **ESACCI Land Cover 2010** generated by Climate Change Initiative (CCI) of European Space Agency (ESA) and **Nepal Land Cover 2010** map created by ICIMOD.

The accuracy of remote sensing thematic data should be known before the application of a product to the intended application (Rwanga&Ndambuki, 2017). The accuracy measurement is an essential procedure that has been followed to check the reliability of the thematic output (Foody, 2002). During the assessing process, the classified thematic categories of the image are verified to the same categories of the reference image (Anand, 2017). The reference data has been generated by applying the appropriate sampling technique or points/pixels are manually generated in the reference image or collect ground truth points visiting the study area to verify with the classified points/pixels. Then, the reference data have been verified with the position of the object of the classified image or vice versa (UoT, 2021). The verified data run through the statistical accuracy measures – the most common measures are the confusion matrix for finding out the performance of a classification model, and the Kappa statistics to measure the level of agreement (Foody, 2010). This study follows the point sampling method where sample points are generated using a stratified random sampling technique. The forest and non-forest classes are taken as strata in which the points are allocated randomly. The allocated points are verified with the original image to compute the confusion matrix and kappa statistics for finding out the reliability of the classified map. This study addresses the selection of the most reliable open-source national as well as the global dataset and gives the methodological insight to compare the remotely sensed forest maps for Nepal.

2. METHODOLOGY

2.1. Study Area

Nepal was taken as a study area for assessing the accuracy of forest maps. The country is situated between China in the North; and India in the east, west, and south with latitude 26^{0} 22'N to 30^{0} 27'N and longitudes 80^{0} 04 E to 88^{0} 12'E.. It expands approximately 885 km from east to west, and widens about 130 km to 260 km north-south with elevation starts from approximately 60 meters from the tropical Terai to the highest 8,848.86 meters peak of the World Mt. Sagarmatha (DFRS, 2015). The forest area varies across the physiographic regions that start from low land in the south to the mountainous reason in the north. Out of 40.36 % of the total area of the country's forest, 20.4% lies in the Terai region, 72.4% in Churia, 52.3% in Middle Mountain, and 29.4% in High Mountain and High Hamal (DFRS, 2016).

2.2. Methodological Flow Chart

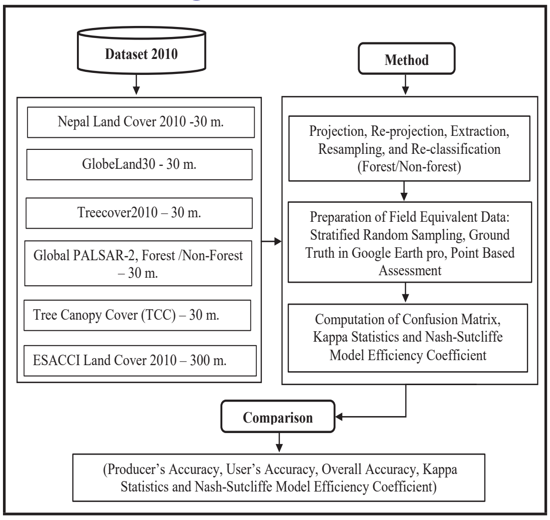

Figure 1: Process flow chart

The flow chart depicts the raster analysis techniques used for the computation of statistical accuracy measures as well as their comparison (Figure 1).

2.3 Data, Classification, and Reclassification

The six forest/non-forest maps were extracted from remotely sensed open-source land cover products of 2010. One is a national LULC product and the others are global coverage. (Table 1). These products were downloaded from the websites of the respective initiatives. Those data were projected, and re-projected to GCS_WGS_1984 to bring different them into a common coordinate system and reference frame Then, the cells were extracted with the administrative boundary of Nepal and resampled to 30x30 meters each datum to make cell size consistent.

The dataset had their own classification system. Some were given in classes and some were in values in the attribute table. Those original classes and values of each dataset were reclassified into the forest, and the non-forest classes according to the classified thematic coverage and given raster values of the respective dataset. The eight categories of Nepal Land Cover 2010 data of ICIMOD have been reclassified into two strata – Forest and Non-Forest. Similarly, GloveLand30 data of China reduced to two strata. The TCC 2010and ESACCI Land Cover 2010 dataset, the original values of the dataset were reviewed and reclassified into two classes. The Global PALSAR-2, Forest /Non-Forest dataset was directly extracted (Table 1).

Table 1: Data source, resolution, and classification of the datasets

Data	Reference	Satellite Data Source	Spatiotemporal Reso.	Classification Technique	Original data classification/values	Reclassification to Forest and Non-Forest for this study
Nepal Land Cover 2010	(ICIMOD 2010)	Landsat TM	30 m. 2010	Object Based Classification	Forest, shrubland, grassland, agriculture, barren area, water body, snow/glacier, Built-up area	Forest and Non-forest (other than forest)
Gloebe Land 30	(NGCC, 2014)	Landsat TM5 and ETM +	30 m. 2010	pixel-object-knowledge based method	10: Cultivated land, Forest, Grassland, Shrubland, Water bodies, Wetland, Tundra, Artificial surfaces, Bareland, Permanent snow and ice	Forest: Lands covered with trees, with vegetation cover over 30%, including deciduous and coniferous forests, and sparse woodland with cover 10 - 30% and other non-forest.
Treecover 2010	(Hansen et al 2013)	Landsat 7 ETM+	30 m. 2010	Decision tree classification	The resulting layer represents estimated maximum tree canopy cover per pixel, 1-100% for the year 2010 in integer values (1-100).	integer values (1-100) and excluded other values
Global PALSAR-2, Forest /Non-Forest	(EORC, 2019)	PALSAR and PALSAR-2	25 m. 2010	SAR processing algorithm: Sigma-SAR IMAGE and Sigma-SAR MOSAIC	classified "forest" (colored in green) and "non-forest" (colored in yellow)	classified "forest" (colored in green)
Tree Canopy Cover (TCC)	(Sexton et al 2013)	Landsat	30 m. 2010	Regression Tree Model	38 classified values with different categories of land cover such as cropland, tree cover, shrubland, grassland, lichen mosses, sparse vegetation, urban areas, water bodies, prominent snow and ice (Values from 0 to 220)	The tree cover categories such as mosaic cropland and natural vegetation, tree cover broadleaved, evergreen / deciduous, closed/ open, closed to open and needle-leaved deciduous/ evergreen, open/ closed, closed to open and mixed leaf type (Value 12 and 30 to 90)
ESACCI Land Cover 2010	(ESA-CCI 2017)	MERIS	300 m. 2010	Unsupervised classification chain with machine learning algorithm	38 classified values with different categories of land cover such as cropland, tree cover, shrubland, grassland, lichen mosses, sparse vegetation, urban areas, water bodies, prominent snow and ice	The tree cover categories such as mosaic cropland and natural vegetation, tree cover broadleaved, evergreen / deciduous, closed/ open, closed to open and needle-leaved deciduous/ evergreen, open/ closed, closed to open and mixed leaf type (Value 30 to 90, 100, 110, 150)

2.4. Preparing Field Equivalent Data

The field equivalent data is crucial for the accuracy assessment (Thomas, 2015). For that, the spatial support unit is taken to compare the locations of classified maps to the reference maps for validation (FAO, 2020). If the study area is large and physically inaccessible, the pixels or points can be a common choice of the assessment unit (Stahman, 2009). The point assessment strategy was implemented in this study. The required sample size was calculated using a sample size calculatoronline (https://www.checkmarket.com/sample-size-calculator/). For that, the area of Nepal was taken with a 95% confidence level and 3% set as a confidence interval, which suggests that 1060 samples are required to achieve the desired level of precision. After determining the sample size, a random stratified sampling method was adopted to prepare the reference data using Sampling Design Tool in ArcGIS. This method allocates the sample size for each land cover category based on the spatial extent, and eliminating class level bias (Stehman, 2009). The classified and ground truth columns were created in the attribute table so that the classified points can be verified with the reference data (ESRI 2020).

The reference data source was Google Earth due to the availability of possible high-resolution imageries and a cost-effective source of spatial information (Ragheb & Ragab, 2015). This platform has been used to verify the multi-temporal land cover classification where the study area is physically inaccessible (Cha & Park 2007). Olofsson et al., 2020 stressed that the "*reference data should be of higher quality than the data used for creating the map*" therefore the GE platform was used to verify the points. For that, the generated points of classified maps were overlayed on GE and check whether each pixel covers the forest area or not for the year 2010 with visual interpretation. When the reference points were not clear due to unclear images, incomplete coverage, and dense clouds on GE for the year 2010, the points were verified by taking the reference imageries of the year 2008 to 2012. Every verified point on GE was edited as the ground truth field of the attribute table to use data to compute the confusion matrix.

2.5. Analytical Approach for Comparison

The classification model performance was tested for each forest/non-forest map by computing the confusion matrix based on the values of verified pixels of classified maps to the ground truth points on GE. By evaluating the records of the confusion matrix, the **producer's accuracy** that relates to the map makers and error of omission was computed by taking the ratio of the number of reference sites classified accurately to the total number of reference sites for that class. Similarly, t**he user's accuracy** that relates to the map users and error of commission - the ratio of correctly classified sites to the total number of classified sites (GPS216, 2019), was calculated. Likewise, t**he overall accuracy** was accessed based on the number of correctly classified pixels and the total number of pixels used for accuracy assessment. The **omission error** was found by reviewing the incorrect classified pixels of reference sites and computed by taking the ratio of the number of incorrectly classified pixels and the total number of reference sites for each class. The large omission errors show that the large difference between the mapped area and the real area. The real land cover type is left out or omitted from the classified map (Olofsson et al 2020). Then, the **commission error** was calculated by reviewing the incorrect classified pixels of the classified site and calculated as the ratio of incorrectly classified sites and the total number of classified sites for each class.

The kappa coefficient is one of the commonly used statistics to test the degree of agreement by chance (Mchugh, 2012). The values range from 0 to 1; where 0 interprets no agreement between the classified and reference images and 1 gives the identical of classified images and ground truth images (Cohen, 1960).. The level of the agreement depends on the value of Kappa that gives the percentage reliability of the data. The value 0 to 0.20 gives the 0-4% reliability that interprets no agreement, 0.21 to 0.39 gives 4-15% reliability with the minimal agreement, 0.40 to 0.59 gives 15-35% reliability that interprets the weak level of agreement, 0.60 to 0.79 gives 35-63% reliability with the moderate agreement, 0.80 to 0.90 gives 64-81% reliability interprets the strong level of agreement and bove0.90 gives 82-100% that interprets the almost perfect level of agreement (Mchugh, 2012). To test the degree of reliability of each map, the Kappa statistics were computed.

The Nash-Sutcliffe Model Efficiency Coefficient (NSE) was calculated to determine the model performance of each dataset by taking the number of pixels of the classified map and the number of verified pixels. It gives how well the observed versus simulated data fits the 1:1 line. NSE model output ranges from -1 to 1. If the calculated value closer to 1, the model would be more accurate (Agrimetsoft, 2020). NSE was computed using an online calculator of agricultural and metrological software -https://agrimetsoft.com/calculators/Nash%20Sutcliffe%20model%20Efficiency%20coefficient.This online software was modeled with the classified points and the verified ground truth points to get the actual NSE value.

3. RESULT AND DISCUSSION

The image classification process always demands the accuracy of thematic maps before being front to the users. The assessment output may vary from application to application but need to rely on the resulted quantitative output to know the map reliability (Thomas et al., 2015). Table 2 provides a summary of the outputs of a quantitative assessment – OA, PA,and UA.The degree of similarity in spatial patterns between the classified map and the reference data.

For the forest and non-forest map of the **Land Cover of Nepal 2010**, out of 1060 pixels, a total of 1001 are correctly classified (411 as forest and 590 as non-forest). The OA value is 0.94 which means the classified image has 94% accuracy that conveys the 6% error in the overall image. The matrix shows that the 26 forest pixels and 33 non-forest pixels are found to be miss-classified. The calculated omission error (OE) for the forest becomes 7 with the commission error (CE) 5. For the non-forest, the OE is 4 and the CE becomes 6. The PA for non-forest is 96% whereas 84% forthe forest. The UA 95% for non-forest and 94% in the forest.Similarly, the **GlobeLand30** has 921 correctly classified pixels (374 forests and 547 non-forest) so OA becomes 87% that notified the 13% overall error. The 70 forest pixels and 69 non-forest pixels are found to be miss-classified. The OE is 16 and CE 11 for forest and the value becomesreverse in non-forest errors. PA is 84 for forest and 89 for non-forest that is similar to UA as it reflects that there is no conflict between map user and producer. Likewise, for the **Treecover2010,** the total 917 correctly classified pixels so OA becomes 87% that is similar to the OA of GlobeLand30. The PA is 80% for forest and 92 for non-forest but the UA for the forest is 87. The 91 forest pixels and 52 non-forest pixels are found to be miss-classified. The OE and CE for the forest are 20 and 14 respectively, and for the non-forest 8 and 13 respectively. The OA of **Global PALSAR-2, Forest /Non-Forest** is 80% which is quite less than the previous maps and has a 20% overall error. The PA is 76 for the forest and 82 for the non-forest whereas UA 75 for the forest and 83 for the non-forest. OE and CE are 24 and 17 respectively for forest and 18 and 25 for non-forest. Also, The **Tree Canopy Cover (TCC)** map has OA and error is similar to PALAR-2 but the OE and CE are quite high for forest ie. 35 and 22 respectively and non-forest ie.10 and 17 respectively. The PA 95 and 90 and UA 83 and 78 for forest and non-forest respectively. Then, the **ESACCI Land Cover 2010**has the lowest OA i.e. 76%,and highest error i.e. 24% among other maps.

Table 2: Statistics of accuracy assessment

Dataset	ClassValue	Non-forest	Forest	Total	UA
Land Cover of Nepal 2010	Non-forest	590	33	623	0.95
	Forest	26	411	437	0.94
	Total	616	444	1060	
	PA	0.96	0.93		OA = 0.94
GlobeLand30	Non-forest	547	70	617	0.89
	Forest	69	374	443	0.84
	Total	616	444	1060	
	PA	0.89	0.84		OA = 0.87
Treecover2010	Non-forest	564	91	655	0.86
	Forest	52	353	405	0.87
	Total	616	444	1060	
	PA	0.92	0.80		OA = 0.87
Global PALSAR-2, Forest /Non-Forest	Non-forest	506	106	612	0.83
	Forest	110	338	448	0.75
	Total	616	444	1060	
	PA	0.82	0.76	0.00	OA = 0.80
Tree Canopy Cover (TCC)	Non-forest	555	154	709	0.78
	Forest	61	290	351	0.83
	Total	616	444	1060	
	PA	0.90	0.65		OA = 0.80
ESACCI Land Cover 2010	Non-forest	420	57	477	0.88
	Forest	196	387	583	0.66
	Total	616	444	1060	
	PA	0.68	0.87		OA = 0.76

Only OA is not sufficient to measure the accuracy so the Kappa coefficient was tested as it is a common statistical measure of agreement (Mchugh, 2012). Figure 2 shows that the Land cover of Nepal 2010 has a strong level of agreement as the value of it lies between 0.08-0.90 that gives 64-81% reliability of the map. Similarly, the statistics of The GlobeLand30 and Treecover2010 lie between 0.60 and 0.79 give 35-63% reliability and havea moderate level of agreement. TheGlobal PALSAR-2 Forest /Non-Forest, Tree Canopy Cover (TCC), and ESACCI Land Cover 2010 have values range from 0.52 to 0.57 those have reliability comes between 15% to 35% that interprets the weak level of agreement.

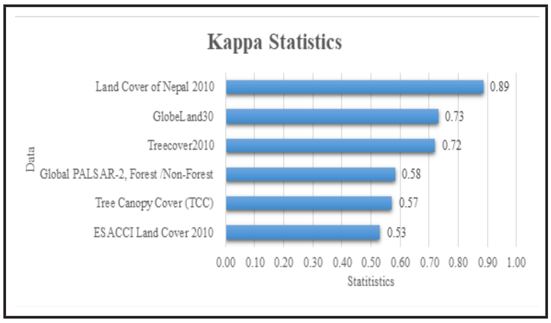

Figure 2: Kappa statistics

The NSE, the model performance indicator gives the coefficient that can be used to find the model performance for each dataset. Table 3 shows that the NSE coefficients for each dataset range from 0.04 to 0.77. The Land Cover of Nepal 2010 has the highest which means the number of pixels of the classified map and the number of reference data has a 77% approximate similarity.Then the second-highest performer becomes GlobeLand30 that has 71% followed by Treecover2010, Global PALSAR-2, Forest /Non-Forest 43%, and 17% respectively. The ESACCI Land Cover 2010 is the least performer ie4% followed by Tree Canopy Cover (TCC) ie8%.

Table 3: Nash–Sutcliffe model efficiency coefficient

Dataset	NSE
Land Cover of Nepal 2010	0.77
GlobeLand30	0.71
Treecover2010	0.43
Global PALSAR-2, Forest /Non-Forest	0.17
Tree Canopy Cover (TCC)	0.08
ESACCI Land Cover 2010	0.04

Fig. 3 shows that the percentage forest coverage of each dataset for seven provinces of Nepal. The extracted forest cover from ESACCI Land Cover 2010 has the highest forest coverage for each province followed by The Global PALAAR-2, Forest/Non-Forest, and TCC. **In Province 1**, 58% forest for ESACCI Land Cover 2010 followed by Global PALSAR-2 (46.7%), Nepal Land cover 2010 (45.5%), GlovbeLand30 (45.1),Treecover2010 (39.3%) whereas least TCC (33.1%) forest coverage. Similarly**, in Province 2**, the highest ie 26.9 % forest of the Nepal Land Cover 2010 followed by Globland30 and Treecover2010 (24.6%), the Global PALSAR-2 (22.9%), TCC (20.4 %) whereas the least ESACCI Land Cover 2010 (20.1%). In **Bagmati Province**, 72.4% i.e. highest forest coverage of ESACCI Land Cover 2010 followed by Treecover2010 (53.8%), Nepal Land Cover 2010 (53.7%), Global PALSAr-2 (49.5%), GlobeLand30 (42.8%) and the least coverage TCC (38.7%). In **Gandaki Province**, the highest forest coverage is 52.2% of ESACCI Land Cover 2010 followed by Global PALASR (41.3%), GlobeLand30 (33.3%), Nepal Land Cover 2010 (32%), and the TCC and Treecover2010 has 28.2% coverage. In **Lumbini Province**, the highest forest coverage is ESACCI Land Cover 2010 i.e. 59.2% whereas the lowest is TCC i.e. 33.1%. The GlobeLand30 has 51.5% i.e. second highest followed by 50.6%, 48.3% and 47.5 for Treecover2010, Nepal Land Cover 2010, and Global PALSAR-2 respectively. In**Karnali Province**, the ESACCI has highest forest coveragei.e. 45.3% whereas the lowest is 20.8% for TCC. The 36.9% for Global PALSAR-2, 34.2% for GlobeLand30, 29.6% for Nepal Land Cover 2010 and 24.2% for Treecover2010 forest coverage. **SudurpashimProvince**has the second highest forest coverage i.e. 61.6% coverage for ESACCI Land Cover 2010 as compared to other products.The Nepal Land Cover 2010 has 51.6% followed by 49.7% of Global PaLSAR-2, 48% of GlobeLand30, 46.1% of Treecover2010, and the least one is 36.6% of TCC. All over, Province 2 has the lowest forest coverage followed by Karnali Province and Gandaki Province whereas SudurpashimProvince has the highest followed by Province 1, Lumbini, and Bagmati.

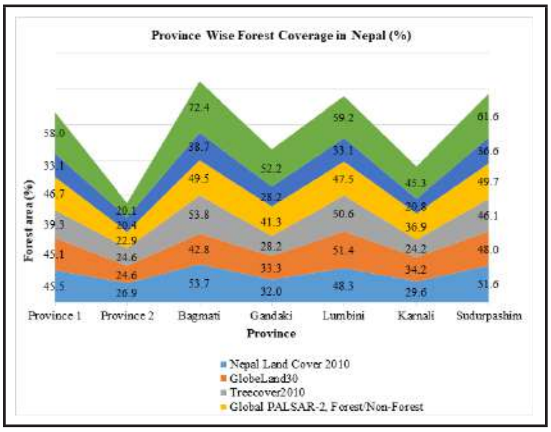

Figure 3: Province wise forest coverage in Nepal

Figure 4 shows the maps of the forest that shaded as leafy green and non-forest that shaded in Sahara sand color, of **Bagmati Province**of Nepal. The forest coverage observed highest in ESACCI Land Cover 2010 whereas it found to be lowest in Tree Canopy Cover (TCC) among six maps.

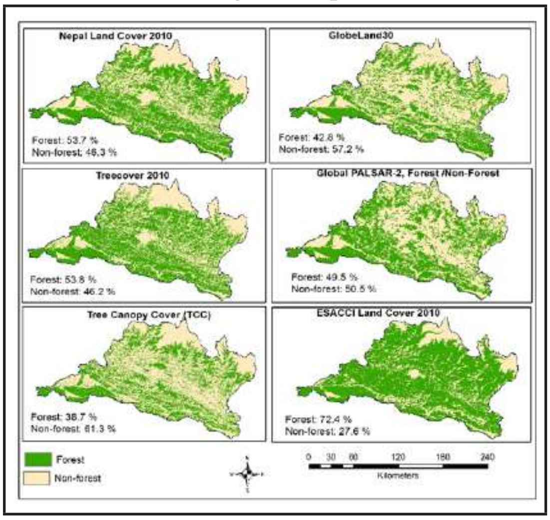

Figure 4: Forest and Non-Forest Coverage of Bagmati Province

4. CONCLUSION

The remotely sensed land resource maps have been prepared using satellite imageries and made those publically available through the different initiatives expecting further use from local to a global scale. The required natural resource coverage can be extracted from those open source thematic maps. The six open-source forest cover maps for the year 2010 were extracted to compare which one is the most reliable for Nepal.. The stratified random sampling was used to create 1060 points to compute accuracy from classified and reference data. The reference data generated from GEhigh-resolution imagery by visual interpretation and validated classified pixels with ground truth for each dataset. Among the six datasets, the forest/non-forest data of Land Cover Nepal 2010 has the highest OA (94%) whereas it is lowest (53%) in ESACCI Land Cover 2010. The GlobeLand30, Treecover2010, Global PALSAR-2Forest/Non-Forest, and TCC were found to be accurate by 87%, 86.5%, 80%, and 79.7% respectively. The Land cover of Nepal 2010 has the highest UA (94%) whereas the lowest (66%) in ESACCI Land Cover 2010 as compared to other maps. The GlobeLand30, Treecover2010, Global PALSAR-2, Forest / Non-Forest and TCC has 84%, 87%, 75% and 83 % UA respectively. The kappa statistics of the Land Cover of Nepal 2010 have 0.89 value which shows a strong level of agreement whereas Global PALSAR-2_Forest /Non-Forest map, TCC, and ESACCI 0.58, 0.57, and 0.53 respectively has a weak level of agreement. The GlobeLand30 has 0.73 and Treecover2010 has 0.72 that shows reliability with a moderate level of agreement. The NSE model has performed best with the Land Cover of Nepal 2010 that has by 77% of approximate similarity to the pixels of classified maps with the reference map. This study would help users on map selection for forest resource monitoring and give methodological insight to compare remotely sensed forest maps for Nepal.

REFERENCE

Agrimetsoft, (2020). *Nash Sutcliffe model efficiency coefficient*. Agricultural and Meteorological software.

https://agrimetsoft.com/calculators/Nash%20Sutcliffe%20model%20Efficiency%20coefficient

Anand, A. (2017). *Unit 14 Accuracy Assessment*. (January 2017), 59–77. Retrieved from https://www.researchgate.net/publication/324943246_UNIT_14_ACCURACY_ASSESSMENTBai, Y., Feng, M., Jiang, H., Wang, J., Zhu, Y., & Liu, Y. (2014*). Assessing consistency of five global land cover data sets in China*. Remote Sensing, 6(9), 8755. https://doi.org/10.3390/rs6098739

Cha, S. and Park, C. (2007). *The Utilization of Google Earth Images as Reference Data for the Multitemporal Land Cover Classification with MODIS Data of North Korea*. Graduate School of Environmental Studies, Seoul National University, Korea

Cohen, J. (1960). *A COFFICIENT OF AGREEMENT FOR NORMAL SCALES*. *XX*(1), 37–46. https://doi.org/10.1177/001316446002000104

DFRS, (2015). *State of Nepal's Forests*. Forest Resource Assessment (FRA) Nepal, Department of Forest Research and Survey. Kathmandu, Nepal.

DFRS. (2016). *Forest Resource Assessment Nepal*. Department of Forest Research and Survey. Kathmandu, Nepal.http://www.dfrs.gov.np/downloadfile/mainresult_1470141289.pdf

EORC, (2019). *Global 25m Resolutions PALSAR-2/PALSAR Mosaic and Forest/Non-Forest.* Earth Observation Research Center.Japan Aerospace Exploration Agency. https://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm#description

ESA-CCI, (2017). *The Land Cover CCI Climate Research Data Package (CRDP).* European Space Agency Climate Change Initiative. http://maps.elie.ucl.ac.be/CCI/viewer/download.php

ESRI, (2020). *Understanding of Segmentation and Classification*. https://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/understanding-segmentation-and-classification.htm

Estoque, R. C., Pontius, R. G., Murayama, Y., Hou, H., Thapa, R. B., Lasco, R. D., &Villar, M. A. (2018). *Simultaneous comparison and assessment of eight remotely sensed maps of Philippine forests*. International Journal of Applied Earth Observation and Geoinformation, 67(January 2017), 289. https://doi.org/10.1016/j.jag.2017.10.008

FAO, (2018). *Time is running out for the world's forests: total area is shrinking by the day*. Food and Agriculture Organization. http://www.fao.org/americas/noticias/ver/en/c/1144234/

FAO, (2020). *Global Forest Resources Assessment 2020*. https://doi.org/10.4060/ca8753en

Foody, G. M. (2002). *Status of land cover classification accuracy assessment. Remote Sensing of Environment*, 80(1), 185–201. https://doi.org/10.1016/S0034-4257(01)00295-4

Foody, G. (2010). Assessing the Accuracy of Remotely Sensed Data: Principles and Practices. In The Photogrammetric Record (Vol. 25). https://doi.org/10.1111/j.1477-9730.2010.00574_2.xGiri, C., Zhu, Z., & Reed, B. (2005). *A comparative analysis of the Global Land Cover 2000 and MODIS land cover data sets*. Remote Sensing of Environment, 94(1), 131. https://doi.org/10.1016/j.rse.2004.09.005

GPS216, (2019). *Introduction to Remote Sensing. Accuracy Matrix*. http://gis.humboldt.edu/OLM/Courses/GSP_216_Online/lesson6-2/metrics.html

Hansen, M.C., Potapov, P.V., Moore, R., Hancher, M., Turubanova, S.A., Tyukavina, A., Thau, D., Stehman, S.V., Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O., and Townshend, J.R.G. (2013). *High-Resolution Global Maps of 21st-Century Forest Cover Change: Science*, v. 342, no. 6160, p. 50-853. http://www.sciencemag.org/content/342/6160/850.abstract

Mchugh, M. L. (2012). *Lessons in biostatistics Interpreter reliability : the kappa statistic*. 276–282. https://doi.org/10.11613/BM.2012.031

Ragheb, A. E., & Ragab, A. F. (2015). *Enhancement of Google Earth Positional Accuracy*. *International Journal of Engineering Research and Technology*, *4*(1), 627–630.

