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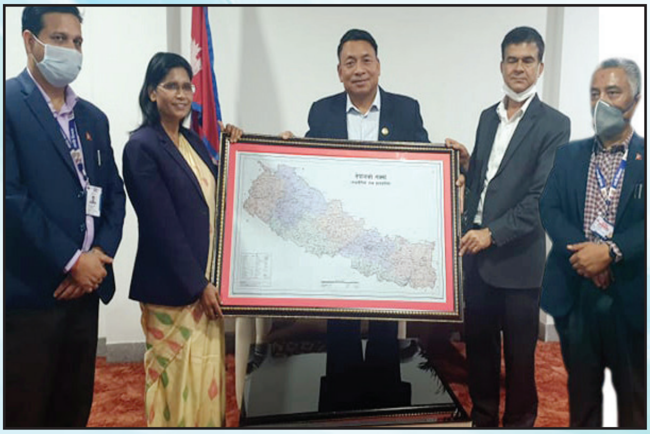
Annual Publication of Survey Department, Government of Nepal

Briefing on process and details on updated map of Nepal from Director General of Survey Department **Mr. Prakash Joshi** to the Honorable Minister **Padma Kumari Aryal**, Ministry of Land Management Cooperatives and Poverty Alleviation.

Handing over of the updated map of Nepal to Rt. Honorable President **Bidhya Devi Bhandari** from Honorable Minister, **Padma Kumari Aryal**, Ministry of Land Management Cooperatives and Poverty Alleviation.



Handing over of the updated map of Nepal to Rt. Honorable Vice-President **Nanda Bahadur Pun** from Honorable Minister, **Padma Kumari Aryal**, Ministry of Land Management Cooperatives and Poverty Alleviation and the team of ministry including Secretary Mr. Kedar Neupane, Director General of Survey Department Mr Prakash Joshi and Deputy Director General Mr. Sushil Narsingh Rajbhandari.

Handing over of the updated map of Nepal to Rt. Honorable Prime Minister **K. P. Oli** from Honorable Minister, **Padma Kumari Aryal**, Ministry of Land Management Cooperatives and Poverty Alleviation and the team of ministry including Secretary Mr. Kedar Neupane and Director General of Survey Department Mr Prakash Joshi

Handing over of the updated map of Nepal to Rt. Honorable Speaker of House of Representative **Agni Prasad Sapkota** from Honorable Minister, **Padma Kumari Aryal**, Ministry of Land Management Cooperatives and Poverty Alleviation and the team of ministry including Secretary Mr. Kedar Neupane, Director General of Survey Department Mr Prakash Joshi and Deputy Director General Mr. Sushil Narsingh Rajbhandari.

Handing over of the updated map of Nepal to Rt. Honorable Chair of National Assembly **Ganesh Prasad Timilsina** from Honorable Minister, **Padma Kumari Aryal**, Ministry of Land Management Cooperatives and Poverty Alleviation and the team of ministry including Secretary Mr. Kedar Neupane, Director General of Survey Department Mr Prakash Joshi and Deputy Director General Mr. Sushil Narsingh Rajbhandari.

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Map of Nepal (Political and Adminstrative) published by Survey Department with Mt. Everest background.

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EDITORIAL

History of annual publication of the Survey Department “Nepalese Journal of Geo-informatics” goes back to 2058 BS (2002 AD) since which, it has been an important asset of the Department and playing a remarkable role in sharing information on Surveying and Mapping, Geo-information and professional knowledge, skills & expertise in this field. In continuation of the effort, Survey Department is publishing 19th issue of “Journal on Geo-informatics, Nepal”. Upto the 18th issue the Journal was published with the title "Nepalese Journal on Geo-informatics" & from this issue we have changed title as stated above.

In last eighteen issues more than 100 articles in different aspects and views of Surveying, Mapping and Geo-information science and its applications in different field have been published. I would like to express sincere thanks to all those incredible authors for their contributions and members of Advisory Councils and Editorial Boards of all those issues of the journal for their persistent efforts to publish the journal.

This 19th issue of the journal contains a wide variety of interesting and worth reading articles on different topics. The papers include "Application of Geo-information Technology in Nepal “During and Post” COVID-19", "Improving Aboveground Carbon Stock Mapping using LIDAR and Optical Remote Sensing Data in Mountain of Nepal", "Application of Hydrodynamic (HEC–RAS) Model for Extreme Flood Analysis in Far-West Province: A Case Study of Chamelia River Basin, Darchula District, Nepal", " Spectral Analysis of Worldview-2 Imagery in Detecting Invasive Plant Species (Mistletoe) in Scots Pine Forest", " Evolution of Unmanned Aerial Vehicles in Nepal".

I feel gratified that the Survey Department entrusted me and gave me the responsibility of the Editor-in-Chief for this 19th issue of the journal. With due advice and suggestions of Advisory Council, we, the members of Editorial Board have been able to bring forth this issue of the journal. On behalf of all the members of the Editorial Board, I would like to express sincere thanks to all contributing authors, members of Advisory Council and all others who have contributed for the publication of this issue of the journal.

Before I stop, on behalf of the Editorial Board, let me humbly request all of you to contribute your valuable thoughts, articles, research papers, success story for the upcoming issue of this journal.

Karuna K. C.
Editor-in Chief,
Ashad, 2077 (June 2020)

नेपाल सरकार

मा. पद्माकुमारी अर्याल
मन्त्री
भूमि व्यवस्था, सहकारी तथा गरिबी निवारण मन्त्रालय

सिंहदरवार, काठमाडौं ।

Government of Nepal
Ministry of Land Management, Cooperatives and Poverty Alleviation
Singha Durbar, Kathmandu

प.सं. : 2076|077
च.नं. : 147

Message from the Minister

Survey Department, the National Mapping Agency of Government has passed 63 years of its establishment. Initial activities of the Department was focused to support land reform program of the government and with change in time and technology, it has enhanced its capacity in line with the development in the technologies. The Department has the history of working from every house of the citizens for cadastral surveying and also the lowest altitude of the country "Kechana" to the highest peak of the world "Sagarmatha" and today I am happy with the publication of 19th issues of the Department's annual publication "Journal on Geo-informatics, Nepal" which is supporting in sharing information and research output in the field of Surveying and Mapping. The regular publication of this kind of enlightening production of the Department is commendable.

Survey Department is conducting remarkable activities in geographical information production and sharing, geodetic survey, landuse mapping, topographical base map update, LiDAR survey, technical activities in international boundary, cadastral survey and much more. I understand, Department is adopting advanced technologies in surveying and mapping field to provide efficient service delivery to the citizens.

Recently, Government of Nepal published updated "Map of Nepal (Political and Administrative)" 2077 in Survey Department did all the technical task to come to this stage of map publication. We received support from Mapping Committee (Technical Sub-committee), Mapping committee and also other committee of the parliament to publish this map. The map has been prepared based on historical documents and evidences. I would like to thank entire team of Survey Department to produce this product in very short span of time, before expected. This journal also includes detail about the history of the map of Nepal and process of preparation of this map.

I believe, this kind of publication definitely support in information sharing regarding all those surveying and mapping activities and 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. This will be a platform for sharing your research output, information on activities to the interested community.

Once again, I would like to thank and congratulate entire team of Survey Department for success in publication of "Map of Nepal (Political and Administrative)", 2077 inacted on Jestha 5th 2077 at the end of 63rd year of its establishment and wish for the continuous publication of this annual publication.

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Padma Kumari Aryal
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

Department of Survey/GoN has been publishing a journal on different aspects of Geo-informatics annually and would like to congratulate for publishing its 19th issue. I feel privileged to keep few words on this annual publication of the Department. I felt happy to see this kind of activities conducted by one of the technical Department of the Ministry. I understand that, publication of this kind of journal will definitely support in knowledge sharing to the interested community.

In short period of time, I have noticed that the department has achieved a commendable progress in the field of Surveying, Mapping and Geo-information data generation, which contribute to the overall national development. Role of Geo-information is very crucial in planning and execution of infrastructure development activities and this journal definitely share information on development of different geo-information and developments in this field.

I feel equally proud to see that the Department has conducted the measurement of height of Sagarmatha (Mt. Everest) and is determined to publish result in the stipulated time frame. Besides that, Department is also conducting different surveying and mapping activities like updating topographical base maps, boundary survey in Nepal-India boundary, land administration services, land use mapping and LiDAR survey. I am very much impressed by the achievement made by Department in this regard. I do believe that the department will further progress in the developments of Surveying and Mapping technology and enhance the service delivery in different aspects. I would like to assure full support from the Ministry to the Department's undertakings in the capacity of Secretary of the Ministry.

Furthermore, I strongly recommend all professionals in the field of Surveying, Mapping and Geo-information to gain benefits from the articles of the journal and also request all the professionals to contribute and share experience in the next issue of the journal.

I would like to appreciate the efforts of Advisory Council and Editorial Board of this journal to bring out the 19th 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.

Kedar Neupane
Secretary
Ministry of Land Management, Cooperatives and Poverty Alleviation
Government of Nepal

FOREWORDS

Survey Department has come with the 19th issues of its annual publication at this stage of sixty-three 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 mention 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 management, generating geo-information services, geodetic control strengthening and other surveying & mapping activities for building geospatial database. 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.

Department has completed the Sagarmatha height measurement program which has heightened the pride of the Department and the nation. Department is conducting field work for LiDAR survey program even in this difficult situation of COVID-19 is setting up milestone in development of high resolution Digital Elevation Model for the first time in Nepal and also shows the dedication of the Department in contributing to the Surveying & Mapping sector even in this harsh condition. Along with this, Department is also conducting landuse mapping, updating of topographical base map, geoportal, geodetic network, CORS & digital database strengthening are other activities worthy to mention besides other several regular program of Survey Department.

Recently, Survey Department succeeded in publication of updated map of Nepal in very short span of time after the decision of the Government to publish the map with updated international boundary. The map has been prepared on the base of historical documents and evidences. New technologies were adopted to define the boundary on the base of historical evidences. Members of Technical Sub-committee and member secretary of Mapping committee analyzed the maps critically and provided constructive suggestions to finalize the map. We have received remarkable support from the Mapping Committee with constructive suggestions and recommendation to the Government of Nepal for publication of this map. At this stage, I would like to thank the entire technical team of Survey Department in preparing and publishing this “Map of Nepal (Political & Administrative)”, 2077. This has proved the capacity of Survey Department. Also, I would like to express my special gratitude to the Secretaries of Ministry of Land Management, Cooperatives and Poverty Alleviation and entire team of Mapping Committee, Technical

Sub-Committee, Minister of Ministry of Land Management, Cooperatives and Povery alleviation and the Government of Nepal. Details on history of map publication of Nepal to this present stage and procedure of present update map is explained one of the paper in this issue, which I hope, will answer many questions of interested readers.

In the capacity of the Director General of Survey Department, I have been trying to invest all my energy in the endeavors aimed at strengthening the Department, its staff and the profession as a whole and my entire staff of the Department from their respective positions, have been together with me in every efforts taken to enhance the image of the Department. I am confident that we will achieve success in showing the tangible results if we continue our efforts sincerely in the days to come with this team work and coordination. Thanks to all the colleagues.

Finally, let me express my sincere appreciation to the fellow colleagues, the members of Advisory Council, and Deputy Director General & Chief Editor of the journal Ms Karuna K.C, entire team of the Editorial Board and specially Chief Survey Officer Mr. Susheel Dangol 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. At the same time, I encourage fellow colleagues from the Department to contribute to the journal by providing quality articles. Special thanks, also, goes to the contributors of the journal for their trust, patience and timely revisions.

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
lightjoshiji@gmail.com

Application of Geo-information Technology in Nepal "During and Post" COVID -19

Reshma Shrestha; Rehana Shrestha; Bhuwan Ranjit
reshma@ku.edu.np, shrestharehana@hotmail.com, ranjit.bhuwan@gmail.com

KEYWORDS

COVID-19, Geo-information Technology, Contact Tracing, Public Health, Citizen Science, Geomatics Engineering

ABSTRACT

At present, the world is facing the challenges to combat the pandemic situation due to outbreak of COVID-19. There is a global realization that the effects of COVID-19 will be in long term affecting various sectors of social and economic development. To support this health crisis, along with various non-pharmaceutical interventions (NPI) the application of geo-information technology have proven to be significant for delaying and containing the COVID-19 pandemic. The application of geo-information technology is one of the interventions adopted basically in the monitoring of the COVID-19 cases. This paper attempt to shade a light on the present scenario in the use of geo-information technology in Nepal and has attempted to throw lights on the need of wider application of such technologies to combat Post COVID-19 crisis. Further, the academic program like geomatics engineering currently running at Kathmandu University can be a contributor of technical human resources and can provide academic research output necessary for strengthening the domain of geo-information technology in the settings of Post Pandemic context.

1. THE GLIMPSE AT COVID-19 AND SHIFT TO NEPAL

The outbreak of virus (initially called 'Novel Coronavirus 2019-nCoV' and later renamed to SARS CoV-2) causing severe acute respiratory syndrome (coronavirus disease COVID-19) in December 2019, originally from Wuhan, Hubei Province, China (Boulos and Geraghty 2020) and had hit 188 countries (Johns Hopkins 2020) by 19th May 2020. There have been 4,735,622 confirmed cases of COVID-19 including 316,286 deaths globally as reported by WHO in 19th May 2020 (6:30 pm) (WHO 2020). Currently, the number of infections and deaths is still increasing rapidly. It is declared a public health emergency in international concern and the outbreak was declared as Pandemic by WHO on 11th March when virus spreading quickly in many parts of the world. The speeding up of global urbanization, increased population and interactions between people, and most importantly shortage of medical protection in developing countries have induced the difficulties of the prevention and control of COVID-19. Various Non-pharmaceutical interventions (NPIs) has been applied for preventing the spread of the viruses. The examples of such interventions are "testing and tracing, bans on large gatherings, non-essential business and school and university closures, international and domestic mobility restrictions and physical isolation, and total lockdowns of regions and countries" (Oliver, Lepri et al. 2020)

Considering the serious threats that COVID-19 has brought in human health there is a serious threats in social and economic development as well. The threats in the sectors like food production, food security, social life functioning, tourism, business, education and many more are of serious concern around the globe.

In fact, this pandemic situation has already kept the questions on the achievement of The United Nations Sustainable Development Goals (SDGs) aiming to address social, economic, and environmental issues from 2015 to 2030. The United Nations SDGs contains 17 goals and 169 targets (Sachs 2012). Among all goals, SDG 3 that aims to ensure healthy lives and promote well-being for all at all ages seems to be difficult to achieve. In addition, the post pandemic situation is going to affect goal 1 that aims to ends poverty in all its forms everywhere and also goal 2 which is about ending hunger and achieving food security.

The outbreak shifted from China to Europe. As per the article published in BBC News, the worst hit European countries are UK, Italy, Spain, France, Belgium, and Germany (BBC 2020). Besides various countries, Nepal has also been counted into the effected countries list in the WHO Dash board. In Nepal, the first COVID-19 case was confirmed on 24th January 2020 when the student of age 31, returned to Kathmandu from Wuhan, tested positive whereas the first death occurred (29th year woman) on 14th May 2020.

2. THE GEO-INFORMATION TECHNOLOGY IN COMBATING COVID

The characteristic of COVID-19 is a long incubation period, strong infectivity and difficulty in detection, which have led to the sudden outbreak and the rapid development of an epidemic (Zhou, Su et al. 2020). This led to the need of Geo-information technology such as GIS, Remote Sensing, UAVs, Mobile/ Web GIS etc. in order to prevent the spread of the epidemic. The rapid responses and analysis of spatial information and fast supply of the spatial information related to the epidemic dynamics is needed to the decision makers supporting them to make a quick decision for preventing and controlling this pandemic.

2.1 GIS based Platform to combat COVID-19 in International Context

After the COVID-19 outbreak, already various initiatives in geographical tracking and mapping of coronavirus disease has been taken in the international context. The use of geo-information technology has been applied for the purposes like real time data collection and dissemination of the COVID-19 confirmed, infected and death cases, contact tracing, surveillance during lock down, aid pledged, received and distributed Some of the examples of aforementioned applications are "Johns Hopkins University Center for Systems", "The World Health Organization dashboard", "HealthMap for analyzing and mapping online informal sources'', "close contact detector", "geosocial app and public service platform", "World Pop and EpiRisk predictive global risk analytics" and "maps for SARS-CoV-2 based on population movements out of Wuhan and travel destinations" (Boulos and Geraghty 2020). John Hopkins COVID-19 dashboard does automatic near-real time tracking and geo-visualization of global confirmed, death and recovered cases. It is by far the most visited site with over a billion hits a day.