Sexton, J. O., Song, X.-P., Feng, M., Noojipady, P., Anand, A., Huang, C., Kim, D.-H., Collins, K.M., Channan, S., DiMiceli, C., Townshend, J.R.G. (2013). *Global, 30-m resolution continuous fields of tree cover: Landsat-based rescaling of MODIS Vegetation Continuous Fields with lidar-based estimates of error*. International Journal of Digital Earth, 130321031236007. doi:10.1080/17538947.2013.786146. https://data.fs.usda.gov/geodata/rastergateway/treecanopycover/

ICIMOD. (2010). *Land cover of Nepal 2010* [Data set]. ICIMOD. https://doi.org/10.26066/rds.9224

Kandel, P. (2010). *Forest resource assessment in Nepal: an assessment of data needs*. http://www.forestrynepal.org/images/publications/Data%7B_%7Dneeds%7B_%7Dfinal.pdf

NGCC (2014). *30-meter global land cover dataset (GlobeLand30): product description*. National Geometrics Center of China. Retrieved from http://www.globallandcover.com/home/Enbackground.aspx (accessed 29.09.19).

Olofsson, P., Arévalo, P., Espejo, A. B., Green, C., Lindquist, E., Mcroberts, R. E., &Sanz, M. J. (2020). *Remote Sensing of Environment Mitigating the effects of omission errors on area and area change estimates.Remote Sensing of Environment*, *236*(January 2019), 111492. https://doi.org/10.1016/j.rse.2019.111492

Rwanga, S. S., & Ndambuki, J. M. (2017). *Accuracy Assessment of Land Use / Land Cover*

Stehman, S. V. (2009). *Sampling designs for accuracy assessment of land cover. International Journal of Remote Sensing*, *30*(20), 5243–5272. https://doi.org/10.1080/01431160903131000

Thomas M. Lillesand, Ralpha W. Kiefer, J. W. C. (2015). *Remote Sensing and Image Interpretation* (Seventh Ed).

UoT, (2021). 15 - Data quality: quality assessment. University of Twente, Netherland. Retrieved from https://ltb.itc.utwente.nl/498/learningoutcome/show/59281

Yang, Z., Dong, J., Liu, J., Zhai, J., Kuang, W., Zhao, G., … Xiao, X. (2017). *Accuracy assessment and inter-comparison of eight medium resolution forest products on the loess plateau, China*. ISPRS International Journal of Geo-Information, 6(5), 15. https://doi.org/10.3390/ijgi6050152

Author's Information

Name	:	Menaka Hamal
Academic Qualification	:	MSc in Natural Resource Management
Organization	:	International Center for Integrated Mountain Development
Current Designation	:	Gender Associate for Gender Atlas
Work Experience	:	10 years
Published paper/article	:	4
E-mail	:	menakahamal@gmail.com

Obituary

All the officials of Survey Department pray to the almighty for eternal peace to the departed soul of the following officials of the department and this department will always remember the contribution they have made during their service period in this department.

Dipendra Giri
Asst. Surveyor,
Survey Office Khairani
2077/06/09

Arjun Gurung
Asst. Surveyor,
Survey Office Khairani
2077/07/26

Tikendra Prasad Dhamala
Surveyor
Survey Office Bardiya
2077/08/19

Prem Thapa
Surveyor
Survey Office Gotikhel
2077/12/17

Prem Raj Sharma
Then Survey Officer
2078/01/17

Baleshwor Prasad Yadav
Surveyor,
Survey Office Hariwan
2078/01/25

Yoddha Shah
Then Secretary
2078/02/03

Ram Naresh Mahato
Surveyor,
Survey Office Dhalkewar
2078/02/18

Bhagwat Yadav
Surveyor
Survey Office Sunsari
2078/02/21

Flood Modeling Assessment: A Case of Bishnumati River

Noor Dangol
noordgl6@gmail.com

KEYWORDS

Flood Modeling, Bishnumati River, HEC-RAS, Flood Hazard

ABSTRACT

Flood, a common water induced disaster of a monsoon season, is the recurring phenomenon in Nepal. To study this disaster, different flood modelling had been conducted for different river basins following different modelling tools. This study describes the technical approach of probable flood vulnerability and hazard analysis of Bishnumati river catchment and analyze the result with previous study done for the same study area. The method adopted for previous study in 2009 was adopted in this study as well in order to compare the results. One dimensional hydraulic model HEC-RAS with HEC GeoRAS interface in co-ordination with Arc GIS was applied for the analysis.. Hazard maps, landuse vulnerability maps of various return periods (10 Yrs, 20Yrs, 50Yrs and 100Yrs), were prepared in ArcGIS. The results of flood frequency analyzed by WECS/ DHM method showed discharges of 445 m^3/s, 541m^3/s, 648m/s, 725 m^3/s for 10, 20, 50 and 100 years return period floods. The primary data of the study showed most of the flooding area had water depth greater than 3m. The assessment of the flood inundated area showed that large percentage of vulnerable area lied in built up areas followed by barren land.

1. INTRODUCTION

Flood is an unusual high stage of a river overflowing its bank and inundating the marginal lands. This may also due to shifting of the course of the river, earth quake causing bank erosion, or blocking of river, or breaching of the river flood banks (Kumar et al., 2017). Flooding is a result of heavy or continuous rainfall exceeding the absorptive capacity of soil and the flow capacity of rivers or streams. Excessive rainfall is the basic cause of a river flood but there are simultaneously other contributory factors. Data of last three decades shows that climate related disasters accounted for almost 25 per cent of deaths, 84 per cent of adversely affected people and 76 per cent of economic losses (MoHA, 2009).

Nepal's geographical location exposes it to extreme precipitation, seismic activities and landslides. Loss of lives and damage to property and infrastructural assets as a result of natural disasters are a regular phenomenon in the Nepalese economic and social landscape. Nepal's water body consists of more than 6,000 rivers and rivulets with a total length of 45,000 km (Tiwari et al., 2018). In June-August 2017, more than half of the 75 districts of Nepal were impacted by floods and landslides triggered by heavy monsoon rains. Over 1.7 million people were affected (with some 160 persons losing their lives), and 43,000 houses were destroyed. On an average yearly, 290 people lost their lives accounting to over 33.8% of those who died due to different types of disasters

(DWIDP, 2008). Each year, floods of varying magnitudes occur due to intense, localized storms during the monsoon months (June to September) in Nepal's numerous streams and rivers (Awal, 2007).

In present case of Kathmandu Valley, excessive rainfall at a time is the basic cause of a river flood but there are simultaneously other contributory factors. Temporarily used backwater effects in sewers and local drainage channels and creation of unsanitary conditions may cause flooding. Also, inundations of large areas are due to overflowing river banks resulting in extensive damage to life and properties (GON, 2013). The River which flows through the centre of main city was found silting due to the improper drainage facilities and encroachment by the local peoples who causes flood (Muthusamy et.al, 2017).

B. OBJECTIVE

Major Objective of the study is to conduct flood modeling assessment. The specific objective of this study includes:

- Preparation of present land use map
- To conduct flood frequency analysis for different return periods
- To prepare flood vulnerability map of study area according to land cover
- To access the results of flood modeling from two different research for same study area

3. STUDY AREA

The study area lies in Bishnumati River of Kathmandu District. The Bishnumati River is one of the major tributaries of the Bagmati River in the Kathmandu Basin. It has six feeder tributaries namely, the Shivapuri khola, Shangla khola, Mahadev khola, Samakhusi khola, Bhachakusi khola and Manamati khola, and flows through densely populated core areas of the city. Shangla khola is large tributary of the Bishnumati River originating from hilly area of Shivapuri range and joins with Bishnumati River at Manohar Tirtha Ghat Bishnumati (GON, 2009). It is a perennial stream fed by storm flow and springs. The average annual rainfall is 1900 mm of which about 80% occurs only during monsoon (July-Sept). The maximum monthly discharge reaches highest (3.4 m3/s) in August and is least (0.024 m3/s) in February according to the data of DHM (1998). The total drainage area of the Bishnumati watershed is 102.09 km² (Tamrakar, 2009). It originates from the Shivapuri hill at above 2,481 m in the north of Kathmandu valley and merges with the Bagmati River at the Teku confluence travelling over 15.2 km. The study area was chosen in order to analyze the result of previous done by Dangol (2015) and compare with this present study.

4. MATERIALS AND METHODS

One dimensional hydrological modeling was adopted for this study. HEC-RAS was used for modeling and HEC-GeoRAS was used for presentation and analysis.

4.1 Data Collection

Satellite image of SAS Planet of year 2019 was used for updating land cover data collected from Survey Department. Freely avilable DEM of 12.5 m generated from ALOS PALSAR was used to create TIN. Cross section of the river at the bridge section was measured at the field. Stream line, centerline and other necessary input data were prepared from the updated land cover maps.

4.2 Flood Frequency Analysis

As per the recommendation of the Water and Energy Commission Secretariat/ Department of Hydrology and Meteorology (WECS/ DHM) of Nepal, the flood flow of any river of catchment area A km² lying below 3000 m elevation are given by the equation developed by WECS and DHM (Sharma, et al., 2003) for 2-year and 100-year floods is adopted for the study.

Q_2 = 2.29(A<3K) 0.86 ………………….. (i)

Q_{100} = 20.7(A<3K) 0.72 ……………….. (ii)

Where Q is the flood discharge in m³/sec and A is basin area in Km². Subscript 2 and 100 indicate 2-year and 100 year flood respectively. Similarly, subscript 3k indicates area below 3000m altitude. Further following relationship (WECS and DHM, 1990) was used to estimate floods at other return periods.

$$Qf = \exp(\ln Q2 + s1\sigma) \quad \text{(iii)}$$

Where σ1= In (Q100/Q2)/2.326 and s is the standard normal variate whose values are given in Table 1.

Table 1: Value of standard normal variate.

SN	Return Period (Year)	Standard Normal Vairate (s)
1	2	0
2	5	0.842
3	10	1.282
4	20	1.645
5	50	2.054
6	100	2.326
7	200	2.576
8	500	2.878

Source: WECS/DHM, 1990)

4.3 Flood Modeling

RAS Geometry in HEC-GeoRAS is used for creating required data sets for creating import file to HEC-RAS. Stream centerline, main channel banks (left and right), flow paths, and cross sections are created with simultaneous referral to Satellite images for verification. The Manning's 'n' value is highly variable and depends on a number of factors including surface roughness, vegetation, channel irregularities, channel alignment, scour and deposition, obstructions, size and shape of the channel, stage and discharge, seasonal changes, suspended material and bed-load.

Land cover map is used to extract the Manning's n value based on Manning's Roughness coefficient as shown in table 2 below. These values are extracted for each cross section depending on the intersection of cross-sections with land cover. Finally, after setting up the layer, the file is exported for further processing.

Table 2: Manning's roughness coefficient for different land cover.

S.N	Land Use code	Manning's value
1.	Forest	0.055
2.	Cultivation	0.06
3.	Sand Area	0.035
4.	Bareen Land	0.04
5.	Bursh, Grass	0.055
6.	Pond	0.035
7.	Bulitup Area	0.08

Source: Chow, 1990)

In the HEC-RAS, after importing the geometric data extracted from GIS, hydraulic data were entered. The import file created by HEC-geoRAS is imported in Geometric Data Editor interface within HEC-RAS. The flood discharge for different return periods were entered in steady flow data. Reach boundary conditions were also entered in this window. Then, water surface profiles were calculated in steady flow analysis.
After simulation, RAS GIS export file was created and water surface profiles were computed. The flow data were entered in the steady flow data editor for four return periods as 10-year, 20 years, 50-year and 100-year. Boundary condition was defined as critical depth for both upstream and downstream. Sub-critical analysis was done in steady flow analysis. Once the water surface profiles were calculated, the results were exported to GIS format. HEC-RAS model simulation results were exported to HEC-GeoRAS for further processing and visualization of flood extents.

5. DATA PROCESSING

All the data processing and modeling were done in HEC-RAS and HEC-GeoRAS platform.

5.1 RAS Mapping

In the last step, HEC-RAS results were imported into the GIS system and a floodplain map for each profile is developed. Flood inundation definition was performed that involves the use of HEC-RAS export for defining the flood inundation extent followed by water surface generation. Though the cross section data were collected in the bridge section, only the cross section data was used but processing on the basis of bridge and levee position was not conducted in this research. Finally, flood plain was delineated to generate flood inundation and flood depth maps for various return periods.

5.2 Flood Vulnerability Analysis

Flood with the same exceed probability will have different levels of vulnerability according to the land cover characteristics and potential for damage. The vulnerability analysis, therefore, consists of identifying the land cover under the potential influence of a flood of particular return period. For this, vulnerability maps were prepared by clipping the land use themes of the floodplains with the flood area polygons for each of the flood events being modeled. The land cover areas under the influence of each of flooding events are reclassified for the calculation of the total vulnerable areas. In this study, land cover vulnerability was analyzed and no other criteria like social, physical, economic, environmental indicators are not included since one of the objective is to analyze with the previous study of this same region and only land cover could be compared between the two research.

6. RESULT AND DISCUSSION

This study presented a systematic approach for the preparation of flood vulnerability map with the application of hydraulic model and GIS. The key findings are as follows.

6.1 Flood Frequency Analysis

The total catchment area of Bishnumati River was found to be 102.09 km^2 for this study. The flow data were entered in the steady flow data editor for four return periods as 10-year, 20-year, 50-year and 100-year. The discharge for various return periods was calculated by WECS/ DHM method for this study. According to the formulation of WECS the discharge for 10-year is 445 m^3/sec, 20-year is 541 m^3/sec, 50-year is 648 m^3/sec and 100-year is 725 m^3/sec. The table 3 result shows that the increment of the return period also increases the discharge value of river.

Table 3: Peak discharge for various return period by WECS/DHM method.

S.N.	Return Period	Discharge (m^3/sec)
1	10	445
2	20	541
3	50	648
4	100	725

Form the study it shows the discharge rate increases in 100 years to 725m^3/sec comparing to other calculated years. From the obtained results as well, as the return period increases the discharge become maximum. The discharge increases as more water is added through rainfall, tributary streams, or from the groundwater sweeping into the stream resulting in floods due to increase of width, depth and velocity of streams (Shravanya, 2016).

6.2 Land Cover of the Study Area

The land cover near Bishnumati River contains cultivation that occupies 66.14 percent of the total land area. The forested area in the surrounding hills covers about 16.78 percent, dry soil and land occupies 3.49 percent and barren land covers about 0.19 percent of total land, whereas the built-up area only covers 13.39 percent of the total land area in which flooded area was digitized to get the results in quick. Table 4 result shows that study area is densely covered by cultivated land, forest area, built-up area whereas dry soil and sand and then barren land are seem to be less covered in compare to other land cover class. Land cover classes such as cultivation land, forest, built up area; barren land lying near the river area has higher probability of flood destruction.

Table 4: Land cover at the study area.

S.N.	Land Use class	Area (ha)	%
1	Cultivated	7486.39	66.14
2	Dry soil and sand	395.92	3.49
3	Forest	1899.75	16.78
4	Built-up Areas	1515.76	13.39
5	Barren land	22.25	0.20
Total		11320.07	100

6.3 Flood Vulnerability Analysis

The table 5 show that 124 ha, 35 ha, 12 ha and 10 ha of built-up, sand/ barren area, cultivation land and grassland are respectively inundated by 10- years flood. Similarly, 195, 48, 20, 18, 1 ha of built-up area, sand/ barren land, cultivation land, grassland and forest area are respectively inundated by 100-year flood, which showed flooded area increased with increase in flooding intensity. Mostly, built-up area was inundated by different year floods, which was followed by sand/barren land, cultivation land, grassland land and forest. As form the field evidence, data analysis maps illustrate that flooding of the river is also inundating considerable distance from the river course because of narrow passage of river channel, slum encroachment, and narrowed river width.

Table 5: Land cover vulnerability.

SN	Land Cover	Total vulnerable area (Ha) in different return period			
		10	20	50	100
1	Cultivation	11.49	13.21	14.52	19.95
2	Sand/Barren	34.3	39.34	41.66	47.15
3	Forest	0.02	0.06	0.61	0.67
4	Grassland	9.32	11.8	13.35	17.77
5	Built-up	123.93	148.11	163.69	194.63
	Total	179.06	212.53	233.83	280.17

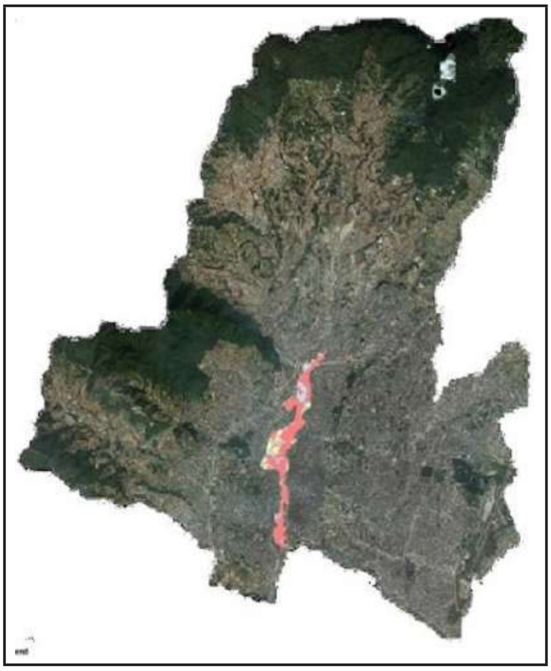

Figure 1: Flood vulnerability map of 10 year return period.

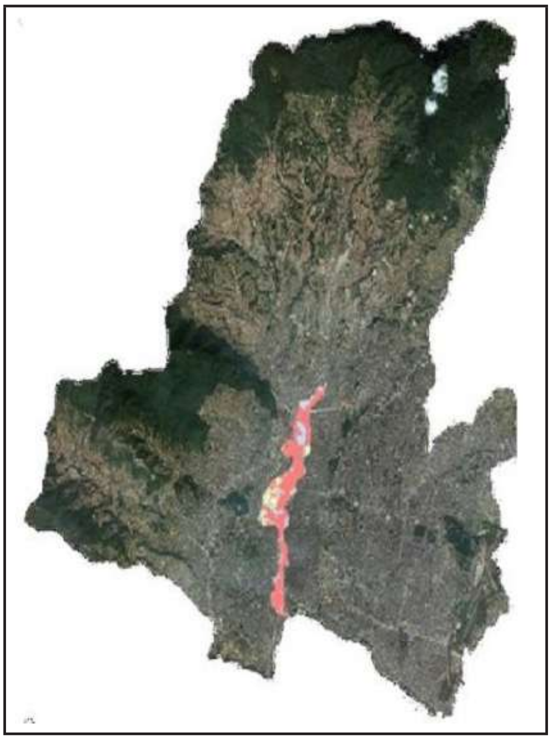

Figure 2: Flood vulnerability map of 20 year return period.

6.4 Flood Modeling Assessment

The flood vulnerability modeling result of Dangol (2015), the research which was done in 2009 was taken as the base result for the comparison between the two researches at same study area in different time period. Vulnerability analysis of Bishnumati catchment was done for the return period of 10, 20, 50 and 100 years (Dangol, 2015). Table shows the comparative analysis of flood vulnerability analysis. Since the study done by Dangol (2015) was in 2009, the 20 year return period will be 2029. And for this present research, 10 year return period will be 2029. Hence, two research done at same area for same period was analyzed.

The past study done by Dangol (2015) show that the total land cover area is mostly covered by built up area with 65.28% coverage and similarly 48.6% by sand/barren land, 23.8 by cultivated land, 14 % by grassland and 0.4 % by forest area whereas also in this study it shows the 69.21 % is densely covered built up area, 19.16 % is sand/barren land, 6.42 % is cultivation area, 5.20 % is grassland and 0.01 percent is forest area. The total area inundated in previous study is 250.7 ha and that for this research is 179.06 ha. Though total inundated area is small than the previous study, increase in inundation of the built up area for the same time period clearly showed that there is increase in built up area.

SN	Land Cover	Total vulnerable area (Ha)			
		20 years of Dangol study ~ 2029		10 year of this study ~ 2029	
1	Cultivation	23.8	9.52	11.49	6.42
2	Sand/Barren	48.6	19.44	34.3	19.16
3	Forest	0.4	0.16	0.02	0.01
4	Grassland	14	5.60	9.32	5.20
5	Builtup	163.2	65.28	123.93	69.21
	Total	250.7	100	179.06	100

7. CONCLUSION

The flood vulnerability analysis has been done with the use of software like HEC-RAS and GIS have wide applications but, in context of Nepal where the availability of river geometric, topographic and hydrological data is limited, the application of mapping is inadequate. The river flooding is highly dependent on the maximum instantaneous flow, river morphology and human interferences. With the use of WECS/DHM method discharge data for 10, 20 50 and 100 years return periods was calculated in which the flood intensity was observed as 445m³/sec, 541 m³/sec, 648³m/sec, 725 m³/sec.

It can be concluded that high vulnerability grade is particularly in Baniyatar, Khusibu and Gongabu whereas most of the places like Balaju, Dhalko and Teku are moderate to high vulnerable to flood. The vulnerability assessment of Bishnumati River flooding was performed with the GIS based approach. HEC-geoRAS extension was used to provide interface been the HEC-RAS and ArcGIS platforms.

REFERENCES

Awal, R. (2007). Floodplain Analysis and Risk Assessment of Lakhandei River. *Applied Research Grants Program for Disaster Risk Reduction, Rounds I and II (2003-2006)*

Brunner,G. (2016). HEC-RAS River Analysis System: *Hydraulic ReferenceManual,Version5.0, USArmy Corps of Engineers–Hydrologic Engineering Center.*

Dangol, S. & Bormudoi, A. (2015). Flood Hazard Mapping and Vulnerability Analysis of Bishnumati River, Nepal. *Nepalese Journal on Geoinformatics*, Vol 14. Survey Department, Government of Nepal.

Government of Nepal.(2009). Ministry of Water Resources Department of Water Induced Disaster Prevention. The Preparation of Flood Risk and Vulnerability Map of the Kathmandu Valley. *Final Annual report.*

GoN. (2013). Nepal Hazard Risk Assessment.

Horritta,M.S & Bates,P.D (2002). Evaluation of 1D and 2D Numerical Models for Predicting River Flood Inundation. *Journal of Hydrology 268 (2002) 87–99.*

ICIMOD. (2007). Hazard-Specific Flash Flood Management Measures. *Resource Manual on Flash Flood Risk Management – Module 2.*

Kumar,P. & Vergheese,O. (2017). Flood Modelling of Mangalam River Using GIS AND HEC- RAS. *International Journal of Advance Research in Science and Engineering , Vol.No .6, Issue No. 06.*

Maharjan, L. & Shakya, N. M. (2016). Comparative Study of One Dimensional and Two Dimensional Steady Surface Flow Analysis. *Journal of Advanced College of Engineering and Management, Vol. 2, 2016.*

MoHA. (2009). Nepal Disaster Report 2009. Government of Nepal 2009 2018-10-06 06-29-11.

Muthusamy, S., Muthusamy, N., Ramasamy, T. & Murugesan, B.(2017). Study and Analysis of Chennai Flood 2015 Using GIS and Multicriteria Technique. *Journal of Geographic Information System, 09*(02), 126-140. doi: 10.4236/jgis.2017.92009

Rees, G. & Gustard, L. (2004). Development and Testing of a Flow Estimation Model for Nepal. Centre for Ecology and Hydrology Wallingford, Oxfordshire, OX108BB,U.K., Department of Hydrology and Metereology, Nepal.

Shravanya,S. (2016). Hydrological Study and Estimating Flow Rate of Sungai Lebir, Kuala Krai, Kelantan. *Thesis submitted for Bachelor of Civil Engineering to Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang.*

Sahid, Nurrohman, & Hadi. (2018). An investigation of Digital Elevation Model (DEM) structure influence on flood modelling. *IOP Conference Series: Earth and Environmental Science, 148*, 012001. doi: 10.1088/1755-1315/148/1/012001

Tamrakar, N. K. (2009). Riverbed-Material Texture and Composition of Bishnumati River, Kathmandu, Nepal; Implications in Provenance Analysis. *Bulletin of the Department of Geology, Tribhuvan University, Kathmandu, Nepal, Vol. 12, 2009, pp. 55–62.*

Teng, A., Jakeman, A.J, & Croke, B. (2017). Flood Inundation Modelling: A Review of Methods, Recent Advances and Uncertainty Analysis. *Environmental Modelling & Software, 90*, 201-216. doi: 10.1016/j.envsoft.2017.01.006.