The China-GI and Location Based Services (LBS) has been found to be used to combat COVID-19 Pandemic. The activities carried out by this application are "reporting the travel activities in the past two weeks, sharing information amongst command and emergency response agencies, disease control departments, highly precise location information of Beidou-Global Navigation Satellite System (GNSS) of China for Wuhan Vulcan Mountain Hospital construction, dynamic web maps via web portals and mobile applications and GI to deploy resources and provide emergency support" (Washaya and Li 2020).

The combination of geospatial technologies-GIS, Artificial Intelligence, Internet of Things and Big data is applied in tracking movement of the people and alerting officials when a quarantined person steps out of the quarantine zone (Zhou, Su et al. 2020).

The application of Unmanned Aerial Vehicles UAVs (Drones), is found to be applied in transporting medical supplies, spraying disinfectant, publicize information, surveillance and patrol, counting people in a specific location using real-time image recognition of images captured using drones(Washaya and Li 2020). In China, (UAV) are transporting crucial medical supplies and patient lab samples. In highly impacted areas, drones reduce human contact with lab samples and free up ground transport assets and personnel (Huber, 2020). Drones are also being used for broad disinfectant operations in China (Brickwood, 2020).

Mobile application-non-pharmaceutical interventions has been applied for self-assessment of possible infection of corona virus. The assessment result provided by the system mainly depends upon the decision rule deployed in the system. Similarly, the individual mobility, contact (close proximity) data including their geographic locations and social network which can be collected through mobile apps has supported in identifying infected persons (Oliver, Lepri et al. 2020). In short, the application of mobile geo-information technology has been applied in the various stages of the pandemic lifecycle to obtain data on human behavior, especially mobility and physical co-presence.

2.2 The Geo-information Technology in combating COVID in Nepal

Government of Nepal has initiated the use of various IT based technology for COVID-19 confirmed, infected and death cases, contact tracing, surveillance during lockdown. Besides there are some initiatives of real time mapping of COVID-19 confirmed, infected and death cases, location maps of essential services like hospitals for COVID test. However, the volunteer apps are not in the formal framework. In this paper, the initiatives from formal platform has been highlighted.

2.2.1 Web Portal

a. Ministry of Health and Population (MoHP)

The Ministry of Health and Population (MoHP) has developed a web portal to deploy demographic information on COVID-19 at National level. Basically, the portal tracks the number of suspected people who are tested through PCR and RDT, confirmed cases, number of people at isolation, quarantine, cured and dead throughout the country. The portal also has given the information of the testing labs, hospitals, isolation and quarantine centers. These spatial details are disseminated using web maps. Further, there is a provision of filling up self-assessment form of the symptoms of COVID-19 to determine the health status as per the information filled-up. In fact, the location information collected of the individuals from the filled-up form will help in minimizing the risk of corona infection by easiness in contact tracing. In short, the spatial information related COVID cases on number of infected, cured, people in isolation, and death as well as data on vulnerable population helped to keep the public and health workers well-informed in real time (MOHP 2020).

b. Ministry of Home Affairs (MOHA)

National Disaster Risk Reduction and Management Authority (NDRRMA) under MOHA developed a dashboard named Nepal COVID-19 Dashboard disseminating demographics of COVID-19 isolated, active, recovered, death cases, total swab tested, quarantined number and resources available to combat the pandemic such as number of hospital beds, isolation beds, Personal protective equipment (PPE) etc. at district and provincial level. Additionally, this dashboard provides self-assessment form comprising questionnaire on travel history and test for symptoms. This portal disseminates aforementioned information on dual languages—Nepali and English. Even though this portal provides information on the number of returnees by country, the returnee number are less frequently updated with last update on 14th April, 2020 (information accessed date: 19th June, 2020). Additional feature unique to this portal is downloadable daily situation report. The information in the daily situation report is limited to provincial level and summary of COVID-19 cases and the available resources to combat the pandemic (MOHA 2020).

2.2.2 Mobile Application

a. MOHA Mobile APP

MOHA has developed a mobile based application named "Hamro Swasthya". It is an interactive application and it provides the same information as MOHA web portal. It is developed by MOHA with collaboration with many other concerned authorities. There is a provision of self-assessment of symptoms for the COVID by filling up the questionnaire in Nepali language (MOHP 2020).

b. COVID NP APP

COVID NP which is also a mobile based application, developed by Government of Nepal, for contact tracing, official information dissemination, self-test, counseling and certification on covid-19 at provincial level. Further, this app has facilities for applying electronic pass for the mobility within the same districts and also between the districts, reporting the suspect cases of COVID and also security issues (Nepal Government 2020).

c. Kathmandu Municipality: Nepal Covid-19 Surveillance System

Nepal COVID-19 Surveillance System is a collaborative effort of Nepal Research and Education Network (NREN), Center for Information and Communication Technology (ICT4D), Innovative Solution Pvt. Ltd. (Insol), I. Click Pvt. Ltd. (iClick), Public Health Concern Trust-Nepal (PHECT-Nepal), Nepal Disaster and Emergency Medicine Center (NADEM) and Innovative Data Solution Pvt. Ltd. (IDS). The system has been designed to detect the spread of diseases in the community level such that it will help government, local government and communities to fight against corona outbreak in the community level.

This system facilitates self-assessment to obtain general information about how likely the person is suspected for the infection. If the person is suspected for the infection, the system automatically suggests the person to remain in the quarantine for the next fourteen days and also ask for regular updating of their health until the person is in self-quarantine. The system also connected with the health service providers such that the doctors/health worker can monitor the health status of the people under self-quarantine. The spatial information in province level regarding PCR Test, infected, recovered and death from COVID-19 seems to be helpful for the decision makers of disaster management team for strategic planning for addressing the critical issue related to COVID on the real time setting.

d . Other Mobile App:

COVID-19 Response App-Nepal developed by Nepal Army (Nepali Army 2020) in which one can report symptomatic persons in their neighborhood.

COVID-19 Quarantine App has found to develop under the framework of smart palika. The App has been developed specifically for contact tracing. Smartpalika—an IT company— developed this free app for implementation in all of the 573 local levels for live tracing, quarantine management, self-assessment, isolation and quarantine details apart from contact tracing (Smart Palika 2020).

3. LESSON LEARNED

Whilst screening the current use and development of geo-spatial technologies in the context of Nepal, following observations can be derived.

3.1 Repeated development of similar kind of application

In the current situation of COVID 19 pandemic, development and use of geo-information in Nepal is found to follow the similar footsteps as in the rest of the world. In particular, most of the works are concentrated in developing interactive dashboard to inform about the case loads. Many organizations, agencies are setting up interactive dashboard to inform about the current case load, confirmed new cases in near real-time.

3.2 Location Based Contact Tracing application:

Similarly, the government has announced that it will put contact tracing application in place to trace all the people who have come in contact with the confirmed cases. While these endeavors indeed deserve applauding, however, this does not mean that the application will produce similar effectiveness in every social, cultural and political context, until and unless careful considerations are given to its effectiveness and implementation. A review of contract tracing approach used during Ebola epidemic in Liberia, suggested various factors influencing the effectiveness of contract tracing implementation (Senga, Koi et al. 2017). Similar challenges might also be relevant in COVID-19 pandemic in the case on Nepal. Lack of integrated surveillance and proper data management system for reporting between the national laboratory, healthcare facilities, quarantine facilities, contact tracing and case investigation field teams might result into its less effectiveness in slowing the epidemic due to missed source cases and contacts. Therefore, strengthening integrated surveillance and electronic data systems, and the early adoption of the applications by wider citizens may improve timely reporting for listing and monitoring contacts. The organizational structure for contract tracing might lead to inefficiencies in its implementation and management. While self-assessment based mobile application seems relevant, challenges with adapting and implementing contact tracing protocols might arise. Similarly, community perceptions, stigma, and mistrust might lead to challenge in obtaining complete and reliable information, to delays or an inability to trace contacts due to evasion, and even to violence (Senga, Koi et al. 2017).

3.3 Wide scope of GIS application is needed

Few ad hoc applications of drones can also be seen in Nepal for activities such as monitoring the lock down situation, or supplying medicines etc. But wider application of geo-spatial technologies by various disciplines and sectors is yet to be seen. For example, GIS provides useful tools to help health organizations to anticipate vulnerabilities and thereby channel control measures such as ramping up hygiene and social distancing. Epidemiologists can use GIS modelling to forecast and visualize the changing rates of disease and its spread across space and time. Apps and maps can be used to provide various information on such as hospitals with available beds, clinics offering medical aid along with current wait times, grocery stores and pharmacies that are open, places to purchase personal protective equipment, and more. Volunteers and residents can use such applications to locate crucial aid and resources. With proper communication between hospitals and authorities, GIS tools can be developed to monitor the capacities of hospitals and compare it against increasing infection rates, allowing real-time rearrangement of resources to boost capacity where response is needed most. Likewise, GIS can also be used to identify underutilized facilities that can serve as makeshift hospitals and match them with concentrations of vulnerable populations and transit accessibility to increase capacity if needed. Another possible application of GIS can be seen in developing digital supply chain maps to support planning and ensuring geographical diversity in suppliers as well as aligning needs with distribution in order to tackle shortage of supplies at various places.

4. CONCLUSION: APPLICATION OF GEO-INFORMATION TECHNOLOGY IN WIDER SPECTRUM (POST-COVID)

The present context reveals that the application of the Geo-information technology in the fight of COVID-19 is concentrated in disseminating information about the case load, finding clusters of hotspots. However, such technology is yet to be adopted in the wider context. Moreover, there is a need to think about the potential of such technologies in post COVID-19 phase and for future pandemic.

There is now sufficient evidence to affirm that COVID-19 is not only affecting human health through direct pathways, i.e. disease spread and mortality. But it is also affecting health of the people by affecting other sectors on which overall health and well-being of people is dependent upon. For example, COVID-19 has affected on agriculture and the food supply chain, mainly affecting food demand and consequently food security, with a great impact on the most vulnerable population. Similarly, this pandemic has made it visible that health of the population is not the responsibility of health sector alone. Collaboration with other sectors are equally important to combat such pandemic and moreover, to improve health of the general population. For instance, public health interventions of hygiene and social distancing are being emphasized in this pandemic, nonetheless, these measures are futile in informal settlements that are characterized by problems of crowding and limited access to basic infrastructure.

Advancing, "Health in All Policies" (HiAP) with integration of Geo-spatial technology can be seen as a way forward to better prepare for future pandemics in an equitable manner. HiAP suggests to integrate health within the mind-set and the general policy imperative of other sectors (WHO 2014). It is a collaborative approach to improving the health of all people by incorporating health considerations into decision making across sectors and policy areas.

This transformative, collaborative approach to improve population health incorporates considerations like health, equity, and resilience into decision making across government agencies and policy areas. At its core, HiAP is about practicing a whole-of-government approach to address challenges that no one level of government, agency, and department can fix on its own as in the case of COVID-19. In this approach, integration of geo-technology can act as useful tool to provide evidence base on health-related impacts of other sectors. For example, such technology can be used to map the physical conditions in informal settlement (Shrestha, Tuladhar et al. 2016) such as crowding, lack of infrastructure and asses the possible consequences of disease spread (Gibson and Rush 2020).

Likewise, by leveraging geo-information technology in citizen science approaches and big data analytics, large amounts of data can be turned into actionable information to authorities for planning public health activities and implementation of the approach “Health in All Policies.

Finally, the academic program like Geomatics Engineering [*see in detail:* (Shrestha and Bhatta 2019)] can be integrated in the health, agriculture related sectors to produce interdisciplinary studies.

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Author's Information

Name	:	Dr. Reshma Shrestha
Academic Qualification	:	PhD, University of Twente, Netherlands
Organization	:	Department of Geomatics Engineering, Kathmandu University
Current Designation	:	Assistant Professor
Work Experience	:	Started as a lecturer since 2010 at Kathmandu University
Published paper/article	:	More than 15 publications including ISI Publication/ Peer-Reviewed Journal/Book Chapter/Conference Proceedings
Web of Science Researcher ID W-8229-2019		
E-mail	:	reshma@ku.edu.np

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)
tirtha43@gmail.com, panthisuman@gmail.com

KEYWORDS

Flood Frequency, Hydrodynamic Model, Flood Hazard, Chamelia River Basin,

ABSTRACT

Nepal is mountainous country originates the several rivers, rivulets and tributaries in different watershed systems mostly from higher level at north to lower level at south part of the country. Some research pointed prediction of the extreme flood level in such low land area can reduce hazard level significantly in the contest of Nepal. The HEC–RAS model is a one of the very successful tools for the rising of water level, flood hazard and inundation forecast purpose. Therefore, in the Chamelia river basin also applied this model for prediction of extreme flood analysis. In this regards Chamelia hydrological station observed extreme flood data (1965–2015) was used for frequency analysis by Gumbel's method. The frequency analysis in different return period 2, 5, 10, 20, 50, 100, 200, 500 and 1000 year results generated design flood of 364 m3/s, 516 m3/s, 617m3/s, 713 m3/s, 838 m3/s , 932 m3/s, 1025 m3/s, 1149 m3/s and 1242 m3/s magnitudes respectively. Flood hazard maps were prepared according to this generated flood magnitude by exporting the Hydrodynamic (HEC–RAS and HEC–GeoRAS) model into the ArcGIS environment the height of water level, flood hazard and Inundation areas in different cross-sectional were identified in the Chamelia river basin.

1. INTRODUCTION

Nepal is a mountainous country; it measures 880 km from east to west and between 130 – 260 km from south to north with total estimated area 1,47,181 km^2. The country shares a common boundary with India on the east south and west. Its Northern boundary is with Tibetan region of China. The country lies between latitudes 26^0 22' and 30^0 27' North and longitude 80^0 04' and 88^0 12' East. The topological features of Nepal are dived into five different regions from 60m in the south to Mt. Everest 8848m in the North with different climates: - Terai Region - 60 to 200m - Tropical Climate, Siwalik Ranges - 300 to 1500m - Mesothermal Climate, Middle Mountains - 1500 to 2500 - Mesothermal Climate, High Mountains - 2000 to 4000m - Microthermal Climate and High Himalaya Region - 4000 to 8848m - Alpine Climate. The country is predominantly a mountainous, mountains and great Himalayas account for 80% of Nepal total land area and only 20% of flat Terai region is suitable for cultivation (Dhimal, et al. 2018).

In Nepal 80 percent of the annual rainfall received between June to September during the monsoon season (Nayava, 1980). Similarly, the highest flood flow found is dominated by summer monsoon and greater groundwater contributions (Kansakar, 2002) in this season. In the monsoon season - floods, landslides and avalanches cause the loss of lives of about 300 people and damage to properties worth about 626 million NPR annually (DWIDP, 2007).

In this context, flood estimation is important to prevent upcoming flood disaster of any area. The physiography of Nepal has developed networking of dendritic drainage system forming numerous watersheds. Different watershed poses different characteristics which has significant impact in flooding of lower lands. Therefore, flood prediction of the area is one of a key model to prevent from flood disaster. Different models are developed for flood estimation in this type of ground. Among the several model, HEC-RAS is one of highly applying method to estimate food and several governmental and nongovernmental organization are using it as a successful tool. In this present study, a case study of use of HEC-RAS to analysis flood hazard is presenting. For the propose, a case of the Chamelia River basin was used.

2. OBJECTIV`E

2.1 Research goals

The main goal of this study is to explore the application of HEC – RAS model for flood hazard analysis in the Chamelia river basin Darchula district, Nepal. Beside the main goal, specific goals of the research include the review different applications of HEC-RAS model in the Nepalese basin; data and methodological framework for the HEC-RAS model; and prepare the flood hazard map for the Chamelia River basin using the HEC-RAS model.

2.2 Research motivation

Developing the policies for land use management planning in different river basin of Nepal for decision making of farmers can plan and choose wisely which crops to be grown in flood prone areas so as to minimize field crop losses associated with flood warning level thereby ensuring food security in the country.