Tiwari K. R., & Rayamajhi S. (2018): Devastating Monsoon: Water Induced Disaster Management Practices in Nepal. Forestry: *Journal of Institute of Forestry, Nepal. No. 15: page 57 to 76.*

Author's Information

Name	:	Noor Dangol
Academic Qualification	:	Master's Degree in Environmental Science
Organization	:	Disaster Management Department (Kathmandu Metropolitan City)
Current Designation	:	Environmentalist
Work Experience	:	1 year
Published paper/article	:	Not yet
E-mail	:	noordgl6@gmail.com

Price of Aerial Photograph

Data	size	NRs. Rate	remarks
Aerial Photo (Scan Copy)	23cm X 23cm	350	
Diapositive (Scan Copy)	Different	350	
Aerial Photo Index	Different	100	

Price of District Level Land Use Digital Data

Data	Unit	Rate	remarks
Present Land Use	Per sq. Km.	5	
GIS Data for Land Resource	Per sq. Km.	5	Except Land Use Zoning Data
Profile	per piece	200	

Price of Local Level Land Use Digital Data

Data	Unit	Rate	remarks
Present Land Use	VDC/Municipality	300	
GIS Data for Land Resource	VDC/Municipality	300	Except Land Use Zoning Data
Profile	VDC/Municipality	200	
Soil Map Data	VDC/Municipality	300	

GIS data for land resource map is available for 20 districts of terai region, Illam and Dhankuta District

Price of Digital Topographic Data Layers

LAYER	Rs/Sheet
Administrative	100.00
Transportation	200.00
Building	60.00
Landcover	300.00
Hydrographic	240.00
Contour	240.00
Utility	20.00
Designated Area	20.00
Full Sheet	1000.00

S.N	Data	Price
1	Seamless Data whole Country	Rs. 300000.00
2	Seamless Data (Layerwise- whole country)	
2.1	Administrative Boundary	Free
2.2	Building	Rs. 15000.00
2.3	Contour	Rs. 65000.00
2.4	Transportation	Rs. 60000.00
2.5	Hydrographic	Rs. 70000.00
2.6	Landcover	Rs. 87000.00
2.7	Utility	Rs. 2000.00
2.8	Designated Area	Rs. 1000.00
3	1:1000000 Digital Data	Free
4	Rural Municipality (Gaunpalika) unitwise- all layers	Rs. 1000.00

Image Data:

Digital orthophoto image data of sub urban and core urban areas mintained in tiles conforming to map layout at scales 1:10000 and 1:5000, produced using aerial potography of 1:50000 and 1:15000 scales respectively are also available. Each orthophotoimage data at scale 1:5000 (covering 6.25Km2 of core urban areas) costs Rs. 3,125.00. Similarly, each orthophotoimage data at scale 1:10000 (covering 25 Km2 of sub urban areas) costs Rs 5,000.00.

Price of SOTER Data	Whole Nepal	NRs : 2000.00.

Fusion of Radar and Optical Data for Land Cover Classification Using Machine Learning Approach

David Nhemaphuki, Kiran Thapa Chetri, Sanjeevan Shrestha
davis10ge@gmail.com, thapachetrikiran@gmail.com, shr.sanjeevan@gmail.com

KEYWORDS

Google Earth Engine, Land cover, Random Forest, Sentinel, Synthetic Aperture Radar

ABSTRACT

This study evaluates the advantages of combining traditional space borne optical data with longer wavelengths of radar for land cover mapping. Land cover classification was carried out using Optical, radar data and combination of both for the Bardiya district using Random Forest algorithm. The fusion of optical and radar shows better land cover discrimination with 96.98% overall accuracy in compared to using radar data and optical data separately with overall accuracy of 69.2% and 95.89% respectively. Additionally, the qualitative result demonstrates that the combined utilization of optical and radar imagery yields useful land cover information over those obtained using either type of image on its own.

1. INTRODUCTION

Land cover information can provide a basis for formulating ecological protection measures and implementing sustainable development. Land Use Land Cover (LULC) dynamics serves as a crucial parameter in current strategies and policies for natural resource management and monitoring. Remote sensing technology has become the primary means of land cover information acquisition and has the advantages of high data acquisition and updating speed, wide range, economic convenience, and rich spatial information (William & Adriano, 2017). Land cover classification using traditional optical remote sensing approaches is not satisfactorily accurate since in certain conditions, similar spectral responses make classes difficult to separate like regions that are mixed, show irregular geometrical forms and change frequently (Soria-Ruiz, et. al.,2010). Moreover, optical remote sensing applications are often limited by cloud cover. In particular, the all-weather capability of synthetic aperture radar (SAR) allows for more reliable earth observation data under cloud covered regions. However, the information content is different from the optical and sometimes difficult to interpret as it is unable to distinguish between the multiple targets. Since optical and radar images vary in spectral, spatial and temporal resolution, the combination of both offer a more complete perception of the target objects and more reliable results (Pohl & Van Genderen, 1998).

There have been reported improvements in crop classification when both visible infrared and active microwave sensor data are used together (Rosenthal, et. al., 1985) (Qinghua, et. al., 2001) (Mcnairn, et. al., 2002); advantages of combining multidate visible, infrared, and SAR sensor datasets have also been demonstrated (Brisco & Brown, 1995); improvement in accuracy land cover/ use mapping was seen when radar data was combined with optical data (Soria-Ruiz, et. al., 2010) (Sim, et. al., 2013) (Joshi, et. al., 2016). Since, among other parameters, plant structure and water content influence the response data for SAR sensors, it is reasonable to assume that improved land-cover classifications of vegetated areas could be obtained using radar and optical data.

The specific objectives of this study are: (a) to classify a land cover map, using optical and radar images from Sentinel-1 and Sentinel-2 respectively; (b) to compare the accuracy of the classification while using radar, optical and both images. Overall, the purpose of the study is to determine whether SAR imagery, when combined with optical imagery, can provide acceptably accurate information about the distribution of important land-cover types, including agricultural, forest, water bodies, urban areas, and barren land and how the result would vary with either type of sensor separately.

2. MATERIALS AND METHODS

The study examines land cover classification and analysis using radar and optical data. To obtain a final land-cover map, the methodology followed these major processing steps: selection of study area, image preprocessing, preparing composite images, selection of samples, hyperparameter tuning for the Random Forest algorithm, land cover map preparation and finally the accuracy assessment.

2.1 Study Area

Bardiya lies in Province No. 5 in mid-western Nepal that covers 2025 square kilometers in area (Figure 1). Most of Bardiya is in the fertile Terai plains, covered with agricultural land and forest.

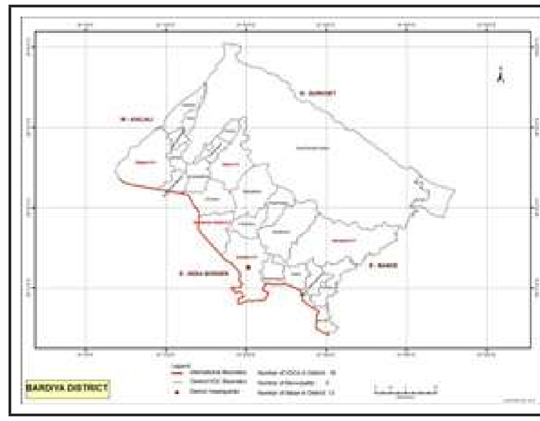

Figure 1: Study Area

(Source:LGCDP)

2.2 Data and Software

Table 1 and Table 2 present the satellite images used and the software used for different tasks in our study respectively.

Table 1: Satellite Images used in the study

S.N.	Satellite Imagery	No. of Bands	Date	Download Source
1	Sentinel-1 C-band	2	October 2020	Copernicus Open Access Hub
2	Sentinel-2 TOA	16		

Table 2: Software Used in the study

S.N.	Software	Usage
1	Google Earth	Sample Collection
2	Google Earth Engine (GEE)	Image Analysis and Classification
3	ArcGIS	Map Preparation

Ground Truth Collection: A total of 60 random samples or regions of interest (ROIs) for each land cover classes were collected. The samples were divided into training (40 samples), validating (10 samples) and testing datasets (10 samples).

2.3 Image Preprocessing

Preprocessing of the images is to be done for reducing any noises that may be present in the images before processing for analysis.

Speckle is a granular 'noise' that inherently exists in and degrades the quality of SAR images and it is reduced by applying spatial filters (Tadesse & Falconer, 2014). It applies a mathematical calculation on the pixel values within the moving window and replaces the central pixel with the new value. Applying speckle filtering reduces visual appearance of speckle and applies smoothing effect. A morphological mean filter was applied to each band with radius 50m.

Sentinel-2 TOA image was masked for cloud coverage area using the information contained in the 16th band QA60. Since Sentinel-2 TOA is reflectance data for the top of atmosphere it is already corrected from variance caused by sun angle, daytime etc and is ready for use.

2.4 Calculation of Normalized Difference Vegetation Index (NDVI)

The NDVI is a numerical indicator which uses visible and near-infrared waves as there is high interaction of energy in the visible and near infrared regions of the electromagnetic spectrum in vegetation. Generally, healthy vegetation absorbs most of the visible light and reflects a large portion of near-infrared light while unhealthy or sparse vegetation reflects more visible light and less near-infrared light. Bare soils on the other hand reflect moderately in both portion of the electromagnetic spectrum (Tadesse & Falconer, 2014). NDVI is calculated from these individual measurements as follows:

$$NDVI \frac{NIR - RED}{NIR + RED} \quad (1)$$

The value of NDVI ranges from -1 to +1 but in practice extreme negative values represent water, values around zero represent bare soil and values over 0.6 represent dense green vegetation. NDVI can be used to distinguish the different land cover types in comparison to other indices which can distinguish a specific land cover e.g. Normalized difference water index (NDWI), Normalized difference built-up index (NDBI) etc.

2.5 Composite Images

Three sets of composite images were prepared for performing the classification. The first set contains the information of SAR image, second set contains Optical information and the last set contains the SAR and Optical information.

Table 3: Composite Images

S.N.	Composite Image	Bands
1	SAR Image	VV and VH
2	Optical Image	Band 2, Band 3, Band 4, Band 8 and NDVI
3	SAR and Optical Image	VV, VH, Band 2, Band 3, Band 4, Band 8 and NDVI

2.6 Land Cover Map Preparation

Preparation of Land cover map is done by Random Forest algorithm. It is an ensemble tool which takes a subset of observations and variables to build decision trees. It builds multiple such decision trees and amalgamates them together to get a more accurate and stable prediction. And using this method, studies have shown a significant improvement in classification accuracy for land cover classification. While using Random Forest algorithm for the classification it includes the following steps:

Hyperparameter tuning: It is the problem of choosing a set of optimal hyperparameters for a learning algorithm. A hyperparameter is a parameter whose value is used to control the learning process. Random Forest has two major parameters i.e. number of decision tree and number of feature considered by each tree when splitting the node. Tuning was performed for the parameter number of decision trees to grow and accuracy was assessed for each image using the validation dataset as shown in Table 4.

Table 4: Hyperparameter Tuning

S.N.	No. of trees	SAR Image	Optical Image	SAR + Optical
1	1	54.10	93.00	93.90
2	5	64.40	93.00	96.60
3	10	67.00	93.80	96.90
4	15	67.80	93.60	96.60
5	20	69.70	93.80	96.40
6	25	69.00	93.60	96.50
7	40	69.50	93.50	96.20

For the number of trees the value 20 was selected as an optimal value as it provides good accuracy in all classified images. A default value was assigned for the parameter number of feature i.e. square root of the total number of features.

2.7 Classification

The Random Forest model was trained using the training sample with the parameters: value of 20 for number of trees and default value for the number of features. The model was used to classify the land cover type from the SAR image, Optical Image and SAR + Optical Image.

2.8 Accuracy Assessment

Accuracy of the classification of Land cover map was performed for all three land cover maps using the test dataset. A much better way to evaluate the performance of a classifier is to look at the confusion matrix. Confusion matrix was obtained and overall accuracy, kappa coefficient; users and producer's accuracy were derived.

Overall accuracy is the probability that an individual will be correctly classified by a test; that is, the sum of the true positives plus true negatives divided by the total number of individuals tested. The Kappa coefficient is a statistical measure of inter-rater reliability or agreement that is used to assess qualitative documents and determine agreement between two rasters. Producer's Accuracy is the map accuracy from the point of view of the map maker. The producer's accuracy can be termed as recall or true positive rate or sensitivity. The User's Accuracy is the accuracy from the point of view of a map user, not the map maker. The user's accuracy can be termed as consumer's accuracy or precision or positive predictive value.

3. RESULT AND DISCUSSION

Land cover maps for the month of October 2020 using SAR image, Optical Image and SAR + Optical image were classified using Random Forest as shown in Figures 2, 3 and 4 respectively.

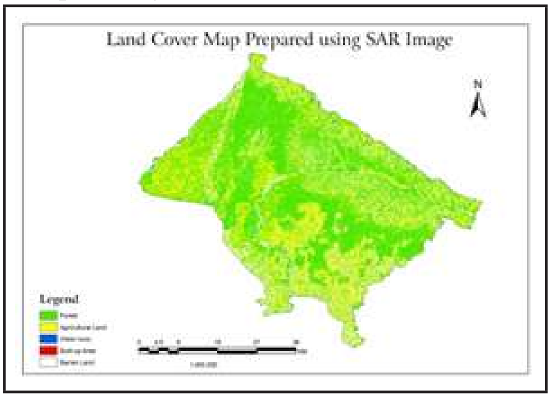

Figure 2: Land cover map (SAR)

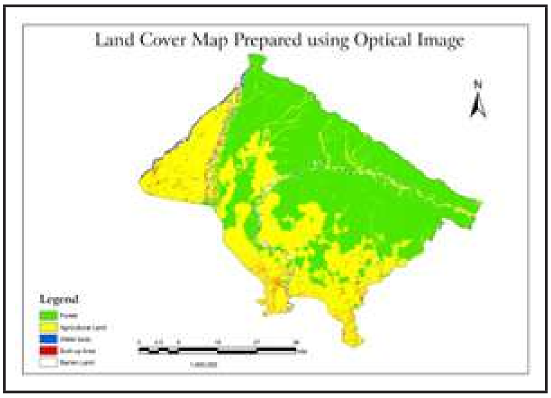

Figure 3: Land cover map (Optical)

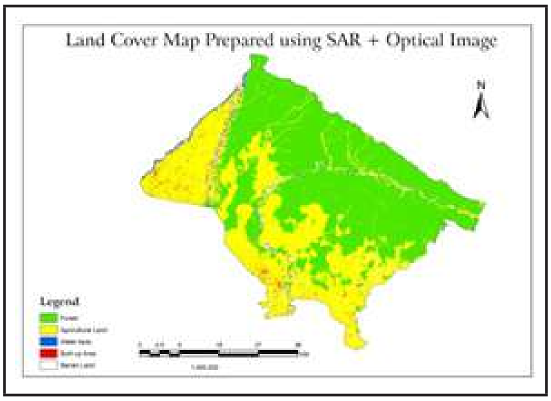

Figure 4: Land cover map (SAR + Optical)

The accuracy of land cover map obtained by using SAR image was 69.29%, Optical image was 95.89% and SAR + Optical Image was 96.98%. Land cover map using SAR image had the least accuracy while there is significant increase in accuracy of the land cover maps obtained using Optical and SAR + Optical image. An increment about 1% in accuracy was observed while using SAR image with Optical image than the Optical image only.

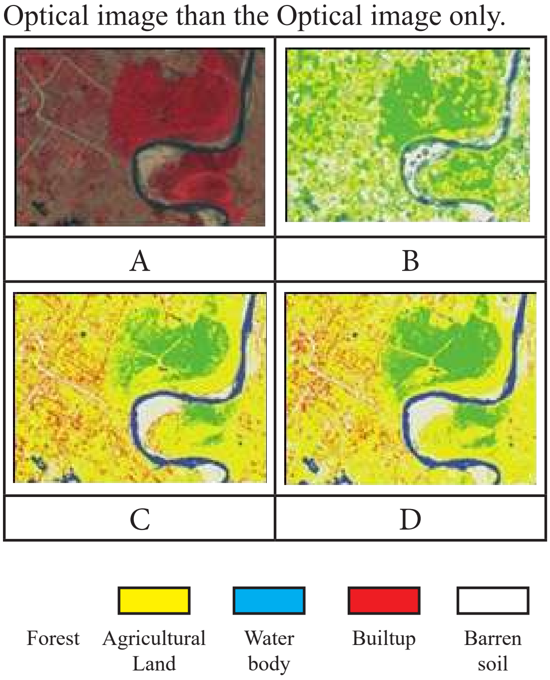

Figure 5: A portion of the study area is shown which covers the built-up area and Babai River. A shows false color composite image where vegetation is represented by red color, water body by dark pixels and bare soil by light pixels; B, C and D represents the classified land cover map using SAR image, Optical image and SAR and optical image respectively.

Using SAR data only the features like forest and water body were distinguishable but other classes were not. Optical data significantly improved the land cover map than the SAR as it was able to distinguish the built-up area, barren land and agricultural area as well. With the addition of SAR data to the Optical data an improved land cover map was obtained as pixels misclassified as built-up area decreased. The producer's and user's accuracy was calculated for the land cover map obtained using SAR + Optical images (Figure 5).

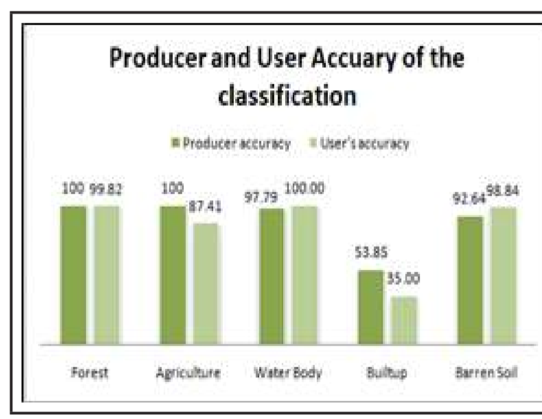

Figure 6: Producers and Users accuracy

Producer's and user's accuracy for each land cover classes were high except for the built-up class. The producer's accuracy was 53.85% while the user's accuracy was 35.00% only, which shows there is high percentage of misclassification in built-up class. About 31% of built-up was misclassified as barren land and about 15% as agricultural area while 65% of area classified as built-up area represents barren land which shows that there is high percentage of misclassification between built-up area and barren land classes.

4. CONCLUSION

This paper focuses on using combined SAR and optical image for land cover classification using Random Forest algorithm and assesses the accuracy of land cover maps prepared using SAR image, Optical image and combination of both images.

The accuracy obtained from land cover map using SAR image was the least while accuracy obtained using optical and combination of both images were found to be high. Also, there was an increment in the accuracy of the land cover map obtained by using optical and SAR image than the optical image only which shows that an improved land cover classification can be obtained providing detailed land cover classes.

REFERENCES

Ali, J., Khan, R., Ahmad, N., Maqsood, I., (2012). *Random forests and decision trees.*

Brisco, B. And Brown, R., (1995). *Multidate SAR/TM synergism for crop classification in western Canada. Photogrammetric Engineering and Remote Sensing*, 61, pp. 1009–1014.

Grinand, C., Rakotomalala, F., Gond, V., Vaudry, R., Bernoux, M., Vieilledent, G., (2013). *Estimating deforestation in tropical humid and dry forests in Madagascar from 2000 to 2010 using multi-date Landsat satellite images and the random forests classifier.*, 139, 68–80.

Horning, N., (2010). Random Forests: *An algorithm for image classification and generation of continuous fields data sets. In Proceedings of the International Conference on Geoinformatics for Spatial Infrastructure Development in Earth and Allied Sciences*.

Joshi, N., Baumann, M., Ehammer, A., Fensholt, R., Grogan, K., Hostert, P., ... & Waske, B. (2016). A review of the application of optical and radar remote sensing data fusion to land use mapping and monitoring. *Remote Sensing*, *8*(1), 70.

Mcnairn, H., Ellis, J., Van Der Sanden, J., Hirose, T. And Brown, R.J., (2002). *Providing crop information using Radarsat-1 and satellite optical imagery. International Journal of Remote Sensing*, 23, pp. 851–870.

Model, T. and Srivastava, T., (2020). Random *Forest Parameter Tuning | Tuning Random Forest.*

Pohl, C. and Van Genderen, J.L., (1998).*Multisensor image fusion in remote sensing: Concepts, methods and applications. International Journal of Remote Sensing*, 19, pp. 823–854.

Qinghua, Y., Zhizhong, L., Hongbin, F., Maocheng, Y., Zhigans, S., Shuenxi, L. And Wenzhang, Q., (2001).*Application Of Radar Image In Land Use Dynamic Monitoring In Beijing.*

Rosenthal, W.D., Blanchard, B.J. and Blanchard, A.J., (1985).*Visible/infrared microwave agriculture classification, biomass and plant height algorithms.* IEEE Transactions on Geoscience and Remote Sensing, 23, pp. 84–90.

Sahebjalal, E., & Dashtekian, K., (2013). Analysis of land use-land covers changes using normalized difference vegetation index (NDVI) differencing and classification methods. *African Journal of Agricultural Research*, *8*(37), 4614-4622.

Sim, C. K., Abdullah, K., Jafri, M. Z. M., & San Lim, H. (2013). Combination of radar and optical remote sensing data for land cover/use mapping. In *2013 IEEE International Conference on Space Science and Communication (IconSpace)* (pp. 224-227). IEEE.

Soria-Ruiz, J., Fernandez-Ordonez, Y. and Woodhouse, I., (2010). *Land-cover classification using radar and optical images: a case study in Central Mexico.*

Tadesse, H. & Falconer, A., (2014).*Land Cover Classification And Analysis Using Radar And Landsat Data In North Central Ethiopia*.

William E., Adriano C., (2017). *Introduction to Satellite Remote Sensing*

Author's Information

Name	:	David Nhemaphuki
Academic Qualification	:	Qualification: Bachelor in Geomatics Engineering
Current Organization	:	Survey Department of Nepal
Current Designation	:	Survey Officer
Work Experience	:	5 years
Published paper/article	:	None
E-mail	:	davis10ge@gmail.com

Price of Maps

S.No.	Description	Scale	Coverage	No. of sheets	Price per sheet (NRs)
1.	Topo Maps	1:25 000	Terai and mid mountain region of Nepal	590	150
2.	Topo Maps	1:50 000	HIgh Mountain and Himalayan region of Nepal	116	150
3.	Land Utilization maps	1:50 000	Whole Nepal	266	40
4.	Land Capibility maps	1:50 000	Whole Nepal	266	40
5.	Land System maps	1:50 000	Whole Nepal	266	40
6.	Geological maps	1:125 000	Whole Nepal	81	40
7.	Districts maps Nepali	1:125 000	Whole Nepal	76	50
8.	Zonal maps (Nepali)	1:250 000	Whole Nepal	15	50
9.	Region maps (Nepali)	1:500 000	Whole Nepal	5	50
10.	Nepal (English)	1:500 000	Whole Nepal	3	50
11.	Nepal Map (Nepali)	1:1000 000	Nepal	1	50
12.	Nepal Map (Nepali)	1:2000 000	Nepal	1	15
13.	Nepal Map (English)	1:1000 000	Nepal	1	50
14.	Nepal Map (English)	1:2000 000	Nepal	1	15
15.	Physiographic Map	1:2000 000	Nepal	1	15
16.	Photo Map			1	150
17.	Wall Map (loosesheet)		Nepal	1 set	50
18.	VDC/Municipality Maps (Colour)		Whole Nepal	4181	50
19	VDC/Municipality Maps A4 Size		Whole Nepal	4181	5
20.	VDC/Municipality Maps A3 Size		Whole Nepal	4181	10
21.	Orthophoto Map		Urban Area (1:5000) and Semi Urban Area (1:10000)	-	1 000
22.	Outlined Administrative Map A4 size		Nepal	1	5

Price of co-ordinates of Control Points

Type	Control Points	Price per point
Trig.Point	First Order	Rs 3 000.00
Trig. Point	Second Order	Rs 2 500.00
Trig. Point	Third Order	Rs 1 500.00
Trig. Point	Fourth Order	Rs 250.00
Bench Mark	First & Second Order	Rs 1 000.00
Bench Mark	Third Order	Rs 250.00
Gravity Point	-	Rs 1 000.00

Geo-Information Modeling of Soil Erosion for Sustainable Agriculture Land Management in Sambhunath Municipality

Bikash Kumar Karna, Shobha Shrestha (Ph.D), Hriday Lal Koirala (Ph.D)
bikashkumarkarna@gmail.com, shova216@gmail.com, koiralahriday@gmail.com

KEYWORDS

Geo-information, Soil Erosion, Land Unit, RUSLE.

ABSTRACT

Geo-information science has attempted to estimate the actual soil loss and its correlative interpretation with land use and cover types in an agricultural land, Sambhunath Municipality. Among several empirical and physically based soil erosion models, Revised Universal Soil Loss Equation (RUSLE) are widely used and employed to estimate soil loss based on rainfall, topographic contour, and soil map. The soil erosion ranges values are found from 0 to 2635 t ha-1 yr-1 in terms of soil loss per year in the municipality. Soil erosion rates are found highly correlated with the increasing exposure of land surface in Chure range mostly on forest area. Agriculture lands spatially concentrated in 51.70% of the Municipality extent, is contributing significantly as of 16293 t ha-1 yr-1 of the total potential soil loss from fertile cropland. Based on severity of soil loss, cultivation agriculture areas are priority for reducing soil loss for optimum agriculture management practices in land use planning.

1. INTRODUCTION

Soil is defined as a loose inorganic particulate material formed from the mechanical and chemical disintegration and decomposition of rocks and minerals on the earth`s crust through the actions of natural or mechanical or chemical agent; with or without organic matter content that supports plant life (Kumar, 2014). Soil formed from the weathering of rocks by various agencies like wind, water, ice, gravity at the place of origin and transported towards along lower land form and termed as sedimentary soils. So, the top soil lost from the mountain area is major cause of raising the riverbeds through siltation in the Tarai and estimated annual rate of 15–30 cm in Nepal (Mandal, 2017).