2.3 Paper overview

The subsequent sections of this paper include; (a) Description of datasets (b) Applications of HEC- RAS Model in the Nepalese basin; (c) the methodological section which describes the datasets used, study area, framework for the HEC-RAS model, flood hazard map generation; (d) results and discussion section which contains a presentation of model results, flood hazard maps and discussions; (e) the conclusion and recommendation section.

3. DESCRIPTION OF DATASETS USED

3.1 Hydrologic modeling datasets

The Rainfall and discharge data were collected from Department of Hydrology and meteorology (DHM), Government of Nepal. The Chamelia river hydrological station data from 1965−2015 was used for this study to calculate the average, minimum, maximum discharge and maximum basin rainfall the graphical view of collected data as shown in Figure 1. Similarly, the digital elevation model (DEM) data obtainable from Department of Survey, Government of Nepal, SRTM (http://vterrain.org/Elevation/SRTM/), and ASTER (https://www.youtube.com/watch?v=0H7AdfY1_gg&t=45) respectively.

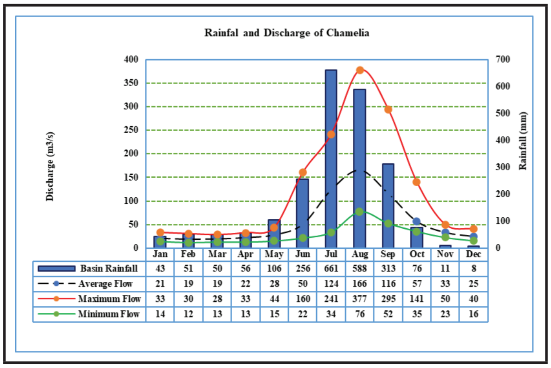

Figure 1: Basin rainfall and discharge of the Chamelia River at Darchula.

3.2 Hydraulic model datasets

Geometrical model datasets required for hydraulic modeling included the following; River name, reach name, river cross section station, downstream reach lengths (LOB, channel, ROB), main channel bank stations. These were all created during data processing using HEC GeoRAS in ArcGIS and then imported to HEC RAS model geometrical editor.

Manning's n values: Manning's value was estimated by "Roughness Characteristics of Natural Channels (1987)" published book by USGS water- supply paper (1849). The physical characteristics of the river Channel, Left Over Bank (LOB) and Right Over Bank (ROB). Contraction and expansion default coefficient parameter values for steady flow regime were automatically assigned by HEC RAS program and Steady flow datasets.

4. APPLICATIONS OF HEC- RAS MODEL IN THE NEPALESE BASIN

During the 2009 monsoon, seven villages were flooded by the swollen Kankai and Biring Rivers in southern Jhapa. More than 500 houses were submerged and thousands of hectares of paddy field were inundated. The Karnali River bifurcates into two branches downstream of Karnali Bridge, creating an island in the Rajapur area of Bardiya district. Floods from the Karnali River in the past have created havoc in the Rajapur area leading to loss of lives and property and causing widespread human suffering. Heavy rainfall in the lower West Rapti basin on 25-27 August, 2006 created havoc due to flooding. Similarly, Banke became the second most flood affected district in the country in 2007 due to flooding in the West Rapti River. At that time, the flood inundated the area for 3-4 days (ICHARM 2008). Gautam and Dulal, 2013, was using the hydrodynamic (HEC-RAS) model which was performed multiple profile and inundation analysis for danger levels and threshold runoffs foresting in different basins; Karnali (42890 sq. km), West Rapti (5200 sq.km), Narayani (31100 sq.km), East Rapti (579 sq.km), Koshi (54100 sq. km) and Kankai (1148 sq.km). Some other river basins of Nepal also applied the hydrodynamic (HEC-RAS) model by additional researcher which is summarized (Table 1).

Table 1: Summary of additional researcher using hydrodynamic (HEC-RAS) model in Nepal.

Reference (Author Publication Year)	Basin Area Sq. km	Paper or Report	Research title (Journal or Report Name)
Talcha bhadel, et. al., 2020	6368.00	Preceding	Numerical Simulation of Runoff Generation and Inundation Process of an Extreme Precipitation Event in Nepal. Proceedings of the 22nd IAHR-APD Congress 2020, Sapporo, Japan
Aryal, et. al., 2020	45269.00	Paper	A Model- Based Flood Hazard Mapping on the Southern Slope of Himalaya. (Water)
Pradhan and Adhikari 2019	99.00	Paper	Flood Hazard Mapping and Vulnerability Analysis of Bishnumati River, Kathmandu. (Environment Science)
Aryal, et. al., 2016	30.74	Paper	Flood Hazard Assessment in Dhobi-Khola Watershed (Kathmandu, Nepal) using hydrological model. (International Research Journal of Environment Sciences)
Adhikari et. al., 2014	2,918.22	Report	Determination of Flood Warning and Danger of Mohana and Macheli River (Mercy Corps Nepal, Inundation Figure 2)

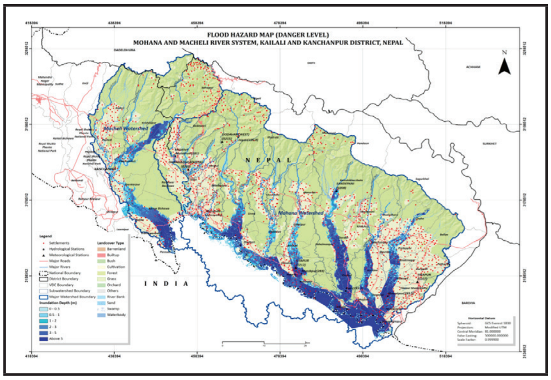

Figure 2: Inundation Map of Extreme flood of Mohana and Macheli River Basin

(Source: Mercy Corps Nepal, 2014)

5. METHODOLOGY

5.1 Terrain processing steps

Terrain processing involved the following steps; 1. Fill Sinks, 2. Flow Direction, 3. Flow Accumulation, 4. Stream Definition, 5. Stream Segmentation, 6. Catchment Grid Delineation, 7. Catchment Polygon Processing, 8. Drainage Line Processing, 9. Adjoint Catchment Processing performed in sequential order.

5.2 Description of the study area

The Chamelia river basin is located in the territory of Apihimal Darchula district in Far-West Province of Nepal. The elevation of the basin is ranged from lowest elevation 521.76 m to highest elevation 7083.6 m. The length of main stream extended from the origin (Apihimal) to Karnali river confluence about 80 km, whereas the average slope of the basin is 0.077 of the Chamelia river basin. The total basin area 1,586 Sq. km of Chamelia river basin up to Karnali river confluence shown in Figure 3.

5.3 Framework for the HEC-RAS model

Generally, to run the HEC-RAS hydro-dynamical model required the hydrological data (extreme of historical flood records), Digital Elevation Model (DEM) and processed geometrical (river center line, bank line, flow path and cross sectional) data by HEC-GeoRAS model (HEC 2002) for the inundation analysis. The geometric data found by using the GIS environment by processing the HEC-GeoRAS model, GIS data development (Figure 4). Then these data were imported to the hydrodynamic HEC-RAS (HEC 2019) model.

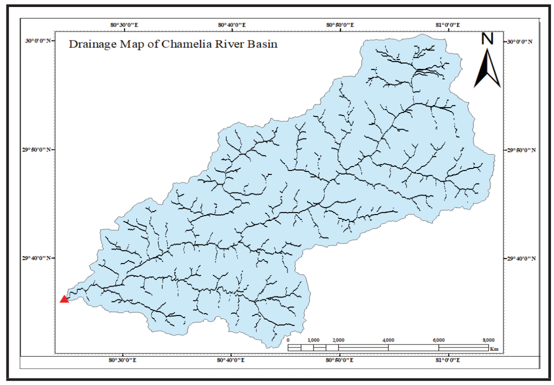

Figure 3: Study area Chamelia River basin, Darchula District

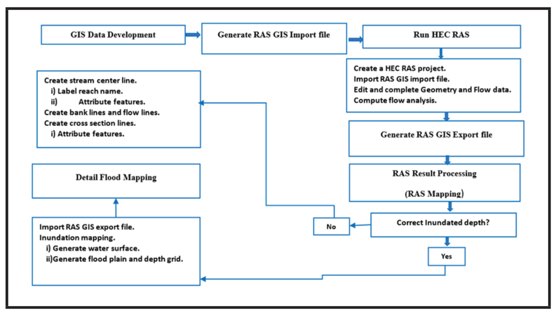

Figure 4: The methodological framework for HEC-RAS model.

5.4 Hydraulic modeling

The Hydrodynamic modelling for extreme flood of High, Medium and Low risk is level performed in HECRAS Software. For the hydraulic computation, the geometric data of river must be imported and flow data must be entered. The required geospatial data is processed from HEC Geo-RAS, a GIS extension tool and exported to HECRAS format.

The Hydraulic data including extreme flood data and associated boundary condition are given into flow plan of HECRAS. The steady state flow simulation is then performed for water surface profile calculation for various magnitudes of discharge.

Once the hydraulic computation is done, the water surface and velocity results again are imported to HEC Geo-RAS for spatial analysis. The automated delineation of water surface of flood Inundation mapping is done with the RAS output files in HEC Geo-RAS Environment.

In this component of HEC - RAS modelling is developed for the calculation of water surface profiles for steady gradually varied flow. In Steady state modelling, the model calculates water levels at discrete cross-sections as according to the flows prescribed by the user. The one-dimensional energy equation is used to compute the unknown variable (stage). Energy losses are evaluated by friction (Manning's equation) and contraction/ expansion (coefficient multiplied by the change in velocity head).

The energy equation is based on principle of conservation of the energy and it states that the sum of the potential and kinetic energy at particular cross section is equal to the sum of the potential and kinetic energy at any other cross section plus or minus energy loss or gains between the sections. Then the water surface profiles are computed from one cross-section to another by solving the equation with an iterative procedure.

5.5 Pre-processing to develop the RAS GIS import file

For the hydraulic computation, the geometric data of river must be imported and flow data must be entered. The required geospatial data can be processed from HEC Geo-RAS, a GIS extension tool. The spatial GIS import file created in Geo-RAS are river, reach, and stations identifiers, cross-sectional cut lines, cross-sectional surface lines, cross sectional bank stations, downstream reach lengths, main channel, cross sectional roughness coefficient etc. These datasets are produced and processed from the existing digital elevation model (DEM).

5.6 Post-processing to generate GIS data from HEC-RAS results

Once the hydraulic computation is done, the water surface and velocity results again may be imported to HEC-Geo-RAS for spatial analysis. The automated delineation of flood plain can be done with the RAS output files. Based on the HEC-RAS output files the cross-section theme and bounding polygons can be generated and the water surface.

5.7 Running HEC-RAS Model in Chamelia River:

To access the extreme flood water level, hydrodynamic modelling was performed in Chamelia river using HEC-RAS and HEC Geo-RAS model to generate the scenarios of flood inundation at 2, 5, 10, 20, 50, 100, 200 500 and 1000 years return period with the subcritical flow regime. Simulation runs in the above different return periods were performed successful simulation of cross section and river profile channel distance of results can be seen in Figure 5 and Figure 6 respectively.

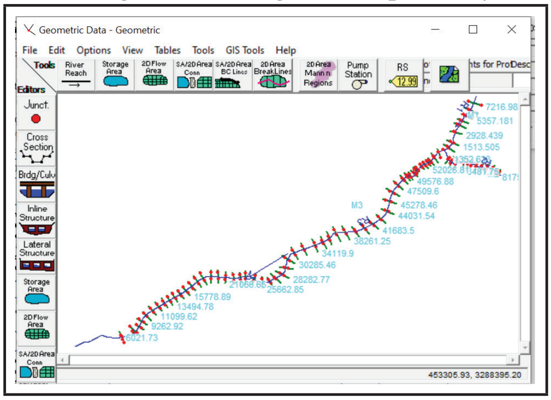

Figure 5: Geometrical and cross-sectional data during the model setup.

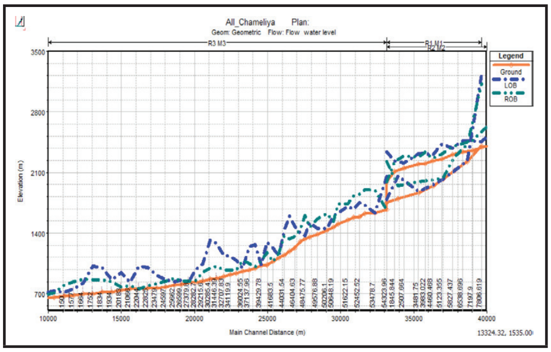

Figure 6: Elevation with main channel distance profile of Chamelia river.

5.8 Flood hazard map generation

Flood hazard maps were generated at 2, 5, 10, 20, 50, 100, 200, 500 & 1000-year return periods (Table 2) of extreme flood discharge with steady flow environment. In HEC-RAS model inflow boundary condition were selected for simulation to extent the inundated map of the Chamelia river. The simulated result was exported from HEC-RAS model to the ArcGIS for preparing the flood hazard maps. According to the field condition and extreme flood discharge the risk level were determined the depths of inundation map shown in Figure 8b and Figure 8b.

6. RESULTS AND DISCUSSION

6.1 Hydrological Result of Chamelia river

The observed peak discharge of Chamelia river at the gauging station corresponding to the 2, 5, 10, 20, 50, 100, 200, 500 and 1000 years return period flood frequency analysis by using the Gumbel's method results are depicted in Table 2.

Table 2: Gumbel's method frequency analysis result of Chamelia river discharge data (1965-2015).

Return Period Year	Flood Flow (m^3/s) (R1)	Flood Flow (m^3/s) (R2)	Flood Flow (m^3/s) Station	Flood Flow (m^3/s) (R3)
2	9	11	264	364
5	13	16	374	516
10	16	19	447	617
20	18	22	517	713
50	21	26	608	838
100	24	29	676	932
200	26	32	743	1025
500	29	36	833	1149
1000	31	39	900	1242

6.2 Hydraulic model results

In 100 year, return period flood flow at hydrological station at Chamelia river was calculated flood flow 676.0 m3/s in the cross section (R1) 7216.982 of the river. Other output data such as flood velocities in the channel (Vel Total) 5.34 m/s), Cross-section area 130.78 m2), Top width of the channel (43.94 m), and the maximum water level depth 2.88 m in the channel (Max Chl Depth 4.30 m), similarly other few cross -section result are shown in Table 3.

Table 3 Chamelia river HEC RAS model output flow results at the gauging station

River Cross Section	Left Sta (m)	Right Sta (m)	Cross-Section Area (m^2)	Top Width (m)	Vel Total (m/s)	Max Chl Depth (m)	Hydr. Depth (m)	Total Flow (m^3/s)	Rimarks
R1 (M1) RS: 7216.982	1007.89	1262.89	130.78	43.94	5.34	4.30	2.88	676.0	
R2 (M2) RS: 8175.308	327.27	740.89	154.64	54.10	5.32	4.66	2.86	823.0	
R3 (M3) RS: 54323.96	903.04	1255.49	170.18	56.05	5.48	4.36	3.04	932.0	
R3 (M3) RS: 8537.769	374.54	1000.98	170.26	56.21	5.47	4.56	3.03	932.0	Figure 5

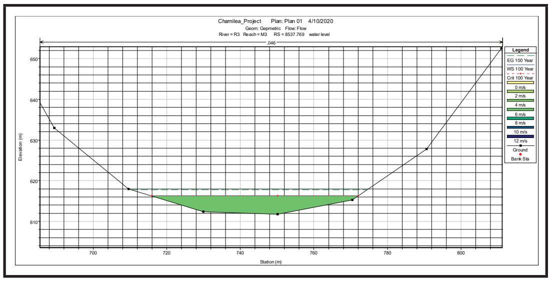

Figure 7: Flow distribution according to the cross section of Chamelia river.

6.3 Flood hazard maps of Chamelia river:

The flood hazard maps were extent in different return period (2, 5, 10, 20, 50, 100, 200, 500 and 1000 year) floods in Chamelia river, the sample of 100-year return period flood inundation map is depicted in Figure 8a and Figure 8b.

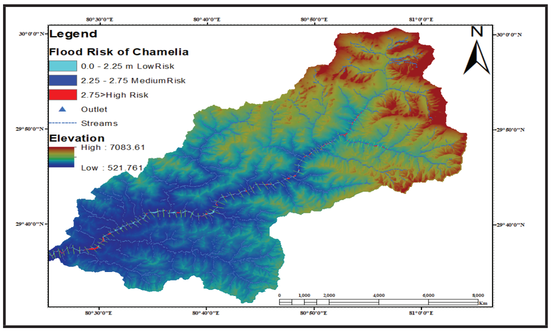

Figure 8a: Flood hazard maps of Chamelia river.