Erosion is a natural geological phenomenon occurring continually over the earth`s surface resulting from the removal of soil particles by rainwater or wind, transporting them to another place. Soil erosion is a process that transforms soil into the sediment. Sediment consists of transported and deposited particles or aggregates derived from rock, soil, or biological material. It is removed the fertile topsoil and transports it into the water bodies, reducing the fertility of arable cultivable land and causing the loss of food production. The transported sediments in water bodies have also degraded water quality and cause eutrophication of freshwater bodies (Pimentel, 2006). It is a major issue in land use planning for minimizing the cause of destruction and sustainability of agriculture upland and ecological restoration through preparing erosion control plans. In humid regions, soil erosion is concerned with high risk in forests and paddy fields, however bare lands such as logging forests, construction areas, and upland crop fields on slopes (Koirala et. al.2019). Several models has used to predict the soil erosion from empirical as USLE (Wischmeier & Smith, 1978), MUSLE (Williams & Berndt, 1977), SLEMSA (Stocking, 1981; Morgan et al. 1984), RUSLE (Renard et al. 1997), EUROSEM (Morgan et al. 1998), WEPP (Flanagan et al. 2001) to physical or process-based as MMF (Morgan et al. 1984). In this research, Revised Universal Soil Loss Equation (RUSLE) has used for modeling the soil erosion. The RUSLE represents how climate, soil, topography, and land use affect rill and inter rill soil erosion caused by raindrop impacts. It has been extensively used to estimate soil erosion loss, to assess soil erosion risk, and to guide development and conservation plans in order to control erosion under different land-cover conditions, such as croplands, rangelands, and disturbed forest lands (Milward &Mersy, 1999; Koirala et. al, 2019). A combination of remote sensing, GIS and RUSLE has more compatible for the potential to estimate soil erosion loss and its spatial distribution on a cell-by-cell basis and feasible for better accuracy.

2. STUDY AREA

Sambhunath Municipality is formulated on 18th May, 2014 by integration of previous Village Development Committees of Khoksar Parbaha, Shambhunath, Mohanpur, Bhangha, Basbalpur and Rampur Jamuwa of Sapatari district in Pronince 2. The municipality got its shape after formulation of Nepalese Constitution 2072; the local level has been reconstructed by reducing the number of local level to 753 local units. However, Sambhunath Municipality has been expanded further in the year 2017 by merging previous Arnaha VDC. The municipality is located at the latitude from 26^0 23’ 35” to 26^0 42’ 36” and longitude from 86^0 37’ 39” to 86^0 44’ 54”. The Study area is shown in Figure 1.

Figure 1: Study Area

The total area of the municipality is 108.46 sq.km having 12 wards as its sub-units. The municipality headquarter office is located at Kathauna Bazar. This municipality is bordered with Dakneshwori Municipality, Belhichapena Rural Municipality and Bishnupur Rural Municipality in south, Khadak Municipality in west, Rupani Rural Municipality in east and Triyuga Municipality of Udaypur district in the north. The naming of the municipality as Shambhunath is because of the one of the famous temples which is situated within the municipality area.

3. DATA USED

The secondary data/information is collected from different sources and used in this research is presented in Table 1.

Table 1: Data Used

S.N.	Description	Source
1	WorldView-2 Satellite images, 2016	National Land Use Project, Nepal
2	Topographical map & digital databases	Survey Department, Nepal
3	VDC level soil chemical data	Survey Department, Nepal
4	Rainfall data	Department of Hydrology & Metrology

4. EXPLANATION OF FRAMEWORK

The framework of RUSLE Model with associated the parameters of the soil loss estimation is explained in Figure 2.

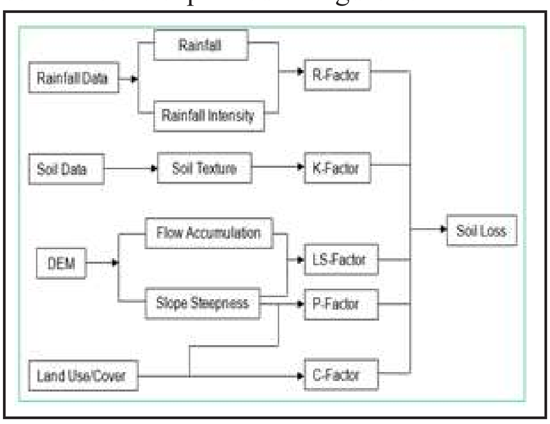

Figure 2: Soil Erosion Framework

Rainfall erosivity factor (R) is computed from the rainfall intensity data that located surrounding to the municipality area having six metrological stations (Rajbiraj, Lahan, Gaighat, Fatepur, Chatara and Barmajhiya). For annual rain, rainfall data of these metrological stations are collected from Department of Hydrology and Metrology at the period of 1970 to 2019 about 50 years. In this study, the average rainfall map was prepared by the spatial interpolation from the average annual rainfall using kriging geostatistical technique in GIS. The generated rainfall has been used for estimation of R factor with the following equation (Morgan, 1985; Mandal, 2017)

$$R = 38.5+0.35\ E \qquad (1)$$

where, E is the annual mean rainfall in mm.

Soil Erodibility Factor (K) describes the susceptibility quantity of soil in the flow of runoff water that transported through erosion process in a given specific rainfall. In this study, the absence of soil structure and soil permeability value, the K factor has estimated with the following equation (Sharpley & Williams, 1990).

$$K = Fcsand * Fsi - cl * Forgc * Fhisand * 0.1317 \qquad (2)$$

where,

$$Fcsand = [0.2 + 0.3 \exp(-0.0256\ SAN(1 - SIL/100))] \qquad (3)$$

$$\mathrm{Fsi-cl} = \left[\frac{\mathrm{SIL}}{(\mathrm{Cl+SIL})}\right]^{0.3} \qquad (4)$$

$$\mathrm{Forgc} = \left[1.0 - \frac{0.25\ c}{c+\exp(3.72-2.95c)}\right] \qquad (5)$$

$$\mathrm{Fhisand} = \left[1.0 - \frac{0.70\mathrm{SN1}}{\mathrm{SN1}+\exp(-5.51+22.9\mathrm{SN1})}\right] \qquad (6)$$

$$\mathrm{SN1} = \frac{1-\mathrm{SAN}}{100} \qquad (7)$$

where, SAN, SiL and Cl are % sand, silt and clay respectively and c is the organic carbon content (organic matter). Fcsand gives a low soil erodibility factor for soil with coarse sand and a high value for soil with little sand content. Fsi-cl gives a low soil erodibility factor with high clay to silt ration. Forgc is the factor that reduces soil erodibility for soil with high organic content. Fhisand is the factor that reduces soil erodibility for soil with extremely high sand content (Koirala et. al. 2019). The sand, silt, clay and organic matter map is generated using kriging technique based on the soil sample data.

Topographic factor (LS) is computed with the reference of two factors (slope length and slope steepness). In the study, both slope length and slope steepness are derived from the DEM and computed from these factors in grid format using the following relation.

$$LS = L * S \qquad (8)$$

where, L is the slope length factor and S is the slope steepness factor. The slope length (L) is computed using the following relation (Gao et.al, 2012; Koirala et. al, 2019).

$$L = \left(\frac{\lambda}{22.13}\right)^{m} \qquad (9)$$

where, λ is the contributing slope length and m is the variable slope length exponent that varies based on slope steepness. The contributing slope length λ is derived from flow accumulation map with the size of grid raster factor as the base for preparing L-Factor map. The flow accumulation map is generated from DEM using hydrological modeling. The slope length exponent ‘m’ is related to the ratio of rill erosion to inter rill erosion (caused by raindrop impact). The contributing slope length is measured from the flow accumulation of runoff in water enters a well-defined channel and grid raster size (Koirala et. al. 2019).

$$m=\frac{F}{1+F} \tag{9}$$

$$F=\frac{Sin\theta/0.0896}{3(sin\theta)^{0.8}+0.56} \tag{10}$$

where F is the ratio of rill erosion to inter rill erosion; θ is the slope angle in degree.

The slope steepness factor (S) was computed from the following relation (McCool et al., 1987).

$$s = 10.8 * sin\theta + 0.03,\ S < 9\%\ (tan\theta < 0.09)$$

$$S = \left(\frac{sin\theta}{sin5.143}\right)^{0.6}, \qquad S \geq 9\%\ (tan\theta \geq 0.09) \tag{12}$$

where θ is the slope angle in degree.

Erosion control practice factor (P-factor) is generated from the existing agriculture practice of land in different slope. Initially, existing land use is categorized into agricultural and other land in major types. Then, agricultural land is sub-divided into six slope classes and assigned p-value for each respective slope class as many management activities reference with highly dependent on slope of the area. In this study, the p-value is assigned with considering local management practices of agriculture land using the following relation in Table.2 (Wischmeier & Smith, 1978).

Table.2: Conservation Practices Factor Value

Land Use	Slope Gradient (%)	P-Factor
Agricultural Land	0-5	0.10
	5-10	0.12
	10-20	0.14
	20-30	0.19
	30-50	0.25
	50-100	0.33
Non-agricultural Land		1.00

(Source: Wischmeier & Smith, 1978)

Cover-management factor (C) is normally assigned based on the existing situation of land use and simply assessment of vegetation cover rather than close analysis of agricultural cropping patterns. In this study, the C factor is assigned with considering management practices of vegetation cover using the following relation in Table.3 (Koirala et. al, 2019).

Table.3: Cover Management Factor Value

S.N.	Land Use	C-Factor
1	Forest	0.03
2	Shrub land	0.02
3	Grass land	0.01
4	Agriculture	0.21
5	Barren land	0.45
6	Orchard/Plantation	0.02
7	Bamboo	0.02
8	Water body	0.00
9	Built-up	0.00

(Source: Koirala et. al, 2019)

The potential soil erosion map is produced from the R, K, LS, P and C factor map in ArcGIS 10.4 by the raster multiplication as the function used in RUSLE model.

5. RESULT AND DISCUSSION

In humid regions likes Sambhunath Municipality, soil erosion is concerned with high risk in forests and paddy fields, however bare lands such as logging forests, construction areas, and upland crop fields on slopes (Koirala et al., 2019). Soil erosion with RUSLE model is used rainfall erosivity, soil erodibility, topography, crop management, and conservation practice factors as parameters for estimation of soil loss through rainfall and surface water flow. The rainfall erosivity factor (R) is described the erosivity of rainfall at a particular location based on the rainfall amount and intensity that reflects the effect of rainfall intensity on soil erosion. The rainfall erosivity is used to quantify the effect of raindrop impact and explain the amount of rainfall and rate of runoff associate with rainfall i.e. rainfall intensity (Wischmeier & Smith, 1978; Koirala et. al, 2019). Soil loss is related to kinetic energy of rainfall through the detachment power of raindrops striking the soil surface and the entrainment of the detached soil particles by runoff water down slope (Mandal, 2017). The rainfall measurement data is essential for preparing R-factor. The rainfall map is prepared from spatial interpolation technique using Kriging from the average rainfall data and R-factor map is generated using Equation (1). The prepared R-prepared factor map is shown in Figure 3.

The rainfall erosivity range is varied between 561 and 580 mm ha-1 h-1 yr-1 in R-factor map having highest in North-western part and the lower values in the South of the municipality.

The Soil Erodibility Factor (K) is characterized the susceptibility of soil or surface material to erosion, transportability of the sediment, and the quantity and rate of runoff given a specific rainfall input as measured under a standard circumstance. K-factor is used for representing the quantitative description of the inherent erodibility component of a particular soil type; based on the susceptibility of soil particles to detachment and transport by rainfall and runoff.

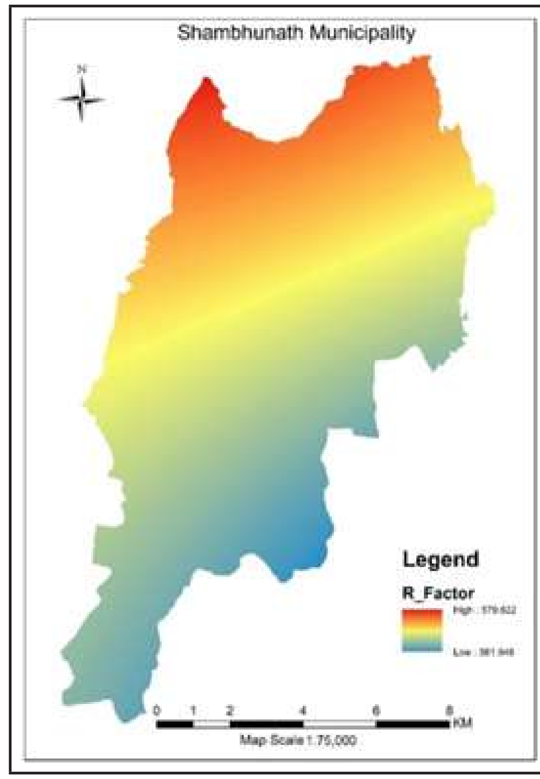

Figure.3: R-Factor Map

The main soil properties influencing the K factor is soil texture, organic matter, soil structure and permeability of the soil profile and reflected the rate of soil loss per rainfall erosivity (R) index. For a particular soil, the soil erodibility factor is based on the rate of erosion per unit erosion index from a standard unit plot of 22.13m long slope length with 9% of slope gradient (Ganasri & Ramesh, 2016) maintained in continuous fallow, tilled up and downcast the hill slope (Kim, 2006). Based on the collected soil sample data; sand, silt, clay and organic matter maps are generated using Kriging spatial interpolation technique in geo-statistical analysis. The R-factor map is prepared using Equation (2) and presented in Figure.4.

The soil erodibility range is varied from 0.024 to 0.058 in the K-factor map. The distribution of K factor is found in the scattered nature on the soil texture properties within the municipality.

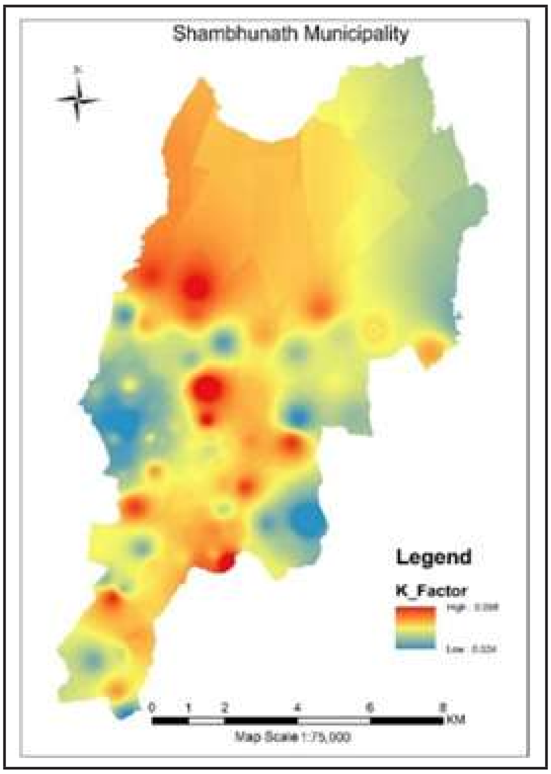

Figure..4: K-Factor Map

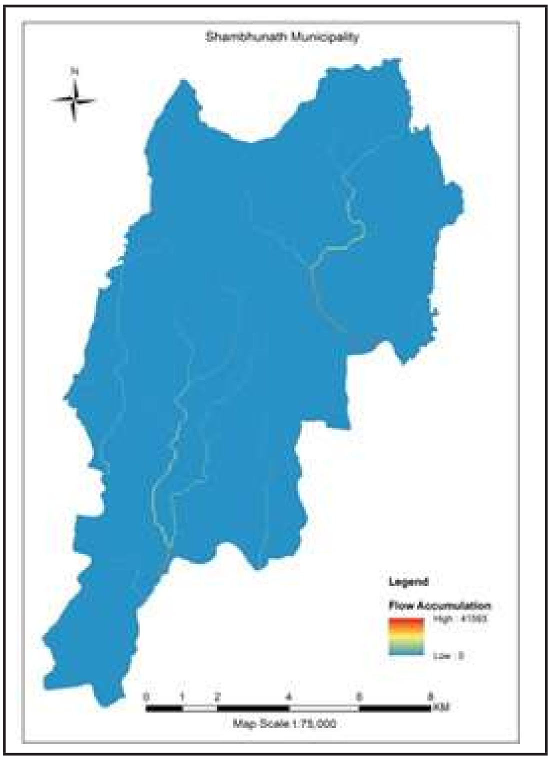

Figure. 5: Flow Accumulation Map

Topographical factors are based on the slope length and steepness for calculating the transport capacity of overland flow (surface runoff). The higher the velocity and greater the concentration of water, there is occurred greater occurrence rate of the soil erosion. Therefore, the topographical factors are the key component for estimating soil erosion risk based on slope length (L) and slope steepness (S). The L is represented the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition begins or the runoff water enters a well-defined channel that may be part of a drainage network or a constructed channel (Mandal, 2017). The S is represented the effect of slope steepness on soil loss to terrain gradient and influenced by the vegetation coverage and the soil particle size (Koirala et. al, 2019). These both L-factor and S-factor are based on flow accumulation map (presented in Figure5).

The slope length (L-factor) map is generated from Equation (9) and shown in Figure. 6.

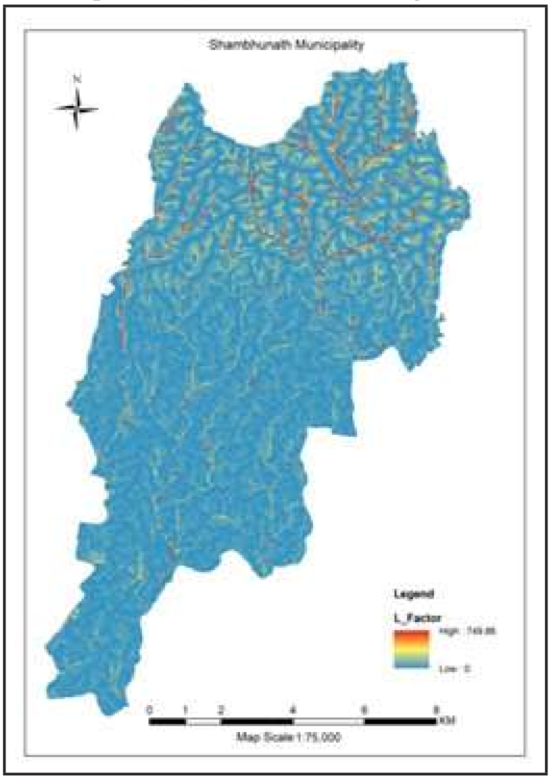

Figure. 6: L-Factor Map

Likewise, slope steepness (S-factor) map is generated from Equation (12) and shown in Figure 7.

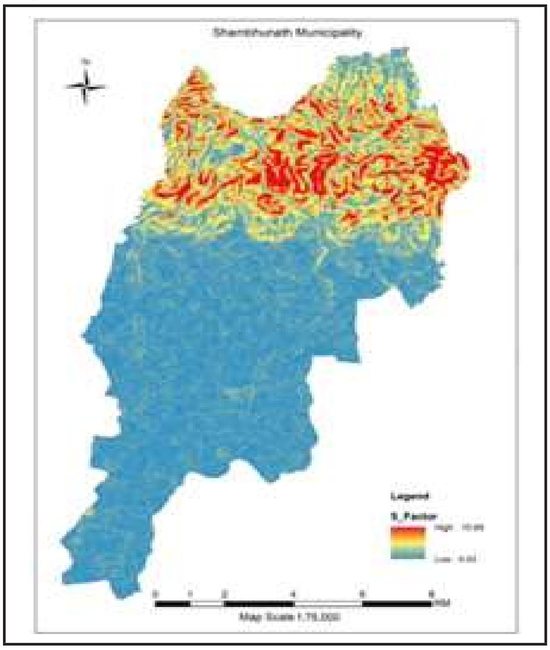

Figure 7: S-Factor Map

The topographical (LS factor) is represented the combined effect of slope length and steepness relative to a standard unit plot and increased LS factor through increase in hill slope length and steepness. The topographical factor map is generated using Equation (8) and shown in Figure.8.

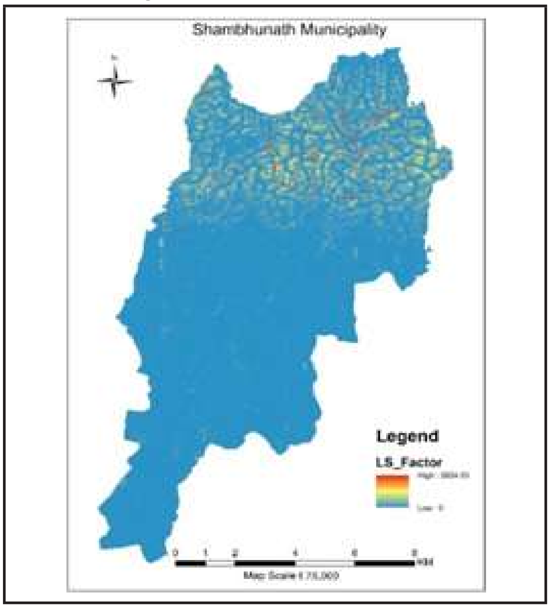

Figure.8: LS-Factor Map

From the slope length factor (L) showed that the L-factor value ranges from 0 to 750 having scattered pattern depending upon the terrain condition and water runoff in drainage channel course in the South of the municipality. From the Slope Steepness Factor (S) map showed that the S-factor value ranges from 0.03 to 10.69 having highly depending upon northern part in the Siwalik hill with steepness of terrain and lesser in southern part of the municipality. The topographical factor (LS) ranges from 0 to 3824 is found from LS-factor map and depicting the highly intensity of LS-factor in northern part of the municipality depending with steepness of terrain and lesser intensity in southern part of the municipality having flat terrain.

Erosion control practice factor (P-factor) is the ratio of soil loss with a specific support practice to the corresponding loss with up slope and down slope cultivation (Wischmeier & Smith, 1978). The P-factor is considered for the control practices to reduce the eroding power of rainfall and runoff by their impact on drainage patterns, runoff concentration, and runoff velocity. The supporting mechanical practices included the effects of contouring, strip cropping, or terracing (Hyeon & Pierre, 2006). The P-factor is generated based on agriculture practices in different slope regimes and assigned for each respective slope class on the many control management activities. The conservation practice value is applied in the integrating land use and slope gradient. The prepared P-factor map is shown in Figure 9.
The cover-management factor (C) is used to reflect the effect of cropping and other management practices on erosion rates. Vegetation cover is the second most important factor next to topography that controls soil erosion risk.

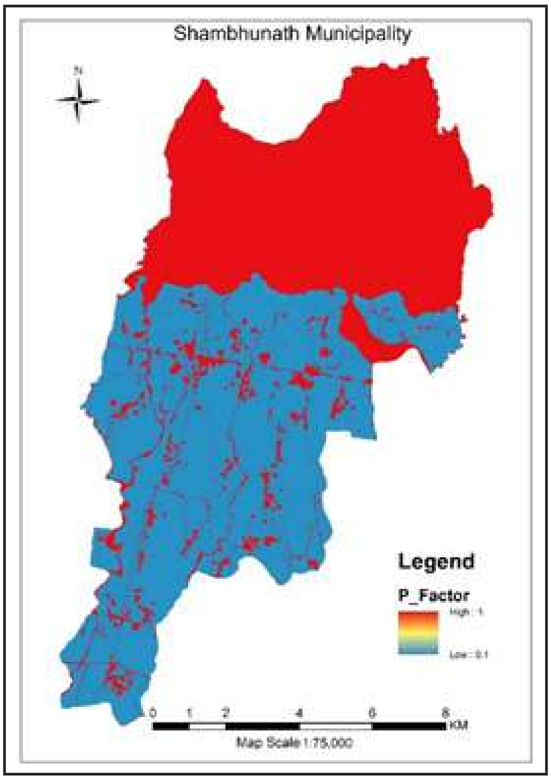

Figure 9: P-Factor Map

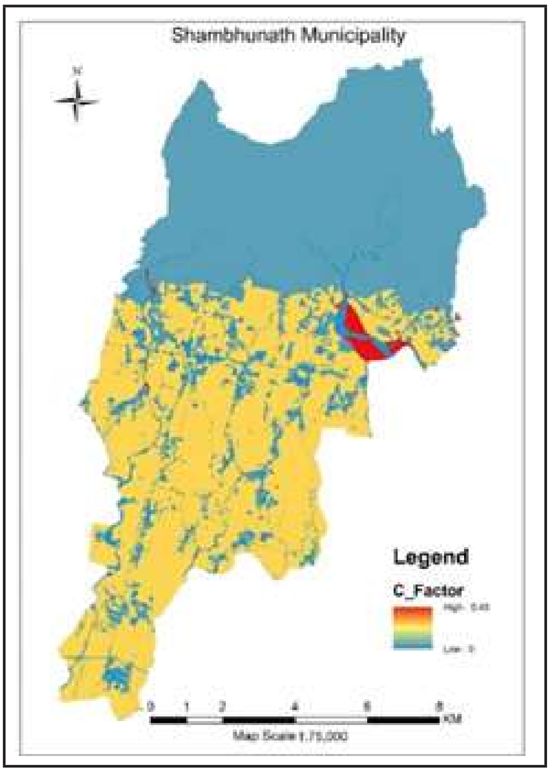

Figure.10: C-Factor Map

The land cover intercepts rainfall, increases infiltration, and reduces rainfall energy. In areas where land uses other than cropping dominate C-factor value is comparatively lower than the cropping area. The C factor ranges is varied from 0 to approximately 1, where higher values indicate no cover effect and soil loss comparable to that from a tilled bare fallow, while lower C means a very strong cover effect resulting in no erosion (Koirala et. al, 2019). The C-factor is generated in term of vegetation covers from land use class based on land cover management activities. The prepared C-factor map is shown in Figure.10.

The potential soil erosion map is produced from the R, K, LS, P and C factor map in ArcGIS by the raster multiplication through map algebra as the function used in RUSLE model.

The soil erosion ranges values are occurred from 0 to 2635 t ha-1 yr-1 in terms of soil loss per year with total 362810 t ha-1 yr-1 in the municipality.

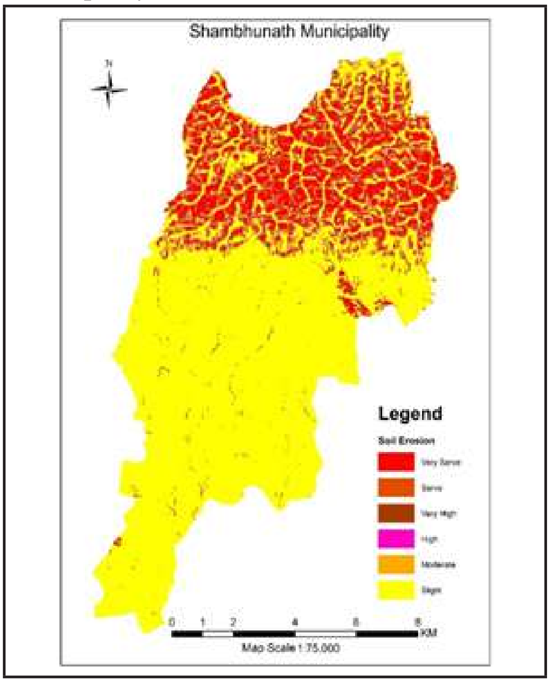

Figure 11: Soil Erosion Map

From the soil erosion results showed that the distribution of the low risk of soil risk has slightly erosion area with 72% having less than 5 t ha-1 yr-1, medium risk of soil risk has moderate erosion area with 5% having soil erosion rate between 5-10 t ha-1 yr-1 and the high risk of soil risk has high, very high, serve and very serve erosion area with 5% having soil erosion rate greater than 10 t ha-1 yr-1. The impact of potential soil risk assessment has carried out by the process of spatial overlay operation using zonal statistics of soil erosion potential layer to land use layer 2017. The potential soil erosion risk in the land use categories is shown in Table 4.