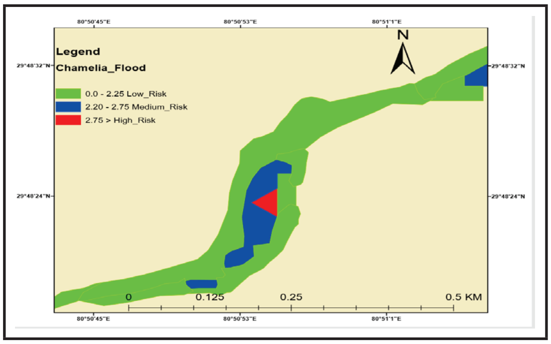

Figure 8a: Zooming view of Flood hazard maps.

7. CONCLUSION

Successfully applied the HEC GeoHMS in ArcGIS environment to generate the geometric data for hydraulic (HEC- RAS version 5.0.7) model in the Chamelia river basin. The flood hazard map generated using the HEC-RAS model is the best for estimating the maximum channel depth, hydraulic depth and water level defined cross section.

7.1 Recommendations

The high-resolution DEM will be better for estimating the reliable height of water (Flood) level. Similarly, discharge measurement, land use data, social data with field survey will be highly applicable for the validation of the result.

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Author's Information

Name	:	Tirtha Raj Adhikari
Academic Qualification	:	PhD
Organizatioin	:	Tirbhuvan University, Central Department of Hydrology & Meteorology
Current Designation	:	Associate Professor
email	:	tirtha43@gmail.com

Price of Aerial Photograph

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

Evolution of Unmanned Aerial Vehicles in Nepal

Biplav Pageni, UttamPudasaini, Darpan Pudasaini& Samrat Pradhan
pbiplav@gmail.com, uttam@naxa.com.np, pudasainidarpan@gmail.com, prd.samrat@gmail.com

KEYWORDS

UAV Surveying, Drone Mapping, Flying Labs, Disaster Mapping

ABSTRACT

Nepal has tremendous geographic diversity rising from as low as 59 metres elevation in the tropical Terai to the highest peak in the world, Mt. Everest, at 8,848 ft. The country ranks 4th, 11th and 30th as the most vulnerable country in terms of risk from climate change, earthquake and flood respectively.[1] As a part of response to any disaster, geographical knowledge of the vulnerable area is the foundation to effectively plan and implement the response. There exist various ways of topographical surveying and mapping which are being used to acquire such geoinformation. The undulating geography of Nepal makes topographical surveying and mapping time consuming and arduous through the traditional ground-based methodologies. Furthermore, the remote sensing techniques are not much useful for a country like Nepal that doesn't have its dedicated satellites and hence lacking ways to obtain timely updated information. The recent few years have seen escalation of some of the frontier technologies including Unmanned Aerial Vehicles (UAVs) in surveying and mapping, aerial photo/videography, surveillance and a number of other applications. UAVs were widely introduced in Nepal in the aftermath of the April 2015 earthquake. An unprecedented number of small and lightweight UAVs were flown over highly damaged areas and heritage sites by journalists and humanitarian responders to assist in immediate rescue, relief, and reconstruction efforts. However, risks to national security by the unregulated use of UAVs was realized by the Government of Nepal, and the Ministry of Home Affairs released a set of strict guidelines that controlled the use of UAVs in a stringent way. This limited use of UAVs in Nepal bottlenecked the increasing adoption of this technology, both for humanitarian responses and private sectors. However, increasing demand has recently led to the release of a comparatively flexible "UAV Flight Guidelines 2075" that provides the authority to grant UAV flight permissions for lightweight UAVs to the local governments, thus simplifying the procedure for most UAV users. It also reflects the positive change in perception of the government towards UAV technology. This study seeks to identify, analyze and document the evolution in application of UAV technology in Nepal across several application areas.

1. INTRODUCTION

Nepal has a huge lag in terms of implementation of newer technologies, with a lot of technologies existing in their elementary phase until a few years ago. The recent few years have seen an escalation of some of the frontier technologies in Nepal, with a lot of involvement from a diverse sector in the development, sensitization and adoption of such technologies. One such dominant technology that has seen an exponential rise in its usage in Nepal is Unmanned Aerial Vehicle (UAV).

UAVs refer to uninhabited flying vehicles that operate based on the pre-entered program and/or on its own recognition of the surroundings (Jee & Kwak, 2014). They can be remotely controlled, semi-autonomous, autonomous, or a combination of these modes of operation. Various types of payloads, mainly cameras and other kinds of sensors, are integrated thereby making UAVs capable of capturing real-world data such as images, videos and geolocation, etc. (Van, 1999). UAVs can be used as tools/mediums of transporting goods, obtaining various kinds of data, and providing better situational awareness through images and videos, higher resolution and more real-time spatial data than satellites. Due to their portability, agility, ever-advancing technology and ever-increasing accessibility, UAVs are increasingly becoming popular and seeing newer use cases every now and then.

An unprecedented number of small and lightweight UAVs were flown in the aftermath of the Nepal Earthquake 2015 by journalists and humanitarian responders to assist in immediate rescue, relief, rehabilitation and reconstruction efforts. The hence seen proliferation of UAVs in Nepal in a very short span of time awakened and encouraged the policy makers to act promptly, to which they responded with enforcement of a flight operation directive. The directive required anyone wishing to legally fly drones within Nepal to obtain permission from multiple ministries and government authorities, and adhere to many restrictions including permissions to fly. The then understanding of UAVs in the general public was of a technology of destruction and privacy obstruction. The perspective of the government authorities themselves on UAVs wasn't very welcoming either, given the lack of UAV experts and enthusiasts within the authorities. Over a short span of time, there was an increase in the use of UAVs by private businesses, researchers and tourists in various applications like topographical surveying & mapping, wildlife monitoring, aerial inspections, photography/videography, etc. The increase in the popularity of UAVs owing to its sensitization among people and authorities, and ever increasing activities relating to the use of the technology has led in better acceptance of drones in the public as well as the government authorities, and has led to a change in perspective about drones, and the drone regulations have also softened over time allowing more applications of drones (MoHA, 2019).

2. USAGE OF UAVS IN NEPAL

The development of UAVs in Nepal can be particularly divided into three stages: prior, during and post Nepal Earthquake 2015.

2.1 Usage of UAVs prior to April 2015

Few hobbyists from Nepal were involved in usage of UAVs prior 2015 with few of the documented ones dating back to 2008/2009. Many engineering colleges, through their robotics clubs, were developing UAVs, mostly for robotics competitions and college projects. Few private institutions had already been working in research and development of UAVs and related technologies from 2013. There were rare cases of documented UAV flights limited to confined purposes of documentary shooting, video filming or some research activities. Below are some significant works done in the field prior to the Nepal Earthquake 2015:

2.1.1. Use of UAVs in anti-poaching efforts - WWF Nepal (2012):

UAVs were used as a conservation technology/tool for the first time in Nepal to monitor the animals and poachers via camera and GPS (www.phys.org). WWF provided two UAVs to the Nepal Army in order to combat poaching and logging. A pilot test of the UAVs was conducted in June 2012 and, following the government's interest in this technology, WWF organized training for the same in September 2012 (WWF, 2012).

2.1.2. Use of UAVs in glacier studies - ICIMOD Nepal (2013):

In coordination with Utrecht University of the Netherlands, ICIMOD Nepal carried out first ever UAV based glacier studies in Lirung Glacier of Nepal. They also later conducted a workshop on the use of UAVs in glacier monitoring in 2015 (UNESCO, 2019).

2.1.3. Academic research projects:

Kathmandu University was leading research regarding use of UAVs in various potential fields like post disaster quick assessment, crop monitoring and biomass estimation, Kathmandu University (KU & CIMMYT, 2019).

A group of students from Kathmandu University carried out an academic study as a part of their thesis and assessed the accuracy of the UAVs in generation of high-resolution surface models in surveying and mapping work (Oli, et. al., 2015).

2.1.4. Research and development of drones (hobbyists and enthusiasts):

Various robotics clubs in engineering colleges and some independent hobbyists and enthusiasts were involved in development of drone prototypes. A technology startup company Engineering ADDA Nepal had worked alongside Nepal Army for over a year in 2014/15 in the prototype development of a defensive system against drones.