Table 4: Soil Erosion Impact on Land Use

S.N.	Land Use Description	Potential Soil Loss (tons/ha)			
		Max	Avg	Total	%
1	Agriculture	174.83	0.26	16293.11	4.49
2	Forest	2635.78	6.81	333104.27	91.81
3	Water body	202.33	0.44	1681.36	0.46
4	Residential	38.69	0.04	109.58	0.03
5	Other	574.72	10.17	11475.92	3.16
6	Public Use	10.45	0.14	139.44	0.04
7	Industrial	1.15	0.01	4.88	0.00
8	Commercial	0.38	0.01	0.93	0.00
9	Cultural & Archeological	0.00	0.00	0.00	0.00
	Total			362809.50	100.00

Potential soil losses in Sambhunath Municipality have estimated with references to the land use and cover types in order to understand its role in determining erosion rate. The potential soil loss by land use and land cover types and its summary statistics are given in Table 4. Soil erosion rates are found highly correlated with the increasing exposure of land surface. In potential soil loss estimation, degraded forest area is sharing about 92% of total soil loss within the municipality extent. Similarly, in case of agriculture, about 4.49% of total soil loss has causal to soil loss in the municipality which has in Terai agriculture watershed as comparatively less than Siwalik hill in the upper portion. Likewise, the other land mainly open space is causal rate of soil loss about 3.16% total soil loss within the municipality extent.

After soil loss analysis, the severity of agriculture land is essential to priorities the areas having high rate of soil erosion for sustainability of agriculture practices. In this context, the priorities in agriculture areas where high rate of soil erosion estimated are observed (Table 5).

Table 5: Priority of Soil Loss in Agriculture Use

Soil loss (t ha-1 yr-1)	Risk Level	Area (ha)	Priority
< 5	Slight	55.20	Low
5-10	Low	38.55	Low
10-20	Moderate	16.76	Moderate
20-40	High	10.45	High
40-80	Serve	6.38	High
>80	Very Serve	16.90	High
Total		144.24	

These areas are spatially concentrated in north east direction of municipality having agriculture practices in degraded situation and instable slope that are to be given high attention for upstream of Khando River watershed conservation and also for sustainability of agriculture development in downstream. Based on severity of soil loss, cultivation areas are also to be given priority with optimum agriculture management practices for reducing soil loss. Soil conservation measures are to be adopted on more degraded areas for sustainable agriculture management required for sustainable land use planning.

6 CONCLUSION

A total of 3.6 million tons soil is estimate the soil lost annually through soil erosion with the ranges of intensity from 0 to 2635 t ha-1 yr-1. Soil erosion rates are found highly correlated with increasing exposure of land surface mostly on forest area in Chure range. Agriculture practices land is concentrated spatially with 51.70% having significantly soil loss 0.16 million ton annually. So, there is required essential management in cultivation areas and prioritized based on severity of soil loss for optimum agriculture management practices in land use planning.

REFERENCES

Flanagan, D.C., Ascough, J.C, Nearing, M.A.& Laflen, J.M. (2001). Water erosion prediction project (WEPP) model. Landscape erosion and evolution modeling. Kluwer Academic Publishers, Norwell.

Ganasri, B.P. & Ramesh, H. (2016). Assessment of soil erosion by RUSLE model using remote sensing and GIS-A case study of Nethravathi Basin. *Geoscience Frontiers*, 7: 953–961.

Gao, G.Y., Fu, B.J., Liu, Y., Wang, S. & Zhou, J. (2012). Coupling the modified SCS-CN and RUSLE models to simulate hydrological effects of restoring vegetation in the Loess Plateau of China. Hydrol. *Earth Syst. Sci*, 16: 2347–2364.

Hyeon, S. K. & Pierre, Y. J. (2006). Soil erosion modeling using RUSLE and GIS on the IMHA watershed. *Water Engineering Research*, 7(1): 29-41.

Kim, H.S. (2006). Soil Erosion Modeling Using RUSLE and GIS on the IMHA Watershed, South Korea. Ph.D. Dissertation. Colorado State University, USA.

Koirala, P., Thakuri, S., Joshi, S. & Chauhan, R. (2019). Estimation of Soil Erosion in Nepal Using a RUSLE Modeling and Geospatial Tool. *Geoscience*, 9: 1-19.

Kumar, U. (2014). Estimation of soil erosion using RUSLE and Arcgis in Dholpur District. Master of Technology Thesis. Malaviya National Institute of Technology, Jaipur, India.

Mandal, U.K. (2017). Geo-information-Based Soil Erosion Modeling for Sustainable Agriculture Development in Khadokhola Watershed, Nepal. Land Cover Change and Its Eco-environmental Responses in Nepal; Springer Geography. Springer Nature Singapor Pvt. Ltd. Gateway East, Sinapore: 223-241.

Milward, A.A.& Mersy, J.E. (1999). Adapting RULSE to model soil erosion potential in a mountainous tropical watershed. *Catena*, 38: 109–129.

Morgan, R.P.C. (1985). Soil erosion measurement and soil conservation research in cultivated areas of the UK. *Geographical J.*, 151: 11–20.

Morgan, R.P.C., Morgan, D.D.V. & Finney, H.J. (1984). A predictive model for the assessment of soil erosion risk. *J Agric Eng Res*, 30:245–253.

Morgan, R.P.C., Quinton, J.N., Smith, R.E., Govers, G., Poesen, J.W.A., Auerswald, K., Chisci, G., Torri, D.& Styczen, M..E. (1998). The European Soil Erosion Model (EUROSEM): A dynamic approach for predicting sediment transport from fields and small catchments. *Earth Surf Proc Land*, 23: 527–544

Renard, K.G., Foster, G.R., Weesies, G.A., McCool, D.K.& Yoder, D.C. (1997). Predicting soil erosion by water: a guide to conservation planning with the revised universal soil loss equation (RUSLE). Agricultural handbook, 703. USDA, Washington DC, USA.

Stocking, M. (1981). A working model for the estimation of soil loss suitable for underdeveloped areas. Development studies, occasional paper No. 15, University of East Anglia, Norwich, UK.

Williams, J. R. & Berndt, H.D. (1977). Sediment yield prediction based on watershed hydrology. *Trans ASAE*, 20: 1100–1104.

Wischmeier W.H. & Smith D.D. (1978). Predicting rainfall erosion losses. In Agricultural handbook, 537. USDA, Washington DC, USA.

Author's Information

Name	:	Bikash Kumar Karna
Academic Qualification	:	Master of Technology in Remote Sensing and Geographical Information System
Organization	:	Survey Department
Designation	:	Chief Survey Officer
Work Experience	:	22 Year
Published Paper/Article	:	8
Email	:	bikashkumarkarna@gmail.com

CALENDAR OF INTERNATIONAL EVENTS

ICSRSDP 2021: 15. International Conference on Satellite Remote Sensing and Data Processing
Date:23-24, September,2021
Country: London, United Kingdom (Digital)
Website:https://waset.org/

ISPRS TC IV: "Smart Data, Smart Cities"2021
Date: 15-17, September, 2021
Country: Stuttgart, Germany (Hybrid Conference)
Website: https://www.udms.net/

INTERGEO 2021
Date: 21-23, September, 2021
Country: Hannover (Live+ Digital)
Website: https://www.intergeo.de/

SPRS WG IV/4, WG IV/9 & WG V/8, FOSS4G 2021
Date: 27 Sep-02 Oct, 2021
Country: Buenos Aires, Argentina
Website: https://2021.foss4g.org/

ISPRSWGI V/7 International Conference Geospatial Asia-Europe 2021
Date: 05-06 Oct 2021
Country: Marrakesh, Morocco
Website: https://www.geoinfo.utm.my/gae2021/

ISPRSTCIV 3D GeoInfo, 2021, The 16th 3D GeoInfo Conference in conjunction with 3D Cadastres
Date: 11-14 Oct 2021
Country: New York City, USA
Website: https://3dgeoinfo2021.github.io/

3rd International Conference & Exhibition Advanced Geospatial Science & Technology
Date: 20-22 October 2021
Country: Tunisia
Website:http://www.teangeo.org/En/

SPRS/WG/IV/1, SCA'21, The 6th International Conference on Smart City Applications
Date: 27-29 Oct 2021
Country: Safranbolu, Turkey
Website: http://www.medi-ast.org/SCA2021/

IGD, Third Intercontinental Geoinformation Days
Date: 17-18 Nov 2021
Country: MersinUniversityTurkey (Online)
Website: http://igd.mersin.edu.tr/2020/

ISAG2021, International Symposium on Applied Geoinformatics
Date: 02-03 Dec 2021
Country: Riga, Latvia
Website: http://isagsymposium.org/

21st International Scientific Geo-Conference SGEM Vienna Green 2021
Date: 07-11 Dec 2021
Country: Vienna, Austria
Website: https://www.sgemviennagreen.org/

JURSE 2021, Joint Urban Remote Sensing Event
Date: 01-04 Feb 2022
Country:Medellin, Colombia
Website: http://www.eafit.edu.co/jurse2021

ISPRS WG V/7, Measurement, Visualization and Processing in BIM for Design and Construction Management II.
Date: 07-08 Feb 2022
Country: Prague, Czech Republic
Website: http://www.mvpbim2022.org/

ISPRS WG I/7, WG I/2, WG I/6, WG II/3
The 12th International Conference on Mobile Mapping Technology
Date: 25-27 May 2022
Country: Padua, Italy
Website: not yet available

XXIVth ISPRS Congress, Imaging today, Foreseeing Tomorrow
Date:06-11 Jun 2022
Country: Nice, France
Website: http://www.isprs2020-nice.com/

COSPAR 2022, 44th Scientific Assembly of the Committee on Space Research (COSPAR) and Associated Events
Date: 16-24 Jul 2022
Country: Athens, Greece
Website: https://www.cospar-assembly.org/

5th Joint International Symposium on Deformation Monitoring JISDM 2022
Date: 6-8 April, 2022
Country: Valencia, Spain
Website: https://jisdm2022.webs.upv.es/

FIG Congress 2022
Date:15-20 May, 2022
Country:Cape Town, South Africa
Website: https://www.fig.net/fig2022/

Measurement of Height of Mt. Sagarmatha

Susheel Dangol, Prakash Joshi, Suraj KC, Mahesh Thapa,
Bigyan Banjara, Shanker KC, Stallin Bhandari
susheel.dangol@nepal.gov.np, lightjoshiji@gmail.com, kcsuraj21@gmail.com, mahesh100thapa@gmail.com, bigyan.banjara@nepal.gov.np,
shankerkc01@gmail.com, stallin.bhandari@gmail.com

KEYWORDS

Sagarmatha, Orthometric Height, Joint Announcement

ABSTRACT

The height measurement of the highest peak of the world "Sagarmatha" was conducted by Nepal for the first time. The methodology for the measurement was finalized from the workshop held in Kathmandu with the constructive comments from national and international experts. Trignometrical levelling, precise levelling, GNSS survey and gravity survey was conducted. Previous air borne gravity data and present surface gravity data was used to determine the precise regional geoid for this program. Thus orthometric height was determined as 8848.86 m from the ellipsoid height observed at the top of Sagarmatha and precise geoid determined. The height was determined on the base of International Height Reference System (IHRS) and final height was announced jointly from Nepal and China on 8th of December 2020 from Kathmandu and Beijing through virtual media.

1. BACKGROUND

Mt. Sagarmatha, the highest peak of the world which was discovered by geodetic survey (Angus-Leppan, 1982), has always been a national pride of Nepal. Since the identification of the peak as the highest peak of the world, several measurements of its height have been conducted in the past. It was first observed by J W Armstrong of Survey of India and named 'Peak b' which was later named 'Peak h' and then 'Peak XV' (Ward, 1995). J. W. Armstrong determined the height of Sagarmatha in 1847 as 8779 m (28799 ft) (Gulatee, 1954). In 1905, Burrard calculated the height of Sagarmatha as 8882 m (29141 ft) (Gulatee, 1954). Andrew Waugh and Nicholson determined its height as 8840 m (29002 ft) in 1849 (Gulatee, 1954). In 1954, B. L. Gulatee precisely calculated the height of Sagarmatha as 8848 m (290028 ft) (Gulatee, 1954). In 1975, Chinese geodetic surveyors measured the height of Sagarmatha and determined its height as 8848.13 m (Dansheng, 1979). Italian surveyors in 1992 determined the snow height of the Sagarmatha as 8848.65 m (Beinat *et. al*. 1992). In 1999, Washburn and Chen determined the height of Sagarmatha as 8850 m (Poretti, et. al, 2006). In 2004, Italian surveyor determined the rock height of Sagarmatha as 8848.82 m and snow height as 8852.12 m (Poretti, *et. al.*, 2006). In 2005, State Bureau of Surveying and Mapping (SBSM) of china determined the rock height of Sagarmatha as 8844.43m (Yamin, 2007). The orthometric heights of the snow surface and rock surface of the summit were determined as 8847.93m and 8844.43m respectively in the 2005 height measurement by China (Chen, et.al, 2010, Chen, et. al., 2006). Table 1 shows some history of height determination of Sagarmatha.

Table 1 : History of Sagarmatha height measurement.

S.N.	Measurement by	Geoidal elevation
1	Survey of India, 1849	8840
2	Sidney Burrard, 1905	8882
3	De Graaf Hunter, 1930	8854
4	B. L. Gulatee, 1954	8848
5	Desio and Caporali, 1987	8872
6	Ev-K2-CNR/SBSM, 1992	8848.65
7	J.Y. Chen, 1999	8849.71
8	Washburn & Chen, 1999	8850
9	EGM 96	8849.82

Source: Poretti, et. al., 2006

In spite of different height of Sagarmatha determined by different organizations, Nepal and the world have been adopting the height determined by B. L. Gulatee in 1954. In the mean time, devastating earthquakes triggered Nepal and arouse the question on change in the height of Sagarmatha due to the earthquake. Hence, to answer this probable query, Survey Department, Government of Nepal conducted the program to measure the height of Sagarmatha.

2. OBJECTIVE

The major objective of this research is to determine the updated orthometric height of the Sagarmatha after devastating earthquake of 2015. Secondary objectives of the research are as follows:

- Establishment of Permannent Bench Marks in the major road alignment of Siraha, Udaypur, Okhaldhunga and Solokumbu district which will be useful in the different engineering and construction works in future
- Establishment and strengthening of GNSS control points in the Siraha, Udaypur, Okhaldhunga, Khotang, Bhojpur, Ramechhap, Dolakha and other surrounding districts
- Derivation of highly accurate Geoid for the Sagarmatha region

3. STUDY AREA

For this program, the study area was selected as such, the regional Geoid can be computed.

Figure 1: District covered for the study.

For this reason, thirteen districts at the periphery of the Sagarmatha were selected which include Sankhuwasabha, Solukhumbu, Dolakha, Ramechhap, Okhaldhunga, Khotang, Bhojpur, Udaypur, Sindhuli, Mahottari, Dhanusha, Siraha and Saptari. The area was chosen such that the Sagarmatha lies at almost middle from east to west. The survey works were evenly distributed over the study area which covers thirteen districts (Figure 1).

4. METHODOLOGY

Different methods were followed in the past during measurement of the height of Sagarmatha. However, it can be seen that the latest available technology had been used during that observation and the technology adopted were seen gradually advanced according to the time of observation.

4.1. History of Sagarmatha Measurement

Different methods were adopted during previous Sagarmatha measurement. J. W. Armstrong used distance and vertical angle to determine the height of Sagarmatha in 1847 (Gulatee, 1954). Waugh conducted trignometrical leveling with reciprocal observations and also consideration of curvature of path and refraction coefficient for calculation of height (Gulatee, 1954). B. L. Gulatee too conducted triangulation and trignometrical leveling for which vertical angles were measured from eight stations viz. Mayam, Laori Danda, Aisyalukharka, Chhulyamu, Pike, Sollung, Upper Rauje and Lower Rauje and deflection of vertical observation was carried out to delineate geoid at Sagarmatha area (Gulatee, 1954). In 1966-68 and 1975 Chinese geodesists carried out two geodetic campaigns which include triangulation, traverse, astronomical and gravimetric measurements for the determination of the height and location of the Sagarmatha (Chen, 1993). The Chinese surveyor team erected a metallic beacon at the top and at the same time, other teams conducted leveling, triangulation, astronomical and gravimetric measurements were conducted (Dansheng, 1979). The height during this survey was determined by a trigonometrical survey from nine points in tibet among which one point was connected to Chinese geodetic height network (Beinat *et. al*, 1992). The Italian surveyors did triangulation as well as GPS measurement at the top together (Beinat, *et. al*. 1992). GPS and Ground Penetrating Radar (GPR) survey were conducted to determine the snow height and rock height respectively in 2004 survey by Italians (Poretti, *et. al*., 2006). In 2005, SBSM conducted GPS measurement at the top of the peak (Yamin, *et. al.*, 2007).

4.2. Methodology adopted by Nepal

Draft methodology was prepared at first from the technical team of the Survey Department. This draft methodology was presented to the community of international scientist in the workshop forum organized by Survey Department on 11-12 December 2017. The participants of the workshop were the experts in the field of geodesy and mountain measurements from China, India, Italy, Japan, Nepal, New Zealand, Switzerland and USA. Experts from different countries made presentations on geodesy, GNSS observations and mountain height measurements which include field measurements as well as remote sensing techniques for height measurement. The final methodology was prepared including the comments from the experts. Figure 2 shows the methods adopted by Survey Department for the measurement of the height of Sagarmatha.

For the program, the whole study area was divided into regular grid stretching 50 kilometers left and 50 kilometer right from Mt. Sagarmatha and from northern border to southern border. In the plain area, 10 X 10 km grid was made and in the remaining area 25 X 25 kilometer grid was made. In each grid, at least one control station was established for GNSS and Gravity survey was conducted. Detail methodology is discussed in the section below.

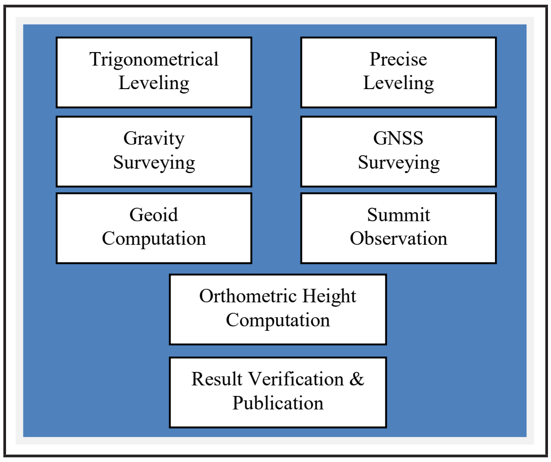

Figure 2: Sagarmatha height measurement methodology.

4.2.1 Trignometrical Leveling

Triangulation was done at 14 control stations within the study area. Among these stations peak observation was made from 10 stations. Meteorological data were also collected at every station. Figurel 3 shows the control stations from where trignometrical leveling and triangulation survey was conducted.

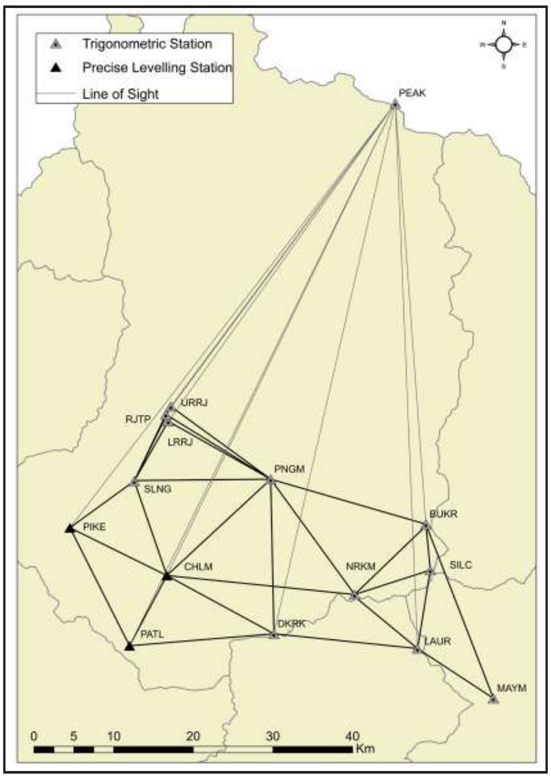

Figure 3: Trignometrical leveling control stations.

4.2.2 Precise Leveling

Precise leveling from Maadar of Siraha district of Nepal at the border between Nepal and India to three stations viz. Chhulyamu, Pike and Pattale was conducted. The total length of precise leveling was 248 kilometers. The datum station was established at the Maadar. To this station, height was carried from bench mark from India, which was supported by Survey of India.

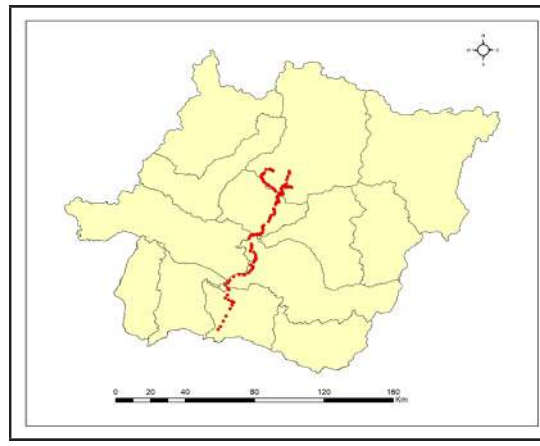

Figure 4: Precise leveling route.

4.2.3 GNSS Surveying

GNSS survey was conducted within the districts of study area. For this purpose, whole study area was divided into specific grid. Considering Sagarmatha at the center, the grid was planned to 50 kilometers east and 50 kilometers west from northern border to southern border. 10 km X 10 km grid was formed at hilly region and 25km X 25 km grid was formed at plain area. The survey was conducted in the control stations established within these grids. Besides these stations, GNSS survey was further conducted at every Permanent Bench Marks (PBM) and Special Bench Mark along the leveling route. GNSS survey was also conducted at the top of Sagarmatha. During GNSS observation at the top, other nine stations were also occupied with the GNSS receiver conducting the survey.

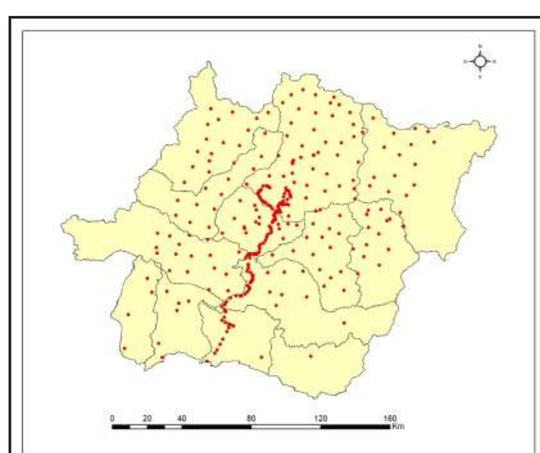

Figure 5: GNSS survey stations.

4.2.4 Gravity Surveying

Gravity survey was conducted at all the stations where GNSS survey was conducted. These observations were used to define the precise geoid. Besides this surface gravity, airborne gravity was also used in order to prepare the geoid of this region.

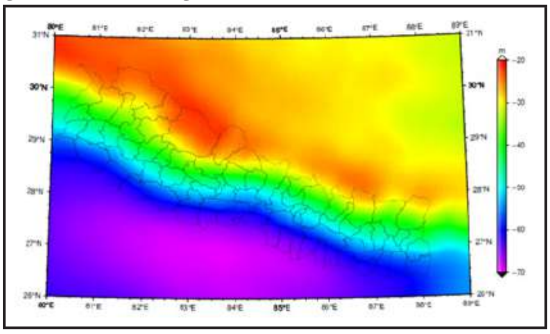

Figure 6: Geoid of Nepal (2020).

4.3 Field Team Composition

For the field observation, different teams were mobilized according to the field activity. The field work was started from early 2018 and completed by 2019. All the technical teams were from the Survey Department. Separate teams were mobilized for separate field work like precise leveling, GNSS survey, gravity survey, trignometrical leveling and summit observation. Following table shows the list of technical staff and the team leader for different field work and season.

Table 2 : Precise leveling field team, season 2074/75

S.N.	Name	S.N.	Name
1	**Rishiram Shrestha (Team Leader)**		
2	Hari Shrestha	3	Deepak Ratna Shakya
4	Rajman Shrestha	5	Basanta Shrestha
6	Purna Bahadur Danekhu	7	Ram Prasad Thusa
8	Gopal Khatri	9	Yagya Prasad Adhikari
10	Janak Raj Joshi	11	Shiva Shankar Chaulagai
12	Bishnu Raj Joshi	13	Sumeet Katila
14	Top Bahadur BK	15	Bishal Gautam
16	Laxman KC	17	Grihendra Lamichhane

Table 3 : Precise leveling monumentation, season 2075/76.

S.N.	Name	S.N.	Name
1	**Rishiram Shrestha (Team Leader)**		
2	Hari Shrestha	3	Deepak Ratna Shakya
4	Rajman Shrestha	5	Basanta Shrestha
6	Ram Prasad Thusa	7	Yagya Prasad Adhikari
8	Hira Maharjan	9	Gopal Khatri
10	Janak Raj Joshi	11	Krishna Dev Raut
12	Sumeet Katila	13	Top Bahadur BK
14	Shiva Shankar Chaulagai	15	Bharat Panthee
16	Laxman KC	17	Bishal Gautam

Table 4 : Precise leveling field team, season 2075/76

S.N.	Name	S.N.	Name
1	**Rishiram Shrestha (Team Leader)**		
2	Hari Shrestha	3	Deepak Ratna Shakya
4	Rajman Shrestha	5	Jeetram Khayergoli
6	Basanta Shrestha	7	Ram Prasad Thusa
8	Hira Maharjan	9	Gopal Khatri
10	Jeevan Gopali	11	Janak Raj Joshi
12	Narayan Prasad Subedi	13	Sumeet Katila
14	Top Bahadur BK	15	Dil Bahadur Tamang
16	Laxman KC	17	Narendra Shrestha

Table 5 : Trignometrical leveling monumentation, season 2075/76.

S.N.	Name	S.N.	Name
1	**Nirmal Acharya (Team Leader)**		
2	Purna Ratna Bajracharya	3	Suraj Bahadur KC
4	Sanjeeb Kumar Raut	5	Stalin Bhandari
6	Shanker KC	7	Bechan Yadav
8	Gopal Krishna Kharbuja	9	Narayan Prasad Subedi
10	Shiva Shanker Chaulagai	11	Bijay Kumar Manandhar
12	Basudev Oli		

Table 6 : Trignometrical leveling, season 2076/77.

S.N.	Name	S.N.	Name
1	**Rishi Ram Shrestha (Team Leader)**		
2	Purna Ratna Bajracharya	3	Gopal Krishna Kharbuja
4	Shanker KC	5	Stalin Bhandari
6	Narayan Prasad Subedi	7	Nagendra Katuwal
8	Shiva Shanker Chaulagai	9	Pravash Kumar Yadav
10	Bhim Bahadur BK	11	Bijay Kumar Manandhar
12	Govinda Gaudel	13	Mahesh Pudashaini

Table 7 : GNSS survey, season 2074/75

S.N.	Name	S.N.	Name
1	**Ajeet Kunwar (Team Leader)**		
2	Purna Ratna Bajracharya	3	Nawaraj Acharya
4	Bigyan Banjara	5	Mahesh Thapa
6	Surya Lal Bhomi	7	Dipesh Suwal
8	Binod Humagai	9	Umang Raj Dotel
10	Gopal Krishna Kharbuja	11	Hira Bahadur Maharjan
12	Jeevan Thapa	13	Lava Bikram Shrestha
14	Purushottam Saud	15	Amit Kumar Shrestha

Table 8 : GNSS Survey, season 2075/76.

S.N.	Name	S.N.	Name
1	**Ajeet Kunwar (Team Leader)**		
2	Bigyan Banjara	3	Umang Raj Dotel
4	Nawaraj Acharya	5	Mahesh Thapa
6	Gopal Krishna Kharbuja	7	Shanker KC
8	Sundar Devkota	9	Rabin Prajapati
10	Mahesh Pudashaini	11	Pravash Kumar Yadav
12	Jeevan Thapa		

Table 9 : GNSS & Gravity survey at high himalaya, season 2075/76.

S.N.	Name	S.N.	Name
1	**Mahesh Thapa (Team Leader)**		
2	Bigyan Banjara	3	Jeevan Thapa
4	Pravash Kumar Yadav	5	Bharat Panthee
6	Amit Kumar Shrestha	7	

Table 10 : Gravity survey, season 2075/76.

S.N.	Name
1	**Umang Raj Dotel (Team Leader)**
2	Bharat Panthee

Table 11 : Gravity survey, season 2076.77.

S.N.	Name		
1	**Bikash Kumar Singh (Team Leader)**		
2	Bharat Panthee	3	Jeevan Thapa

Table 12 : CORS establishment at Lobuche

S.N.	Name
	Bigyan Banjara (Team Leader)
	Mahesh Thapa

Table 13 : GNSS survey at the peak.

S.N.	Name
1	**Khimlal Gautam (Team Leader)**
2	Rabin Karki
3	Suraj Singh Bhandari (Base camp)
4	Yubaraj Dhital (Base Camp)

5. DATA PROCESSING

Dedicated team for precise data processing was formed for whole process. The processing team include Mr Suraj Bahadur KC, Mr Mahesh Thapa, Mr Bigyan Banjara, Mr. Shanker KC and Mr Stalin Bhandari. Python was used for processing of trignometrical leveling, Trimble Business Center (TBC) was used for processing precise leveling, TBC and Bernese was used for GNSS data processing and GRAVSOFT was used for gravity data processing. Airborne gravity data was integrated with surface gravity data to generate the precise geoid and hence orthometric height was calculated from the ellipsoid height obtained from the GNSS data processing for the top of the Sagarmatha. International Height Reference System (IHRS) was adopted as the common height datum for Nepal and China. The final height was determined as 8848.86 m (IHRS) jointly.

6. TECHNICAL SUPPORT

Technical support from different organization and personnel were also received for the successful conduction of this program. For the high altitude GNSS and gravity survey, it was supported by Simrik Air for helicopter service and for the GNSS survey at the peak, it was supported by Peak Promotion Pvt. Ltd. for Sagarmatha expedition. Trimble (Inc) supported with GNSS receivers and total station. The GNSS receiver was used to conduct GNSS survey at the top of the peak and the Total Station was used to measure the distance between two controls station during triangulation. National Geographic Society supported with meteorological stations and GPR. Further, Survey of India supported by conducting field work of precise survey to carry height to the datum station established at Maadar of Nepal from Indian bench mark which were connected from the sea level.

Besides these technical supports, other supports in capacity development were also received. Dr. Christopher Pearson from University of Otago, New Zealand visited

Survey Department to train the staff from the department in GNSS data processing. On the request and budget from Survey Department, University of Bern, Switzerland conducted GNSS data processing in Bernese and Technical University, Denmark, conducted gravity data processing and geoid computation for the staff involved in data processing of this program.

7. JOINT ANNOUNCEMENT

Announcement of the height of Sagarmatha was conducted jointly between Nepal and China. The joint announcement was agreed between Nepal and China at president level, which was stated in the joint communiqué released during the visit of Chinese president to Nepal. After that, series of bilateral meetings were conducted between the two countries and formally formed Steering Committee and Technical Committee to finalize the common height and announce it jointly. From Nepal side, Steering Committee was led by Director General of Survey Department Mr. Prakash Joshi with the members Deputy Director General (DDG) Ms Karuna KC, DDG Mr Sushil Narsing Rajbhandari, DDG Mr Amir Prasad Neupane, DDG Mr. Susheel Dangol and Director Mr Damodar Dhakal. The Technical Committee from Nepal was led by Deputy Director General Mr Susheel Dangol with the members Mr Damodar Dhakal, Mr Sudeep Shrestha, Mr Suraj Bahadur KC, Mr Mahesh Thapa, Mr. Bigyan Banjara, Mr Shanker KC and Mr. Stalin Bhandari. Similarly, Steering committee from China was led by Director General of Department of Land Surveying and Mapping Mr. Wu Wenzhong with the members DDG Dr Wang Qian, DDG Ms Chen Jun, Division Director Ms Jiang Xiaohong, Division Director Mr Yan Ronghua, Councilor Mr Sun LUshan, Dty. Division Diretor Mr Li Hu and Director Prof. Dang Yamin. The technical team from China was led by Director of Chinese Academy of Surveying and Mapping Prof Dang Yamin with the members Mr Chunxi Guo, Prof. Chuanyin Zhang, Asst Prof. Tao Jiang, Mr. Chuanlu Cheng, Mr Bin Wang, Mr. Wenli Wang and Mr Quiang Yang. Technical team finalized the height and submitted the final result to Steering committee on October 12, 2020 and Steering Committee agreed on the final height and submitted the final result to the respective government on October 18, 2020. The final height was approved for joint announcement from Council of Ministers, Government of Nepal on November 25, 2020 (2077/8/10).

On 8th December 2020, the height was jointly announced by Foreign minister from both the countries Hon. Pradip Kumar Gyawali and Hon. Wang Yi and Minster for Land Management, Cooperatives and Poverty Alleviation Hon. Padma Kumari Aryal and Minister for Natural Resources Hon. Lu Hao. The height was announced by deliberating the message from Rt. Hon. President Bidya Devi Bhandari from Nepal and Xi Jinping from Peoples Republic of China.

8. ACHIEVEMENT FROM THE PROGRAM

Sagarmatha height measurement has given the new updated height of the peak after the devastating earthquake to the world. This is the direct product of the program. Besides this output, the program has brought different achievements. The most important and remarkable achievement is the development of human resources in the field of geodesy and mountain measurement. Since this was the first time Survey Department conducted the height measurement, department has developed capacity of the staff in mountain height measurement and geodetic data processing.

Another achievement is the establishment of infrastructure required for development activities. During the execution of this program, huge number of control points has been established. These control points are very necessary for survey works of infrastructure development activities. Hence, by using these points, the cost of the infrastructure development project will be reduced by the cost required for establishing this kind of control points.

9. CONCLUSION

Orthometric height of the Sagarmatha was determined with the field measurement from latest technology. Nepal, for the first time conducted the height measurement of Sagarmatha and finalized the latest accurate height as 8848.86 m after the devastating earthquake occurred in Nepal. This result helps in giving solution to the query regarding the change in height of the peak after the earthquake. The joint announcement from Nepal and China further supported in fostering the friendly relation between the two countries showing the strong eternal relationship between both.

REFERENCE

Angus-Leppan, P.V. (1982). The Height of Mount Everest. Survey Review, Vol:26, Pg:367-385, DOI: 10.1179/sre.1982.26.206.367

Chen J.Y. (1993). On the Redetermination for the Height of the World Highest Peak. In: Montag H., Reigber C. (eds) Geodesy and Physics of the Earth. International Association of Geodesy Symposia, vol 112. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-78149-0_82.

Ward, M. (1995). The Height of Mount Everest. *The Alpine Journal.* 1995, Vol:100, Pg:30–33.

Gulatee, B. L. (1954). The Height of Mount Everest "A New Determination (1952-1954). *Technical Paper No. 8*, Survey of India.

Dansheng, G. (1979). *The Determination of the Height of The Qomolangma Feng.*

Beinat, A., Marchesini, C. & Poretti, G. (1992). The New Measurement of Mount Everest. *Scientific Report.*

Poretti, G., Mandler, R. & Lipizer, M. (2006). The Height of Mountains. *Bollettino di Geofisica Teorica ed Applicata*, Vol 47, n 4, Pg. 557-575.

Yamin, D., Chuanlu, C., Junyong, C. & Peng Z. (2007). Geodetic Height Determination in 2005 Qomolangma Survey. *Geospatial Information Science,* Vol 10, Issue 2, DOI-10.1007/s11806-007-0042-z

Chen, J., Zhang, Y., Yuan, J.,Guo, C. & Zhang, P. (2010). Height Determination of Qomolangma Feng (Mt. Everest) in 2005. Survey Review. Vol 42, Issue 316.

Chen, J, Yuan, J., Guo, C., Zhang, Y. & Zhang, P. (2006). Progress in Technology for the 2005 Height Determination of Qomolongma Feng (Mt. Everest). *Science in China Series* D 49, 531–538 (2006). https://doi.org/10.1007/s11430-006-0531-1, Springer Publication.

ACKNOWLEDGEMENT

Authors would like to acknowledge all the technical persons who were involved in the field and all other personnels and organizations who directly or indirectly supported this Sagarmatha height measurement program to conduct it successfully.

Author's Information

Name	:	Susheel Dangol
Academic Qualification	:	Master of Science in Geoinformation Science and Earth Observation (ITC)
Organization	:	Survey Department
Current Designation	:	Deputy Director General
Work Experience	:	14 years
E-mail	:	susheel.dangol@nepal.gov.np

Online Service Delivery in Survey Offices: Step towards e-Land Administration

Susheel Dangol, Prakash Joshi, Tanka Prasad Dahal
susheeldangol@nepal.gov.np, lightjoshiji@gmail.com, tpdahal@gmail.com

KEYWORDS

Online service, NeLIS, MeroKitta, e-land administration

ABSTRACT

Survey Offices established at the districts under Survey Department are supporting with cadastral survey and the updating the parcels according to the land transactions. Almost all of the district offices among 131 of such are conducting its daily activities in digital environment. At present all the district survey offices have their own server and individual desktop applications are running to conduct the daily activities. In the recent development, Survey Department has developed three tier client-server based system architecture where application and database server are managed in central server hosted in Government Integrated Data Centre and clients access these server to provide the service. This system has enabled to integrate all the cadastral data from district survey office to single central archive. "Nepal Land Information System (NeLIS)" for daily service delivery from the survey offices and "MeroKitta" to get online service facility from survey offices has been developed and implemented in few numbers of the survey offices and planned to replicate in further offices.

1. BACKGROUND

Survey Department, the National Mapping Organization of Nepal, is responsible for topographical survey, geodetic survey, cadastral survey, international boundary survey and also acts as National Spatial Data Infrastructure hub for the country. The department is also the governing body to regularize the production and use of spatial information. To conduct all these task, department has specific divisions and district survey offices (Figure 1).

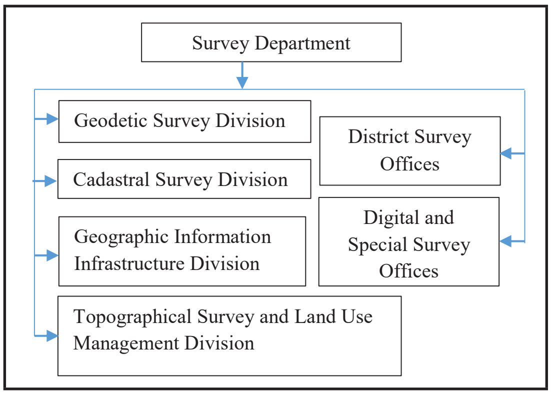

Figure 1: Organization structure of Survey Department.

District Survey Office (SO) is responsible for the cadastral survey and updating of the cadastral data at district level. There exist 131 district survey offices including five special survey offices and one digital cadastral survey office.

Tasks of SOs are mentioned as follow;

- Management of cadastral documents
- Map print
- Parcel Subdivision
- Field book Print
- Plot register print
- Parcel integration
- Parcel boundary marking in ground
- Cadastral survey (New and Resurvey)
- Area Computation etc

2. EXISTING SYSTEMS

Survey Offices have different responsibilities according to the Terms of Reference defined by Survey Department. Some SOs have the responsibility of cadastral data update only while some offices have the responsibility of both cadastral survey and cadastral data update whereas some of the offices have only responsibility of cadastral survey.

According to the responsibility, survey offices are adopting different systems developed by the Survey Department. SOs which has the responsibility of cadastral data update is using Spatial Application Extension (SAEx) for executing their daily transactions and the SOs which is conducting Cadastal Survey digitally is using Parcel Editor (PE). This shows that the SOs which have the responsibility of cadastral data update and cadastral survey are using two different systems in same office.

Further, both of these systems are customized for Arc Map software. Hence, huge amount of investment was required for license purchasing and annual renewal of the license. The system developed as such is totally isolated in each work station. To some extent, local servers were maintained in the office and databases were stored in it and the workstation access to these servers during transaction. No central server and access system available in these systems. The business process can easily be bypassed by not using the tools available in the system but using the standard tools of Arcmap. Hence, history of the transaction and the task log cannot be stored and maintained. Hence it could not be monitored from the central system. The personal geodatabase created are easily accessible and editable from any other third party software. So there is huge risk of data insecurity too.

2.1 Spatial Application Extension (SAEx)

SAEx is specifically developed to handle the secondary data derived from digitization of the paper cadastral maps. Major focus of this system is to handle the updating part of the cadastral data. The cadastral data in the SO goes for parcel subdivision if needed during land transaction. This kind of updating task is conducted by this system in SO. The application deals with cadastral map printing as well. The major features of SAEx are;

- Digital archive of paper maps
- Cadastral map updating (parcel subdivision)
- Map printing etc.

This application does not care about the cadastral Survey and document preparation part.

2.2 Parcel Editor Application

Parcel Editor Application is specifically developed to prepare cadastral maps and database on the basis of primary field survey. The application is able to handle cadastral data updating and map printing facility. The platform for this application is ArcGIS9x and Windows7 operating system. The major features of this application are;

- Multipurpose Cadastral data management (including data if topography and utility services)
- Parcel Subdivision
- Map printing
- Field book printing
- Plot register Printing
- Land owner and Tenant record management
- Land ownership record and certificate printing
- Land owner and tenant record management etc.

3. PRESENT DEVELOPMENTS

Survey Department from past few years initiated to develop and integrated system which can handle both field work and office work of SOs, i.e. preparation of cadastral map and database from the primary survey and cadastral data update during daily transaction. Survey Department initiated the system in order to enhance the efficiency of the office in context of service delivery and the performance of the offices. For this, the department developed "Nepal Land Information System (NeLIS)", the system which is based on Free and Open Source System (FOSS). Since its based on open source software, there is no need of license cost and annual renewal cost for software license. The only cost is the development cost and one time implementation. Besides this benefit, in this system, all the database of district offices are stored in one single database at central server whose backup is also maintained. The database is highly secured and the system can also be monitored from the centre. NeLIS is particularly developed to conduct the daily transaction and cadastral survey from the Survey Offices. Hence, this system is for internal official users. Besides, the department also developed an online system to provide information services to the citizens termed as "MeroKitta". Detail is discussed in following sections.

3.1 System Architecture

NeLIS is developed in client-server architecture (Figure 2). Application server, database server are maintained in Government Integrated Data Center (GIDC) which is secured by firewall. The backup of the entire database is also maintained at Disaster Recovery (DR) site of the GIDC. All the desktop users in the client part at the SO and GIDC server is connected through the private network.

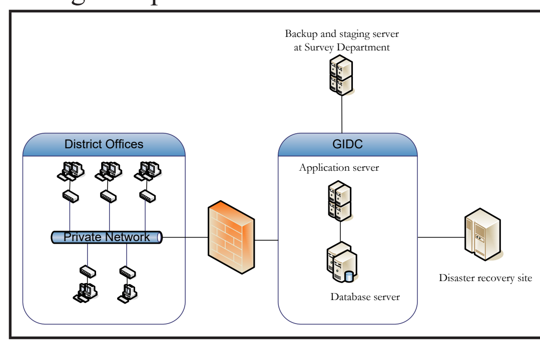

Figure 2: System architecture of Nepal Land Information System.

The cadastral database of whole country is single database managed in PostgreSQL. The client will use the desktop application which will run from the application server. The user accounts are managed within the system and the accessibility to the system and the privilege to the conduct the task for the users are properly maintained.

3.1.1 "Nepal Land Information System (NeLIS)"

NeLIS is the system developed to conduct the activities of the Survey Office in digital environment and in the client-server working mode. The client computer only use the desktop application of NeLIS which is running at the application server maintained at GIDC. These applications communicates with the database server, render the data in desktop, completes the transaction and then again stores back in the server. For example, the parcel subdivision request comes from the land revenue office or the citizen request for map print at the SO. When the request is received, the information provided is verified in the system and if the information is valid, the service is provided for the map print request. For sub-division, the system search for the parcel in the database, conducts the parcel editing as per the requirement, inputs required information regarding land owner and other related information and delivers the service (Figure 3). All these workflow is maintained digitally.

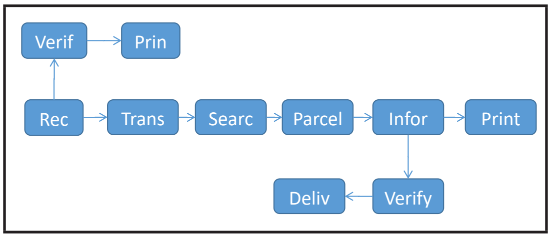

Figure 3: Business workflow throughNeLIS.

Besides the service delivery, the system also provides necessary information like total number of transaction according to the types of transaction like map print, parcel sub-division, field book print, total amount of revenue etc.

3.1.2 Requirements at the Survey Offices for implementation of NeLIS

Requirements can be categorized in two sectors as physical infrastructure and database structure. Besides the strong infrastructure at the central server, the client side at the district office requires sufficient computers which are well networked within the office. Networking with firewall and network switch/router is minimum requirement at the survey office. The network of the office is linked to GIDC server with private network (intranet). This network infrastructure strengthens the security of the data and enhances the service delivery through quick and uninterrupted real-time access to database.

Another very crucial requirement is data cleaning and updating. Since this system migrates existing geodatabase, it uses standard rule to migrate the data to this system. Hence, the geodatabase should be very clean and update for full migration of the data successfully. For example, no fields in the geodatabase should have null value. Like, district code, then VDC code, parcel key should not be null value and if it is so, then the particular parcel will not be migrated and there will be void in the NeLIS system. Also, the database should not have any sliver polygon or null polygon. The topology need to be checked an all the errors should be cleaned before migration. If these errors are not eliminated, then the error will arise during the land transaction.

3.2Information Architecture

The information and services to the public, bank or local level is provided through the internet connectivity whereas the internal transaction process in the SO is conducted through intranet connectivity. The database is connected through *NeLIS* desktop application via intranet and transaction process is completed. For the information, the database is connected through https://nelis.dos.gov.np. For the public, bank or financial organization and local level, the information is accessed through https://merokitta.dos.gov.np. "Merokitta" communicates with *"NeLIS"* and *"NeLIS*" link with the database (Figure 4) and the service seekers get the service through the same *"Merokitta*" website.

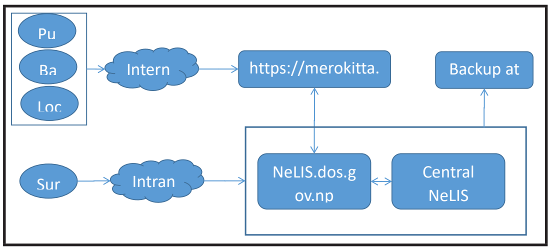

Figure 4: Information architecture.

3.2.1 "MeroKitta"

"MeroKitta" is the online system where the clients request for the service through the website https://merokitta.dos.gov.np. The client and track the status of the application for the service in the same website and also get the final deliver of the service for download in the same website again.

The system has two types of users. One is individual user who doesn't need any login credentials but need to provide the valid mobile number where SMS will be sent through the system regarding every middle process before final service deliver. Another user of the system is an institutional user which needs to get the login credential to receive the service. **Figure 5** shows how the information is provided from the system.

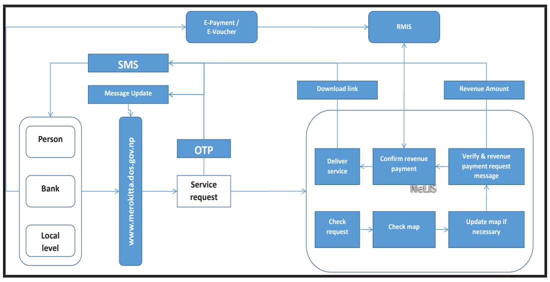

Figure 5: Workflow of information services.

a) Receiving service by individual users.
The individual users need to fill up the minimum necessary information required to receive the service. During the application, the user needs to provide the valid mobile number and also upload the scan copy of land ownership certificate and citizenship certificate. The client should select the office where he/she is requesting for the service, which local level and what service he/she is requesting for. The client should also provide the information about initial local unit information, ward number, map sheet number and parcel number of the parcel for which the service is being requested.

After the service request has been lodged, the system will send the SMS informing that the application has been initiated and also providing One Time Password (OTP). The mobile number and the OTP will be used in the whole system to check the status of the transaction and final download of the service. The user at the SO verifies the information of the parcel provided with the database of the office and sends the SMS requesting for the revenue payment. The client can pay the revenue through online payment system inbuilt in the *"MeroKitta*" system, or any other e-payment system or the client can print the electronically generated bank voucher and visit the nearby bank to deposit the revenue.

The status of the payment is shown in the *"NeLIS*" side of the office users. After the payment has been verified, the SO users upload the document and the client receives the SMS regarding finalization of the service and request for download of the service. The client will receive the message about every step of the transaction in the mobile number provided during application for service. Also, the client can check the status of the transaction and download of the final product at https://merokitta.dos.gov.np by using the same mobile number and OTP provided in this mobile number.

b) Receiving service by institutional users.
The institutional users are banks, financial organizations or local level offices. These organization need to request for the user credential through the system. The user needs to request for user credential through the provided system. During the application, they need to confirm in which SO they are applying for the service. The Local System Administrator (LSA) at the SO will verify the application and Chief System Administrator (CSA) will approve the application. After this, the client will receive the login credential with the use of which, the organizations can receive the services from this online system. After login in the system, all the other process

is same as the individual user does. But the institutional user can request for the bulk amount of request one at time for many clients.

4. PRESENT STATUS AND FUTURE PLAN

This type of client-server architecture based system is implemented in survey offices for the first time. In the fiscal year 2077/78 NeLIS and MeroKitta is implemented in ten survey office namely, Kalanki, Lalitpur, Bhaktapur, Dillibazaar, Chabahil, Tokha, Sankhu, Manamaiju, Rasuwa and Dolakha. For coming fiscal year, 2078/79 the implementation of the system is planned for thirty survey offices next year. The remaining office will be implemented accordingly in following years.

5. BENEFITS OF *"NeLIS"* AND *"MEROKITTA"*

Development and implementation of *"NeLIS*" and *"MeroKitta*" has many benefits and positive implications against the present digital system being used in the SOs major of which are discussed in the sections below.

5.1 Technically strong infrastructure

Since the system is based on the client server architecture and with the concept of central server for application and database, there is no hassle for server management at the individual SOs. All the data from every SOs are stored in the central single database in PostGre SQL server. The client does not have direct access to the database and hence enhances the security of the database. Each and every step taken by the users in the system are recorded and history is maintained too. This function controls the fraud transactions. Further, the system and every transaction at any of the survey office can be monitored from the central office too. The provision of super admin user has the privilege to check all the activities at the office. This makes the client users to be reluctant to do the fraud transactions.

Since the system is working on the base of application server, every survey offices use the same version of the system in contrary to the different versions being used in present system at the offices. If the new updated version is available then all the system at client part will receive the message about availability of the update version and the client can just update the system to newest version. Developer or the support from the center doesn't need to provide update package individually to the survey offices. With this client-server architecture, all the district offices will be working in same single database and same single software from the server. But the particular office will be provided access to the respective data only and cannot view or edit the data of other office. But, if the legal provision is enabled, then in future, the access and permission for different offices can be granted from super admin analyzing the work load of that office. For example, if survey office Lalitpur has huge volume of task and having problem in conducting the transaction in due time because of any circumstances, then the job can be transferred to other district office where there is very less work load. But this kind of facility needs to be explicitly described in the act.

5.2 Support in E-land Administration

This is the first step taken by Survey Department for providing online services to the client. Through the "MeroKitta" the client can request for the service through any common web browser or smart devises and also easily download the service from the browser itself or the device. On the other hand the internal office user also works on the base of central database. Further, the client also can conduct the payment through online medium.

At the NeLIS part, the land transaction starts when any request from Land Revenue Office (LRO) comes to the survey office. In the manual system, the client need to visit to SO carrying all the paper documents prepared from LRO. But in this NeLIS system, it has the provision to receive the request digitally. The system that is being implemented in the LRO needs to communicate with the NeLIS and send request to it. This provision is still need to be developed. This way, this system support in e-land administration which is inline with the objective of the Government of Nepal to enhance e-governance and support in building digital Nepal.

5.3 Increasing Transparency and Reducing Corruption

Since the user need to provide the mobile number during requesting for the service, all the messages are provided to the same mobile regarding every steps being taken in action for the request submitted. The client receives the message about successful submission of the application and OTP for tracking the request and downloading the service. The client can also check the status of his/her application through the *"MeroKitta*" website with the same mobile number and OTP. This gives the transparency in service delivery of the SO.

Also, in this service, the client doesn't need to pay cash at the office or request any other middle person for helping with getting the service. Client can directly pay through the e-payment system inbuilt in the system or use any other online payment system or print the bank voucher and visit nearby bank to pay the revenue. This type of e-payment reduces the corruption since it reduced the involvement of the middle man.

5.4 Reduction of government investment

This online service delivery system is based on the free or open source platform. There is no need to invest huge amount of money in procurement of proprietary software. Using of proprietary software also need a regular cost for renewing of the license, which in turn bring the need of regular cost for the software. Use of open source software reduces all these kinds of cost. The only cost that will incur is the cost of system development. Once the system is matured, no extra cost will be required. Hence, use of this kind of software will reduce the cost of using commercial software (ArcGIS in our context) and update of license as well.

Besides these stated benefits, there are lot more benefits from the implementation of the system like there is less use of paper, the client doesn't need to visit SO and stay in long queue to get the service, doesn't need to request for legal writers to help them for getting necessary application which need the extra money for their help besides the necessary revenue payment and many other minor benefits. This system directly supports in good governance in land administration sector of the country.

6. CONCLUSION

Survey Department has started to provide the online services to the clients from SO which has increased the efficiency of the service delivery from the SOs. The department has initiated the service from few number of SO and has plan to replicate the system to SO around the country in near future. With the implementation of the system, all the database of the SO around the country can be integrated to the single database through which the department can get the scenario of the existing land parcels, its rights, total area etc. from all over the country. At present the system has spatial data or the cadastral data where the data is migrated from the SAEx and both spatial and attribute data where the data is migrated from Parcel Editor.

In future, until the LRO and SO are integrated and one single land administration office is established, the system from both the office needs to be linked technically. NeLIS should be linked with the Land Records Information Management System (LRIMS) from LRO.

This way, both spatial and attribute data will be linked from which a lot of information can be retrieved from the integrated system like total number of land owners, total area of land that the land owner is holding, land beyond the ceiling, different types of land, land owners etc.

Hence, implementation of this system in all the SOs will increase the efficiency of the service delivery of the SO. It plays important role in establishment of good land administration within country. This is the first step of the Survey Department towards online service and e-land administration. The system has still room for improvement which needs to be incorporated in future and make the system very powerful to implement in whole country.

7. BIBLIOGRAPHY

GoN, (1963). *Land (Survey and Measurement) Act.* Government of Nepal.

GoN, (2001). *Land (Survey and Measurement) Rules.* Government of Nepal.

GoN, (2016). *The Directives on Land Survey and Measurement Including Map and Document Updating. Survey Department*, Government of Nepal.

Author's Information

Name	:	Susheel Dangol
Academic Qualification	:	Master of Science in Geoinformation Science and Earth Observation (ITC)
Organization	:	Survey Department
Current Designation	:	Deputy Director General
Work Experience	:	14 years
E-mail	:	susheel.dangol@nepal.gov.np

Preparation of High-Resolution DTM and Orthophoto Using LiDAR in Nepal

Abhash Joshi, Sumeer Koirala
theabhash@gmail.com, mailtosumeer@gmail.com

KEYWORDS

Lidar; DTM; DEM; Orthophoto; Survey Department

ABSTRACT

The high-resolution terrain model has varied usages including development planning, engineering works, environmental management, disaster management, urban planning, irrigation, geological study, archeological study and cadastral application. Currently, this data is not available for Nepal and it has also hindered the socio and economic development of the country.Airborne Lidar is economically cost-effective and viable means for topography related data collection.Lidar which is an acronym for Light Detection and Ranging is an active remote sensing technology in which Laser beams are used for surveying and mapping. The Survey Department of Nepal has taken initiative to prepare the High-Resolution DTM and Orthophoto of about 20,000 square kilometres of Nepal using Lidar surveying and mapping. Survey Department is conducting a LiDAR survey in the western terai regions of Nepal from Chitwan to Kanchanpur district. Airborne LiDAR survey data along with a very high resolution(0.15 m) orthophoto shall begenerated. Further, processing of LiDAR points data will generate a highly precise digital terrain model of 1 m grid data having an accuracy of 0.25 m and finally 0.5 m contour interval data.This endeavor is one of the milestones in the surveying and mapping sector of Nepal and it will have far-reaching consequence in the social and economic development of Nepal.

1. INTRODUCTION

Terrain Model and orthophoto provide a snapshot of our environment. High-Resolution Digital Terrain Model(DEM) and Orthophoto are the basis of many planning and decision-making works. Currently, high-resolution DEM and orthophoto for the whole of Nepal are not available. This has not only added a challenge in existing development work but also many development works are not started in the first place because of lack of data. Thus,the unavailability of this data has a high socio-economic cost for Nepal.

The need for high-resolution DEM for Nepal has been realized for a long time. The importance of high-resolution DTM and DEM for Nepal and its need to prepare different scale derived maps are highlighted in the Roadmap to Second-generation Reform in Land Governance of Nepal document (Ministry of Land Reform and Management, 2014). The post-disaster recovery framework has also emphasized the importance of high-resolution DTM and orthophoto for preparedness, recovery and rehabilitation from the disaster (National Reconstruction Authority, 2016).

Airborne Lidar is one of the most cost-efficient and effective methods for terrain data collection. Lidarstands for Light Detection and Ranging system is type of active remote sensing technology. It uses terrestrial, airborne and satellite-based platform to transmit laser light and receive reflected laser light to study the environment. It uses light in the form of a laser beam to measure ranges. In case of airborne LiDAR system light pulses are recored along with other flight and LiDAR sensor based data recorded at airborne system generate precise, three-dimensional information about the shape of the Earth and its surface characteristics (NOAA, 2018). This method has now become a standard norm to obtain DEM and DTM. It has special importance if the area is large and also if the topography is not uniform.

Traditional field surveying method can also be used to prepare high-resolution DEM. However,these methods are time-consuming and not cost-effective for the larger area. Further, this method does not work well in dense forest. Conventional surveying in Nepal mountainous terrains is not only time consuming, error-proneand expensive, it is almost impossible in many remote terrains. A well-calibrated Lidar system equipped with GNSS and Inertial Navigation System (INS) hasthe potential to provide highly accurate digital elevation data.(Filin & Csatho, 1999). Its ability to provide 3d coordinates directly in very coarse resolution makes it an appealing system.It can provide accurate and precise data from all parts of the terrain, remote or not. The accuracy of Lidar is similar to that of photogrammetry in many areas and even better in some area. (Xiaoye Liu, 2008). Lidar performs better than photogrammetry in a forest area with a dense canopy (Kraus & Pfeifer, 1998)and also advantageous in the urban area as it is free from shadow.

Though Commercial application of airborne Lidar systems started in the mid-1990s (Pfeifer and Briese, 2007), Nepal has not used it on a large scale till now. There were few applications in a small scale of Airborne Lidar in private sectors for Hydropower survey, cable car survey and geological study only.

In Nepal, Survey Department is a national mapping agency and is responsible to prepare different base data. The department has prepared the topographical maps of the Lumbini zone through the assistance of JICA. Similarly, with the assistance of the Finland Government, topographical maps rest of the part of Nepalwas prepared. The whole country is covered by 706 sheets of 1:25,000 and 1:50,000 scale. The 1:25,000 data consist of contour at the interval of 20 meters and the data at the 1:50000 scale consists of contour at an interval of 40 meters.

The Survey Department of Nepal has now taken endeavour for Lidar Surveying and Mapping to generate high-resolution terrain models and orthophoto of whole Nepal.
The goal of the LiDAR surveying and mapping program is to generate High-Resolution DEM and Orthophoto Map with the application of Airborne Lidar surveying and Mapping. The major objectives of the program are:

- Prepare contour at an interval of 50 cm contour,
- Prepare Digital elevation model of resolution 1 m
- Prepare a 15 cm GSD orthophoto map for the entire project area

2. WORKING AREA

In this phase of the project, the working area consists of an approximately 20.000 square kilometre area of Terai, Siwalik and Mid hill region from Kanchanpur district to Chitawan district of Nepal. The area extends from79.9to 84.5 degree east longitude and 27.2 to 29.2 degree North latitude.

Figure 1 Project Area (Background Source: Google Earth)

3. METHODOLOGY

Lidar technology combines three separate technologies (lasers, the Global Positioning System (GPS), and inertial navigation systems (INS))into a single state of the art technology. The single narrow beam of the laser system is transmitted from the LIDAR system to the object, which reflected from the object is received by the receiver system in LiDAR. Travel time of the pulse from the LiDAR and back to the receiver is accurately measured. In LiDAR system range can be computed using the relation of speed of laser(equivalent to speed of light) and travelling time of the pulse. Computed range, laser scan angle, laser position based on GPS and laser orientation measured by INS computed precise location of the object on the ground surface.

To preparethe High-Resolution DTM and Orthophoto using Airborne Lidar technology following work shall be accomplished.

- Setting up of GNSS station monuments complying with IGS standard forgeodetic grade operation, covering entire project area. Construction of checkpoints covering the study area.
- Acquisition of Airborne Lidar data and producing classified and geo-referenced point clouds from these data
- Acquisition of Orthophoto data using a 4 band RGB and IR (Near Infrared) cameraproviding a 15 cm GSD frames.
- Preparation of Digital Surface Model and Digital Terrain Model of 1 m resolution, and topographic contour with 0.5 m contour interval.
- Setting up a Data Processing Lab with all required hardware and software installed.

To accomplish the above-mentioned work the project work is divided into the following steps. Until the date of this writing, aerial data acquisition is being conducted.

4. FLIGHT PLANNING

Planning the flight is one of the major initial tasks for the Lidar survey. The type of aircraft to be used, topography, number of points per square meter and flight paths based on them should be determined during the flight planning phase. In this project entire coverage area is subdivided into three major zones: Zone-1, Zone-2 and Zone-3 and each zone is subdivided into operational areas. One base is selected in each zone for flight operation. Flying Operations in Zone-1 is based at Bhairahawa (VNBW) airport,flying Operations in Zone-2 is based at Nepalgung (VNNG) airport and flying Operations in Zone-3 is based at Dhangahdi (VNDH) airport. LiDAR flight plan should maintain forward overlap (forelap) between successive exposures in each run minimum of 15 percentage. Also, the lateral overlap (sidelap) between adjacent strips should be a minimum of 15 percentage.

5. GNSS STATION AND CHECKPOINTS ESTABLISHMENT

Primary control network consisting of 46 IGS grade GNSS monuments referenced to the geodetic control network are established covering the whole project area. The spatial location of the stations is selected in such a way that the aircraft remains inthe 15km maximum range from any of these base stations at all time during flight operation. These CORS GNSS monuments serve as base stations during the flying operation.

The GNSS system on-board aircraft will use these base station data for estimating accurate and precise positions of the aircraft at each instant of time. The aircraft positioning accuracy is linked to the absolute positional accuracy of the Lidar points on the ground. So, these 46 DGPS stations are important for the ultimate accuracy of the final Lidar deliverables. These stations are the Datum station for the project and all the positional accuracy of entire project deliverables are linked to these 46 stations.

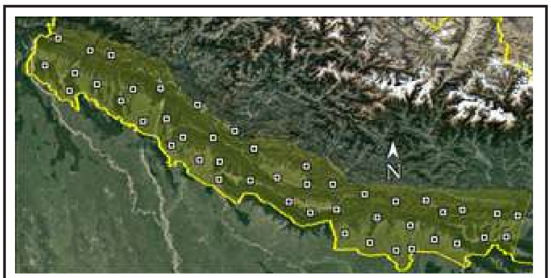

Figure 2.Distribution of GNSS points in the project area

Also, 400 checkpoints are established in the study area which is used for orthophoto generation and for ensuring the accuracy of the Lidar data.

6. AERIAL FLIGHT

Airborne LiDAR and photogrammetry data acquisition should becarried in the season when vegetation coverage is minimum, clear sky isavailable, the ground is not covered with floodwater or harvested vegetation, and ground fog andmist are absent. The best season is thus theMarch-June period, immediately after the winter and before the monsoon clouds arrive. Aerial flight for the project will be conducted until June before the arrival of Monsoon.

LiDAR sensor collects the returned pulse after reflection. During the LiDAR flight, LiDAR sensor sends the laser beam to the ground surface in the form of mass points, the first return of LiDAR mass points generates digital surface model whereas DTM is generated from the LiDAR mass point data which is classified as "Ground".

The data was archived on daily basis to alocal computer before archiving to Data Centre inside the Survey department premises. Data processing will be carried out at the data centre in Kathmandu.

7. DATA PROCESSING

Lidar data and photogrammetric data will be processed at the Data centre of the Survey Department. Data processing will be also a big challenge because of the large volume of data. High performance computation techniques using GPU and multiple CPU shall be used for processing. Terrasolid software shall be used for orthorectification and Lidar data processing.

8. OUTPUT

The major outputof the study can be summarized as follows.

- Raw LiDAR (point cloud) survey data comprising all returns (1st, 2nd, etc.., and last return), representing all ground and non-ground returns and including overlapping swathes. LiDAR Point Density shall be 9-14 points/square meter.
- Digital Surface Model and Digital Terrain Model of 1m grid resolution. Fundamental vertical accuracy: Root Mean Square Error<= +/- .25 m. or better on the clear or vegetated ground.

- The contour of 0.5m interval
- Near-natural colour-balanced digital photographyfor photogrammetry application.
- Orthorectified multispectral digital photograph with 15 cm GSD. Fundamental horizontal accuracy of orthophoto should be <= +/- .10 m.
- Colour balanced mosaic with15 cm GSD
- A report containingthe location and description of all GNSS stations.

9. SPATIAL DATA VALIDATION

The fundamental vertical accuracy of the point cloud dataset will be determined with checkpoints located only in open, relatively flat terrain, where there is a very high probability that the sensor will have detected the ground surface. The vertical accuracy of the point cloud dataset will be tested using a TIN surface constructed from bare-earth LiDAR points compared against ground survey checkpoints. The number of checkpoints (locations) is dependent on the extent of the survey. A minimum of 20 checkpoints (locations), then 1 point per 50km^2 in 7 km * 7 km grid in different vegetation types with 95 percent confidence interval.

10. BENEFITS

Lidar data will have varied application in development work, planning and spatially enabled decision making.The data can be used for monitoring and studying landslides all over Nepal. Flood modelling, flood-disaster planning and developing flood early warning system needsDEM which comes from this Lidar project.Lidar data is essential not only during the planning and construction phase of road and railways but also in Improving the resilience of the infrastructures(Soilán et al., 2019).Similarly, this data can also be used for the archeological study. Lidar imagery is a powerful tool for an archeological study especially in thearea covered with trees and vegetation because of its penetrating capacity (Chase et al., 2011).The raw data will have immense scientific value in different research works such as earthquake monitoring, climate change studies, vegetation monitoring, glacial study etc. Finally, the data can be used to make the cadastral maps also.

11. CONCLUSION

Lidar is a state of the art technology that has revolutionised how terrain data are collected.This visionary initiative from the Survey Department will have a far-reaching consequence on economic and social development in Nepal.The relative speed at which it can be used to collect, analyses and prepare digital elevation model data, compared to any other technology, will support the Survey Department to meet the demand for accurate survey datasets in a timely fashion. LIDAR can greatly reduce survey time and effort in areas where This translates directly into cost savings. The methodology adopted in this project is the best practice adopted in this field. The methodology should evolvewith the development of new technologies.

LiDAR surveying and mapping program has also been categorized as a game-changer project by the National Planning Commission's annual development programme for fiscal year 2077/78. The Survey department will also begin LiDAR surveying and mapping in eastern terai region of Nepal(from Chitwan to Jhapa District) in collaboration with JICA in fiscal year 2077/78. The Survey Department is planning to conduct LiDAR all over the country in near future.

REFERENCES

Chase, A. F., Chase, D. Z., Weishampel, J. F., Drake, J. B., Shrestha, R. L., Slatton, K. C., Awe, J. J., & Carter, W. E. (2011). Airborne LiDAR, Archaeology, and the Ancient Maya Landscape at Caracol, Belize. *Journal of Archaeological Science*, *38*(2), 387–398. https://doi.org/10.1016/j.jas.2010.09.018

Filin, S., & Csatho, B. (1999). A Novel Approach for Calibrating Satellite Laser Altimeter Systems. *International Archives of Photogrammetry and Remote Sensing*, *32*(3W14), 47–54.

Kraus, K., & Pfeifer, N. (1998). Determination of Terrain Models in Wooded Areas with Airborne Laser Scanner Data. *ISPRS Journal of Photogrammetry and Remote Sensing*, *53*(4), 193–203.

Ministry of Land Reform and Manangement. (2014). *Roadmap to Second Generation Reform in Land Governance of Nepal*. www.molcpa.gov.np

National Reconstruction Authority. (2016). *Post Disaster Recovery Framework*.

Soilán, Sánchez-Rodríguez, Río-Barral, Perez-Collazo, Arias, & Riveiro. (2019). Review of Laser Scanning Technologies and Their Applications for Road and Railway Infrastructure Monitoring. *Infrastructures*, *4*(4), 58. https://doi.org/10.3390/infrastructures4040058

Xiaoye Liu. (2008). Airborne LiDAR for DEM generation: Some critical issues. *Progress in Physical Geography: Earth and Environment*, *32*(1), 31–49. https://doi.org/10.1177/0309133308089496

Author's Information

Name	:	Abhash Joshi
Academic Qualification	:	Msc Geoinformatics
Organization	:	Survey Office, Manang
Current Designation	:	Survey Officer
Work Experience	:	9 Years

ARTICLES IN PREVIOUS ISSUES

Journal 1 (Published in 2059B.S)

1. National Geographic Information Infrastructure : A perspective view
By Rabin K. Sharma

2. National Geographic Information Infrastructure Programme to support National Geographic Information System in Nepal
By RR Chhatkuli

3. Need of licensing in Surveying profession in Nepal
By Buddhi Narayan Shrestha

4. Georefrencing Cadastral maps in the pretext of Digital Cadastre
By Durgendra M. Kayastha

5. Innovation in Aerial Triangulation
By Toya Nath Baral

6. Status of Land Reform, Legislation, Policies, Programmes and its implementation in Nepal
By Rabin K. Sharma

7. Database generalization and production of derived maps at 1: 100 000 and 1: 250 000 scales using NTDB in NGII context
By Durgendra M. Kayastha

Journal 2 (Published in 2060 B.S.)

1. A Study on Digital Orthophoto Generation of Mount Everest Region
By Prof. Dr. Michael Hahn, Toya Nath Baral & Rabin Kaji Sharma

2. Land Management And Human Resource Development Policies In Nepal
By Hari Prasad Pokharel & Mahendra Prasad Sigdel

3. Topographical Survey Branch WithRemote Sensing
By T.B. Pradhananga

4. An Overview On Time Series Of Geodetic And GPS Network Of Nepal
By Niraj Manandhar, Maheshwor P. Bhattarai

5. Global Positioning System On Cadastral Survey Of Nepal
By Krishna Raj Adhikary

6. Orthophoto Mapping: A Fundamental Data LayerFor Urban GIS in NGII in Nepal
By R.R. Chhatkuli

7. Towards Strategic Planning For Building Land Information System (Lis) In Nepal
By Arbind Man Tuladhar, Krishna Raj BC & Nama Raj Budhathoki

8. Updating Geographic Information Using High Resolution Remote Sensing Optical Imagery
By Nab Raj Subedi

Journal 3 (Published in 2061 B.S.)

1. National Geographic Information Infrastructure in Nepal for Strengthening Planning and Resource Management
By R.R. Chhatkuli

2. Global Positioning System and Strengthening of Geodetic Network of Nepal
By Krishna Raj Adhikary & Shree Prakash Mahara

3. A Perspective View on Space Application in Nepal
By Rabin K. Sharma & Babu Ram Acharya

4. Traffic problem in Kathmandu and Use of GIS in Urban Traffi c Management
By Anil Marasani & Jeni Rajbamshi

5. Building Geographic Information Infrastructure at National Level: Nepalese Experience
By Nama Raj Budhathoki & R.R. Chhatkuli

6. Survey Department in the Forum of International Activities: A Brief Overview
By Rabin K. Sharma

7. Digital Conversion of Analogue Cadastral Maps of Kathmandu Metropolitan City
By BabuRam Acharya, Nabraj Subedi & Toya Nath Baral

8. Issues on Land Management and Land Fragmentation
By Rabin K . Sharma

9. Assessment of Accuracy of IKONOS Image Map,Traditional Orthophoto Map and Conventional Line Map of Kathmandu Valley: A Pilot Study
By D.M Kayastha, R.R Chhatkuli & Jagat Raj Paudel

Journal 4 (Published in 2062 B.S.)

1. Comparision Of Tin And Grid Method of Contour Generation From Spot Height
By Niraj Manandhar

2. Human Resource Development Policy in Space Technology Sector in Nepal
By Rabin K. Sharma & Babu Ram Acharya

3. Registration of 3rd Dimension: the Context of Nepalese Cadastre
By Ganesh Prasad Bhatta, Giri Raj Khanal & Rabin K. Sharma

4. Spatial Data Infrastructure for Prosperous Nepal
By Rabin K. Sharma & Babu Ram Acharya

5. Study of change in Urban Landuse
By Jagat Raj Paudel & Sudarshan Karki

6. Web-based Metadata Administration System
By Durgendra Man Kayastha

7. One Plus one is more than two- The making of the Population and Socio-Economic Atlas of Nepal
By Suresh Man Shrestha

Journal 5 (Published in 2063 B.S.)

1. Analysis Of 3D Cadastre Situation In Nepal
By Dev Raj Paudyal and Rabin K. Sharma

2. Maximizing Benefits of Space Technology for Nepalese Society
By Toya Nath Baral and Ganesh Prasad Bhatta

3. Principal – Agent theory approach for determination of appropriate 'Activity Model' for cadastral information updating in Nepal
By D. R. Paudayl

4. RS/GIS For Hazard Mapping & Vulnerability Assessment, Earthquake Disaster Management, Kathmandu, Nepal
By Sudarshan Karki and Pramod Karmacharya

5. Technical Deficiencies and Human Factors in Land Disputes: In the Context of Nepalese Cadastral Surveying
By Ganesh Prasad Bhatta

6. The Role of Mapping in Disaster Management
By Kalyan Gopal Shrestha

Journal 6 (Published in 2064 B.S.)

1. A Proposed National Surveying And Mapping Policy In Nepal
By Krishna Raj Adhikary & Dev Raj Paudyal

2. Assessment of the Digital Cadastre in Nepal from the Cadastre 2014 Vision
By Dev Raj Paudyal

3. Astronomy And Gravity Surveying In Nepal
By Punya Prasad Oli

4. Cadastre In Nepal: Past And Present
By Krishna Raj Adhikary, Dev Raj Paudyal & Prakash Joshi

5. Customer satisfaction model and organisational strategies for Land Registration and Cadastral Systems
By Arbind Man Tuladhar & Paul van der Molen

6. Data Standards In The Context Of National Geoinformation Infrastructure
By Durgendra Man Kayastha

7. Evaluation of Topographic Mapping Possibilities From Cartosat High Resolution Data
By Govinda Prasad Baral, Sudarshan Karki & Durgendra Man Kayastha

8. Evaluation of various filter kernels for extraction of linear features from satellite imagery
By Sudarshan Karki

9. From Cadastral Survey Plan To Geographic Information Infrastructure: Fifty Years Of Evolution Of Geo-spatial Data Policy In Nepal
By Raja Ram Chhatkuli

10. Land Administration (In A Nutshell)
By Bekha Lal Shrestha

11. Less Means More - NTDB: At Scale 1:100 000
By Suresh Man Shrestha

12. Monitoring Land Cover Change In Kathmandu City Using Spatial Metrics And Remote Sensing Techniques
By Rajesh Bahadur Thapa, Yuji Murayama & Monika Bajimaya

13. NSDI Initiatives in Nepal : An Overview
By Ganesh Prasad Bhatta
14. Production of DTM by using the existing contour data lines
By Nab Raj Subedi &Raja Ram Chhatkuli

15. Space Education And Awareness Activities In Nepal
By Krishna Raj Adhikary

16. Surveying & Mapping in Nepalese Context
By Tritha Bahadur Pradhananga

17. Surveying: Profession And Professionalism
By Nab Raj Subedi

18. Tissot Indicatrix: A Means To Map Distortion Analysis
By Bishnu Bahadur Karkey

19. Twenty-five years in Nepal-india Border Demarcation
By Buddhi Narayan Shrestha

20. नक्शा राष्ट्रको सुरक्षा, विकास र जनताको लागि पथ प्रदर्शक हुन नारायण कृष्ण न्हुछे प्रधान

Journal 7 (Published in 2065 B.S.)

1. Concepts towards cm-geoid for Nepal GPS to replace conventional leveling using airborne gravity
By Niraj Manandhar and Rene Forsberg

2. Effects of Urbanization on River morphometry: A case study for Nag River Urban Watershed using Geomatics Approach
By Pinak Ranade and Y.B. Katpatal

3. Geomatics Engineering Education in Nepal
By Dr. Bhola Thapa

4. Institutional and Legal Aspects in Land Disputes: the Context of Nepalese Cadastral Surveying
By Ganesh Prasad Bhatta

5. Licentiate Surveyor System in Nepal
By Buddhi Narayan Shrestha

6. Professional Organizations of Geoinformatics in Nepal
By Rabin K. Sharma

7. The Role of NGII in Disaster Management and Mitigation Program
By Shijan Kumar Dhakal

Journal 8 (Published in 2066 B.S.)

1. Applications of open source software in land administration: An initiation with land administration education
By Ganesh Prasad Bhatta

2. Development of educational courses on space science technology in Nepal
By Krishna Raj Adhikary

3. Land policy in perspective
By Nab Raj Subedi

4. Land use land cover change in mountainous watersheds of middle Himalayas, Nepal
By Basanta Raj Gautam and Paban Kumar Joshi

5. Need of professionalism in geomatics profession for the development of sustainable system
By Umesh Kumar and Rabin K. Sharma

6. Role of geo-potential models in gravity field determination
By Niraj Manandhar and Rene Forsberg

7. Theory of error and least square adjustment: Application in coordinate transformation
By Madhusudan Adhikari
8. Updating of topographic maps in Nepal
By Kalyan Gopal Shrestha

Journal 9 (Published in 2067 B.S.)

1. Adopting Geo-ICT in Survey Department: Need for Capacity Building
By Kalyan Gopal Shrestha

2. Assessment of Groundwater Recharge Using GIS
By Susheel Dangol

3. Involvement of Survey Professional Organizations in International Activities
By Rabin K. Sharma

4. Land Management: A Global Prospective
By Prof. Stig Enemark
5. Land Policy Issues in Nepalese Context
By Gandhi Subedi and Raja Ram Chhatkuli

6. Optimizing Orientation by GCP Refinement of Very High Resolution IKONOS Satellite Images
By Madhusudan Adikari

7. Surface Gravity Information of Nepal and its Role in Gravimetric Geoid Determination and Refinement
By Niraj Manandhar

8. The Strategies For Strengthening National Geographic Information Infrastructure in Nepal
By Nab Raj Subedi

Journal 10 (Published in 2068 B.S.)

1. A Study on Squatter Settlements of Kathmandu Using GIS, Aerial Photography, Remote Sensing and Household Survey
By Mr. Kiran K.C. and Dr. Krishna Pahari

2. An Approach to Determine Coordinate Transformation Parameter for Nepal GPS Network
By Kalyan Gopal Shrestha

3. Impacts of Climate Change and Remote Sensing Technology in its Mitigation Options through Forest Management
By Rabindra Man Tamrakar
4. Spatial Analysis: An Assessment of the Road Accessibility
By Madhu Sudan Adhikari

5. Study of Geodetic datum of Nepal, China and Pakisthan and its transformation to World Geodetic System
By Niraj Manandhar

6. Survey Department at the Cross Roads
By Rabin K. Sharma

Journal 11 (Published in 2069 B.S.)

1. A Prospect of Digital Airborne Photogrammetry Approach for Cadastral Mapping in Nepal
By Rabindra Man Tamrakar

2. Detection of Building in Airborne Laser Scanner Data and Aerial Images
By Dilli Raj Bhandari

3. Evolution of Land Use Policy in Nepal
By Rabin K. Sharma

4. LIS Activities in Nepal : An Overview in prospect of DoLIA
By Ram Kumar Sapkota

5. Role of Survey Department In Disaster Management In Nepal
By Suresh Man Shrestha

6. Transliteration SystemFor Nepali Language
By Suresh Man Shrestha

Journal 12 (Published in 2070 B.S.)

1. Consolidation of Stakeholders' Initiatives to Mitigate Adverse Impacts of Climate Change in Nepalese Context
By Rabindra Man Tamrakar

2. Identification of Locations for Potential Glacial Lakes Formation using Remote Sensing Technology
By Yagol P., Manandhar A., Ghimire P., Kayastha R.B., Joshi J. R.

3. Improvement of Cadastral System: Scope in Nepal
By Susheel Dangol, Buong Yong Kwak

4. Object Based Land Cover Extraction Using Open Source Software
By Abhasha Joshi, Janak Raj Joshi, Nawaraj Shrestha, Saroj Sreshtha, Sudarshan Gautam

5. Potential Use of GPS Technology ForCadastral Surveys in Nepal
By Rabindra Man Tamrakar

6. Replacement of Professional Photogrammetric Workstations with Low Cost or Free of Charge Photogrammetric Software and Services for Image Triangulation and Image Matching
By Umesh Kumar

7. Urban Sprawl Modeling using RS and GIS Technique in Kirtipur Municipality
By Bikash Kumar Karna, Umesh Kumar Mandal, Ashutosh Bhardwaj

Journal 13 (Published in 2071 B.S.)

1. Importance of Geo-informatics Professional Organizations of the World
By Rabin K. Sharma

2. Influential Factors of Geo-Information Sharing
By Shanti Basnet

3. Integrated Approach for Building Extraction from InSAR and Optical Image using Object Oriented AnalysisTechnique
By Bikash Kumar Karna, Ashutosh Bhardawaj

4. Multihazard Mapping of Banepa and Panauti Municipalies
By Laxmi Thapa, Shrijana Panta, Sanjeev Kumar Raut, Florencia Ma na Tuladhar Janak Raj Joshi, Nawaraj Shrestha,Prashant Ghimire, Anish Joshi

5. Road Network Planning for Sustainable Urban Development in Kirtipur Municipality, Nepal
By Bikash Kumar Karna

6. Technical Aspects of Digitization of Cadastral Maps
By Ram Kumar Sapkota, Ganesh Prasad Bhaatta

7. Use of Geo-Informatics in Flood Hazard Mapping: A Case of Balkhu River
By Susheel Dangol

Journal 14 (Published in 2072 B.S.)

1. Bye-Bye EQ2015,11:56AM
By Kalyan Gopal Shrestha

2. A Review of Geodetic Datums of Nepal and Transformation Parameters for WGS84 to Everest 1830
By Niraj Manandhar

3. Connecting space to village SERVIR Himalaya at work for bringing earth observation to societal benefits
By Birendra Bajracharya

4. Education and Research Enhancement in Land Administration Sector at Kathmandu University
By Subash Ghimire

5. Flood Hazard Mapping and Vulnerability Analysis of Bishnumati River
By Susheel Dangol, Arnob Bormudoi

6. Land Records Information Management System
By Mr. Hira Gopal Maharjan

7. Nigeria-Cameroon Border Demarcation
By Prabhakar Sharma

8. S in Geoinformatics Profession
By Rabin K. Sharma

9. Spatial Structure Of Urban Landuse In Kathmandu Valley
By Shobha Shrestha, PhD

Journal 15 (Published in 2073 B.S.)

1. A Secure Service Oriented Architecture Based Mobile SDI Model For Mineral Resources Management In India
By Rabindra K. Barik, Arun B. Samaddar, Shefalika G. Samaddar

2. Capacity Building In Geo-Information Sector(A Case Of Kathmandu University)
By Subash Ghimire

3. Community Land Governance And Its Conflicting Theories
By Sanjaya Manandhar & Dr. Purna Bahadur Nepali

4. Comparison of Different Resolution Satellite Imageries For Forest Carbon Quantification
By H. L. Shrestha

5. Data Acquisition For Search, Rescue And Relief Operation In Affected Areas Caused By Natural Disaster
By Rabin K. Sharma

6. Exploring Spatial Data Sharing Factors And Strategies For Catchment Management Authorities In Australia
By Dev Raj Paudyal, Kevin Mcdougall, Armando Apan,

7. Identifying Spatial Scale And Information Base: An Essential Step For Watershed Management And Planning
By Shova Shrestha, PhD

8. Necessity Of Disaster Mapping Unit In Survey Department: The Context Of 2015 Gorkha Earthquake And Disasters In Nepal
By Kalyan Gopal Shrestha

9. Remote Sensing And GIS Application In Landslide Risk Assessment And Management
By Dinesh Pathak

10. Role Of Land Professionals And Spatial Data Infrastructure In Disaster Risk Reduction: In The Context Of Post 2015 Nepal Earthquake: General Review
By Ganesh Prasad Bhatta, Susheel Dangol, Ram Kumar Sapkota

11. Towards A Modernized Geodetic Datum For Nepal Following The April 25, 2015 Mw 7.8 Gorkha Earthquake
By Christopher Pearson, Niraj Manandhar

12. Parcel Fragmentation And Land Consolidation
By Bharat Singh Air, Dr. MotiLal Ghimire

13. Immediate Recovery Vision For Geo-Information Sector In The Context Of Post 2015 Earthquake Reconstruction
By Krishana Raj B.C., Ganesh Prasad Bhatta, Suresh Man Shrestha, Niraj Manandhar, Anil Marasini

Journal 16 (Published in 2074 B.S.)

1. Roadmap for Re-establishment of Geospatial Relationship of the Control Points and Features in Nepal due to Gorkha Earthquake 2015
By Rabin K. Sharma

2.Concept in Determining the Height of Mount Everest (Sagarmatha)
By Niraj Manandhar

3. Integrated Approach of Risk Sensitive Land Use Zoning: A Case Study of Banepa Municipality
By Lekha Nath Dahal

4. Utilizing Geo-information for Mountain Community
By Adaptation Adish Khezri, Arbind. M. Tuladhar, Jaap Zevenbergen

5. Signal Coverage Mapping of Local Radios
By Tina Baidar, Anu Bhalu Shrestha, Rita Ranjit, Ruby Adhikari, Janak Raj Joshi, Ganesh Prasad Dhaka

6. Survey of Location Sensing Techniques
By Abhasha Joshi

7. Applicability of Stream Order Data for Morphometric Analysis and Sub-watershed Prioritization
By Shobha Shrestha, PhD

8. Impervious Surface Detection in Semi-Urban Environment Using Lidar Data and High Resolution Aerial Photographs
By Govinda Baral

9. State and Public Land Management: Issues of Encroachment and Protection Technique
By Sanjaya Manandhar, lanak Raj Joshi, Subash Ghimire

10. Identifying Suitable Areas for Urban Development in Rampur Municipality of Palpa District, Nepal
By Ashim Babu Shrestha, Dr. Shahanawaz, Dr. Bhagawat Rimal

11. United Nations/Nepal Workshop on the Applications of Global Navigation Satellite Systems *By Niraj Manandhar (Geodesist), Er. Susmita Timilsina*

Journal 17 (Published in 2075 B.S.)

1. Pixel to Picture and Picture to Person
Rabin K. Sharma

2. Geoid Determination and Gravity Works in Nepal
Niraj Manandhar & Shanker K.C.

3. Positional Accuracy of Online Geocoding Services: Case Study of Bhaktapur District
Er. Amrit Karmacharya

4. Status of Land Tenure Security in Nepal
Harisharan Nepal & Anil Marasini

5. The Importance of RRR In Cadastral System
Sanjaya Manandhar, Bijaya Kumar Manandhar, Pradeep Sapkota Upadhyaya-PhD, Tanka Prasad Dahal

6. Spatial Distribution and Temporal Change of Extreme Precipitation Events on the Koshi Basin of Nepal
Sanjeevan Shrestha & Tina Baidar

7. Cadastre 2014: Performance of Nepal
Susheel Dangol & Ganesh Prasad Bhatta

8. GNSS Practice In Survey Department
Sushmita Timilisina, & Bibek Nepal

Journal 18 (Published in 2076 B.S.)

1. Remote Sensing of Nepal's Forests and Trees:Ascertaining the Front Line of Human-Induced Tree Cover Changey
Prof. Amulya R Tuladhar

2. Application of Geographic Information Infrastructure: In the context of restructuring the country
By Er. Jyoti Dhakal

3. Address System in Korea
By Byungyong Kwak, Susheel Dangol

4. Image Fusion Technique: Algorithm to Application
Prakash Ghimire & Dr. Lei Deng

5. Gravity for Geodetic Purpose: Geoid-Ellipsoid Separation and Orthometric Height System
Shanker KC

6. Coding the Administrative Units of Nepal for Data Integration and Visualization
Suresh Man Shrestha, Cartographic Engineer

7. Road Network Rating Based on Land Use of Pokhara
Sushmita Subedi & Roman Pandit

8. Precise Point Positioning (PPP): Method and its Geodetic Usage
By Timilsina, Sushmita

Journal 19 (Published in 2077 B.S.)

1. Application of Geo-information Technology in Nepal "During and Post" COVID -19
Reshma Shrestha, Rehana Shrestha & Bhuwan Ranjit

2. Application of Hydrodynamic (HEC–RAS) Model for Extreme Flood Analysis in Far-West Province: A Case Study of Chamelia River Basin, Darchula District, Nepal
Tirtha Raj Adhikari (PhD) & Suman Panthee (PhD)

3. Evolution of Unmanned Aerial Vehicles in Nepal
Biplav Pageni, UttamPudasaini, Darpan Pudasaini & Samrat Pradhan

4. Improving Aboveground Carbon Stock Mapping Using LIDAR and Optical Remote Sensing Data in Mountain of Nepal
Sajana Maharjan,& Rajesh Bahadur Thapa

5. Realization of Geocentric Datum for Nepal: Ingredients, Recipe and the Cooking
Er. Mahesh Thapa & Er. Bigyan Banjara

6. Spectral Analysis of Worldview-2 Imagery in Detecting Invasive Plant Species (mistletoe) in Scots Pine Forest
Mr. Sunil Thapa

Nepal Remote Sensing and Photogrammetric Society (NRSPS)

Executive Committee

Rabin K. Sharma, ***President***
rabinks51@gmail.com

Ganga Bahadur Tuladhar. ***Vice President***
ganga.b.tuladhar@gmail.com

Susheel Dangol, ***Secretary***
susheel.dangol@nepal.gov.np

Dr. Him Lal Shrestha, ***Assistant Secretary***
hlshrestha@gmail.com

Jagat Raj Poudel. ***Treasurer***
jagatrajpoudel@hotmail.com

Members
Raj Kumar Thapa
thapark2008@yahoo.com

Anu Bhalu Shrestha
shrestha.anu17@gmail.com

Umesh Kumar Mandal
umesh_jee@hotmail.com

Mahendra Aryal
mahendra5aryal@gmail.com

E-mail: nrspsociety@gmail.com

International Workshop

An International Workshop on Capacity Building and Education Outreach in Advanced Geospatial Technology and Land Management was organized by Land Management Training Centre from December 10-11, 2019 (Magh 24-25, 2076) in which International Society for Photogrammetry and Remote Sensing (ISPRS), Nepal Remote Sensing and Photogrammetric Society (NRSPS) and Nepal Institution of Chartered Surveyors (NICS) were the Co-oganizers.

Mr. Rabin K. Sharma, President, NRSPS received opportunity to deliver welcome speech during opening ceremony and to present resolution of the workshop during closing ceremony of the workshop.

Felicitation from Survey Department

Secretary of the society Mr Susheel Dangol was felicitated from Survey Department during joint announcement of the height of Mt. Sagarmatha in Kathmandu on 8th December 2020 from Kathmandu and Beijing. Mr. Dangol had been working as the coordinator of the height measurement program conducted by the Department.

Nepal Surveyor's Association (NESA)

NESA CEC
Secretariate

Mr. Ambadatta Bhatta
Acting President

Mr. Saroj Chalise
General Secretary

Mr. Prakash Dulal
Secretary

Mr. Durga Phuyal
Secreatry

Mr. Sahadev Ghimire
Treasurer

Mr. Dadhiram Bhattarai
Co-treasurer

Mr. Hari Prasad Parajuli
Member

Ms. Jyoti Dhakal
Member

Other Officials

Mr. Ram Sworup Sinha
Vice President
Eastern Development Region

Mr. Tanka Prasad Dahal
Vice President
Central Development Region

Mr. Gopinath Dayalu
Vice President
Western Development Region

Mr. Ramkrishna Jaisi
Vice President
Mid-Western Development Region

Mr. Karansingh Rawal
Vice President
Far-Western Development Region

Other Members:
Mr. Premgopal Shrestha
Ms. Geeta Neupane
Mr. Laxmi Chaudhari
Mr. Kamal Bahadur Khatri
Mr. Bibhakta Shrestha
Mr. Sahadev Subedi
Mr. Balam Kumar Basnet
Mr. Nawal Kishor Raya
Mr. Santosh Kumar Jha
Mr. Khim Lal Gautam

Background

Utilizing the opportunity opened for establishing social and professional organizations in the country with the restoration of democracy in Nepal as a result of peoples movement in1990, Survey professionals working in different sectors decided to launch a common platform named Nepal Surveyors' Association (NESA) in 1991, as the first government registered Surveyors' Organization in Nepal.

Objectives

The foremost objective of the association is to institutionalize itself as a full fledged operational common platform of the survey professionals in Nepal and the rest go as follows

- To make the people and the government aware of handling the survey profession with better care and to protect adverse effects from it's mishandling.
- To upgrade the quality of service to the people suggesting the government line agencies to use modern technical tools developed in the field of surveying.
- To upgrade the quality of survey professionals by informing and providing them the opportunity of participation in different trainings, seminars, workshops and interaction with experts in the field of surveying and mapping within and outside the country
- To upgrade the quality of life of survey professionals seeking proper job opportunities and the job security in governmental and nongovernmental organizations
- To work for protecting the professional rights of surveyors in order to give and get equal opportunity to all professionals without discrimination so that one could promote his/her knowledge skill and quality of services.
- To advocate for the betterment of the quality of education and trainings in the field of surveying and mapping via seminars, interactions, workshops etc
- To wipe out the misconceptions and illimage of survey profession and to uplift the professional prestige in society by conducting awareness programs among the professionals and stakeholders
- To persuade the professional practitioners to obey professional ethics and code of conduct and to maintain high moral and integrity
- To advocate for the satification of Survey Council Act and Integrated Land Act for the better regulation of the profession and surveying and mapping activities in the country.

Organizational Structure

The Organization is nationwide expanded and it has the following structure: 14 Zonal Assemblies (ZA), 14 Zonal Executive Committees (ZEC), 5 Regional Assemblies (RA), 5 Regional Executive Committees (RAC), Central General Assembly (CGA) and a Central Executive committee (CEC).

Membership Criteria

Any survey professional obeying professional ethics and code of conduct, with at least one year survey training can be the member of the Association. There are three types of members namely Life Member, General Member and Honorary Member. At present there are 2031 members in total.

Nepal Geomatics Engineering Society (NGES)

contactgeomatics@gmail.com

ExecutiveCommittee

President
Er. Sharad Chandra Mainali
Vice-President
Er. Umang Raj Dotel
Secretary
Er. PoshanNiraula
Joint-Secretary
Er. Arun Bhandari
Treasurer
Er. Rabin Karki
Executive Members
Er. Upendra Oli
Er. Bhagirath Bhatt
Er. Rajeev Gyawali
Er. Amir Bhandari
Er. Bibek Adhikari

About NGES

Nepal Geomatics Engineering Society(NGES) is a non-profit organization formed to function as an umbrella for all Geomatics Engineers of Nepal.Geomatics Engineering program for the first time was launched in 2005 AD by Purbanchal University, in 2007 AD by Kathmandu University and in 2012 AD by Tribhuvan University. Till date, there are more than 400 geomatics graduates in Nepal working in different sectors.

Geomatics as a new global profession can be used as a special tool in planning, policy building and decision making. In order to explore and enhance the role of Geomatics engineering in nation building through cooperation among the geomatics graduates and professional practice, the geomatics pioneers of Nepal recognized the importance of a society and hence formed Nepal Geomatics Engineering Society in August 26, 2015.

As driven by the society's regulation, the executive committee is paying its full strength to develop cooperation among geomatics professionals through various professional and recreational activities.

NGES organized a e-talk program Serries I on "Use of Geospatial technologies against COVID 19 and other diseases" on 11 June 2020 and "Mount Everest Height Measurement" on 5 July, 2020.

NGES organized "COVID 19 Mapathon" on 10 September 2020.

President and Members of NGES participate in **UNWGIC** in China

NGES voluntarily supports DhurmusSuntali Foundation in Construction Survey of **Gautam Buddha Cricket Stadium** in Chitwan.

Career Counselling (Session with NGES**)** to Geomatics Students of WRC /TU

Global Surveyors' Day - March 2, 2019 was a mega event for the professionals and academia of Geomatics in Nepal. The program on the initiation of NGES was jointly organized by NGES, NeSA, NSPRS and NICS. Two da long program included friendly footwall tournament, Map competition, Inspirational speech, Panel discussion on five different generations on Surveying and Mapping in Nepal (5Gs) and Networking Sessions. Minister of Land Management, Cooperatives and Poverty Alleviation – Hon. PadhmaAryal was Chief Guest of the program.

Call for papers

The editorial board requests for papers related to geo-information science and earth observation for the publication in 21th issue of the Journal on Geoinformatics, Nepal.
Last date of submission is 30th March 2022.
For more information, please contact editorial board

Survey Department

P.O. Box 9435, Kathmandu Nepal
Tel: +977 1 4106508, 4106957, Fax: +977 1 4106757
email: info@dos.gov.np

Instruction and Guidelines for Authors Regarding Manuscript Preparation

- Editorial Board reserves the right to accept, reject or edit the article in order to conform to the journal format.
- The contents and ideas of the article are solely of authors.
- The article must be submitted in Microsoft Word by email.
- Editorial Board has no obligation to print chart/ figure/table in multi colour, in JPEG/TIFF format, the figure/picture should be scanned in a high resolution.
- Authors are also requested to send us a written intimation that the same articles is not sent for publication in other magazine/journal.

Page size: A4

Format: Single line spacing with two columns.

Margin: upper 1", left 1.15", right 1", bottom 1".

Length of manuscript: The article should be limited upto 6 pages including figures and references.

Body text font: Times New Roman "11".

Title: The title should be centrally justified appearing near top of 1st page in Cambria, "20" point (Bold).

Authors Name: Authors name should be in Times New Roman "10" with Upper and lower casing, centrally justified. There should be a gap of one lines with 11 pt between the title and author's name.

Authors Email: Authors email should be in Times New Roman "10" centrally justified. There should not be gap between the name and email.

Keywords: Four to five keywords on paper theme

in Times New Roman "10" with two spacing under

the Authors email left justified.

Abstract: Single line spacing after keywords, limited to around 300 words in Italic, Times New Roman "10".

Major heading (Level 1) should be flushed with the left margin in Times New Roman "10" bold font and with Upper casings. Color Dark blue. Numbering 1

Minor heading (Level 2) should be flushed with the left margin in Times New Roman "11" Bold font and with Upper and Lower Casing. Color Dark blue. Numbering 1.1

Minor heading (Level 3) should be flushed with the left margin in Times New Roman "11" Bold font, Italic and with Upper and Lower Casing. Color Dark blue. Numbering 1.1.1

Minor heading (Level 4) should be flushed with the left margin in Times New Roman "10" Italic and with Upper and Lower Casing. Color Dark blue. Numbering 1.1.1.1

BulletPoint: Use only (•).

Placement of photographs/tables: Photographs or tables should be pasted in appropriate place of manuscript pages with caption in their positions in Times new Roman "10" with Upper and lower casing.

Equations: All equations should be in Times New Roman, "11" and italic with consecutive equation numbers placed flush right throughout the paper.

References: References should be listed in alphabetical order at the end of paper in following sequence and punctuation. Author's last name, Author's initials, (Year of publication). *Title of references article in italic,* name of book or journal, volume number, country or city, name of publisher etc.

Citation: All papers are to be cited like (Rajabifarad, 2012), (Dangol & Kwak, 2014), (Zebenbergen, *et. al*., 2018). Upto two authors, the last name should be cited for both and if more than two, then cite it as *et. al.*.

(Primary) Author's Information: The author should provide

Name, Academic Qualification, Organization, Current Designation, Work Experience (in years),

Published Papers/Article (Number) and scanned copy of author's passport size photo.

Note: "Author should send the picture of all the figures kept in paper as separate file."

The joint announcement of the height of Mt Sagarmatha between Nepal and China organized virtually from Kathmandu and Beijing.

Hon. Minister of Land Management, Cooperatives and Poverty Alleviation, Dr. Shivmaya Tumbahangphe distributing land ownership certificate of village block during the inauguration program of land ownership certificate distribution at Kirtipur municipality

Hon. Minister Dr Shivmaya Tumbahangphe, Secretray Mr Tek Narayan Panday, Joint Secretary Mr Janak Raj Joshi, Director General Mr Prakash Joshi and Chief District Officer of Rupandehi district Mr Asman Tamang during inauguration program of LiDAR survey

Hon. Foreign Minister, Hon. Land Management Co-operatives & Poverty Alleviation Minister, Secretaries of Ministry of Foreign Affairs & Ministry of Land Management Co-operatives & Poverty Alleviation during Height Announcement of Mt. Sagarmatha.

Group of engineers dedicated in implementation of Nepal Land Information System (NeLIS) and MeroKitta together with Director General Mr Prakash Joshi and Deputy Director General Mr Susheel Dangol

Director General, Deputy Director Generals, Directors and Chief Survey Officers from Survey Department during inauguration of "MeroKitta"

Making Sense of Geo-spatial data for total solution in National and Local Development Activities

Available Maps and Data

- Geodetic Control data
- Aerial Photographs
- Topographic Base Maps
  - Terai and middle mountain at the scale of 1:25,000
  - High hills and Himalayas at the scale of 1:50,000
- Land Use Maps
- Administrative and Physiographic Maps of Nepal
- Digital Topographic Data at scales 1:25,000 & 1:50,000
- Cadastral Plans
- Orthophoto Maps
- Orthophoto Digital Data
- SOTER Data
- Topographic Digital Data at scales 1:100,000 1:250,000 1:500,000 1:1,000,000

Available Services

- Establishment of control points for various purposes of Surveying and Mapping
- Cadastral Surveying
- Photo Laboratory Services
- Surveying and mapping for development activities
- Topographic and large scale mapping
- Digital geo-spatial database support
- GIS Development

Price of some of the publications of Survey Department

- List of Geographical Names, Volume I to V – NRs 600/- per volume.
- The Population and Socio - Economic Atlas of Nepal (HardCopy) NRs.2,500.00 (In Nepal), €200.00 (Outside Nepal)
- The Population and Socio - Economic Atlas of Nepal (CDVersion) NRs.250/-

Contact Address:

SURVEY DEPARTMENT

Min Bhawan, Kathmandu, Nepal
Phone: +977-1 -4106508, Fax: +977-1 -4106757
E-mail: info@dos.gov.np
website: www.dos.gov.np

ISSN 2717-5022
9 772717 502009