The mentioned activities refer to some of the documented usage of UAVs in Nepal prior to the earthquake. The major areas of focus were seen to be research and studies, and not for the professional/industrial applications.

2.2 Usage of UAVs during Nepal Earthquake 2015

UAVs were widely introduced to the public and the government agencies in Nepal in the aftermath of the Nepal Earthquake 2015. After the seismic disaster hit Nepal, several humanitarian organizations, journalists and emergency responders used UAVs, mostly within the Kathmandu valley. Aerial photography and videography were done using UAVs in a large number of places mostly by aid workers for situational awareness. Large bird's-eye-view maps, technically termed as orthophoto maps, provided quality ground information like never before, helping a great deal to lots of people and organizations working in data collection, relief efforts and disaster response.
Following are the documented uses of drones in Nepal during the earthquake:

2.2.1. Damage Mapping & Situational Awareness:

Research institutions like ICIMOD, NSET and Kathmandu University used UAVs for mapping damages occurred from the recurring quakes in different locations (Baral, 2015).

A survey team including Nagoya University, Metropolitan University and the National Research Institute for Earth Science and Disaster Resilience used UAVs to survey the damages occurred in Langtang Valley.

Canadian UAVs maker Aeryon Labs, partner company MonaUAV of Monaco and the Canadian humanitarian aid organization Global Medic used UAVs to help aid relief operations during the earthquake by using UAVs to help photograph and map areas affected by the earthquake, and the information was passed to aid crews and rescue workers on the ground (BBC, 2015).

2.2.2 Search and Rescue Operations:

UAVs were also used by Nepal police and Nepal army in limited occasions and places, although the efforts were not scalable as they did not have sufficient equipment, expertise and skills for the use of UAVs. However, the limited use of UAVs showed better situational awareness, relief and rescue operations and gave rise to the popularity of UAVs among responsible institutions and authorities.

2.2.3. UAV Journalism and Story Maps:

During the earthquake, several organizations started using UAVs particularly for photography and videography. With the international media making use of aerial images and videos for news coverage and reporting, the significance of such contents was highly felt and hence led to the increase in use of UAVs in Nepal afterwards.

NBC News which had used UAVs in international reporting a couple of times covered a story during the devastating disaster. Their belief was that UAVs can provide unique views otherwise not possible from any ground or other aerial means of capturing (Tompkins, 2015). News media agencies like AP Media Insights used UAVs for reporting.

The mentioned activities refer to some of the documented usage of UAVs in Nepal during the earthquake. The major area of focus has been using UAVs for better coverage of ground situation, situational awareness and surveying and mapping of damages.

2.3 Usage of UAVs post April 2015 Earthquake

A lot of applications of UAVs were seen post-earthquake. Some significant applications of UAVs post-earthquake in Nepal have been mentioned below:

2.3.1. Surveying and Mapping to aid reconstruction efforts:

UAVs were used in inspecting areas and preparing maps and utilities to aid in the reconstruction efforts. The high-quality maps and photos obtained from UAV based surveying made it possible for preparation of village/community relocation plans and master plans quickly and more effectively. Among several humanitarian agencies working to support reconstruction efforts, a US based nonprofit agency Build change was leading several drone mapping related initiatives to map earthquake damage, create time series progress of reconstruction works and high-resolution maps for resettlement planning (Zechar, 2017).

2.3.2. Hazard Mapping:

A joint research team from the University of Michigan, University of Southern California in the US and Tribhuvan University in Nepal used UAVs in Earthquake induced landslide mapping efforts which otherwise would have been almost impossible owing to the steep topography and large size of landslide at few places. A humanitarian organization Medair, together with Nepal Flying labs, carried out mapping of a huge landslide in Ramechhap district to assess the potential risk of the landslide in locations where new houses were being built (Pudasaini, 2017).

2.3.3. UAVs for Humanitarian and Crisis Mapping:

A first of its kind training titled "Professional UAV training for Disaster Preparedness and Recovery" was held at Kathmandu University in September 2015 jointly by UAViators (humanitarian UAV network), Kathmandu University, Kathmandu Living Labs (a local civic tech institution), DJI (leading UAVs manufacturer) and PIX4D (leading UAV data processing company). The team together with Panga (Kirtipur) also did a UAV based survey of the affected community in Panga-Kirtipur, printed a flex map and shared it with the Community Disaster Management Committee (CDMC), Panga. A group of 30 Nepalese individuals from different sectors were trained in the use of UAVs for post disaster mapping and data processing. This marked an epoch in the brewing of many local professionals using UAVs for crisis mapping and humanitarian response in Nepal (GSW, 2015, Soesilo, 2015, KU, 2016).

2.3.4. Establishment of first ever local expert center on UAVs:

Following the first UAV training in the UK, a significant milestone was achieved which was the establishment of a local entity to take forth similar activities and create a favourable ecosystem around the use of UAVs and robotics in Nepal. An international organization, WeRobotics, established the first ever Flying labs - Nepal Flying Labs to localise UAVs and suitable robotics solutions by the capacity building of local experts in Nepal so that the local experts here can use these solutions in a sustainable way. Nepal flying labs since its establishment has been leading several UAVs based social good, humanitarian projects and also advocating for a favourable environment around UAV use in Nepal (Meier, 2016).

2.3.5. Establishment of UAV based service provider companies

As a milestone in terms of creation of a UAVs based market in Nepal, a company named Dronepal was initiated shortly after the Nepal Earthquake 2015, with their sole focus on the usability of UAV technology in various application areas in the context of Nepal, as well as sensitization and capacity-building programs to enable the UAV ecosystem to grow. Since then, Nepalese market has seen the growth in private businesses making use of drones in many diverse applications of UAVS, and many existing companies adopting drones in their workflows. Some other companies like Abhiyaan, Airlift Nepal, Madhuka are providing drone related services (WeRobotics, 2017).

2.3.6 Agriculture:

Different agencies and institutions like ICIMOD, Himalayan College of Agricultural Sciences and Technology, Kathmandu University, Mercy Corps Nepal and CIMMYT Nepal have been implementing the use of UAVs in the agricultural sector for research studies. We are yet to experience professional usage of UAVs in the sector.

2.3.7 Rural Healthcare

In rural Nepal, one of the biggest challenges for healthcare is the lack of an effective transport infrastructure. Healthcare workers or patients have to take hours-long walks to reach healthcare services, and many a time, the essential supplies get out of stock.[20] A UAVs based approach towards facilitating rural healthcare in Nepal was introduced in the form of a pilot project in 2019 namely Drone Optimized Therapy System (DrOTS) that aims to improve access to healthcare access in rural villages of Nepal. With support from WeRobotics, Nepal Flying Labs and Dronepal teamed up with Stony Brook University, BiratNepal Medical Trust (BNMT), the Liverpool School of Tropical Medicine, the Ministry of Health and Population (MoHP Nepal), the National TB Center, the District Public Health Office (DPHO Pyuthan) and the Simons Foundation to bring expertise in cargo drones to this significant public health project (WeRobotics, 2019, The Nepali Times, 2019). The project has already concluded its first phase successfully in Pyuthan, and now is on the works for the second phase with scaling to other areas in its work plan.

The aforementioned activities refer to some of the documented post-earthquake usage and milestones of UAVs in Nepal. The major focus however has mainly been in three sectoral areas: aerial photo/videography for media and filmmaking, surveying and mapping and, research and development on use of UAVs.

3. UAV REGULATIONS AND REGISTRATION

3.1 UAV Directives

The increase in the usage of UAV forthwith the earthquake invited a lot of concerns from the Government of Nepal. While UAVs aided a great deal to the numerous foreign and local volunteers, aid workers, and international and national media agencies, dedicatedly working in different ways from data collection to relief operations, few of the UAV operators were caught flying UAVs in highly sensitive areas such as world heritage sites, historic artefacts, military peripheries and police stations. The Government of Nepal realized the consequences of the unregulated use of UAVs and the Ministry of Home Affairs expeditiously released a set of strict UAVs guidelines. This greatly limited the use of UAVs in Nepal and resulted in a decrease in the rate of adoption of the technology for humanitarian causes. The first UAV directive of Nepal was released in May 2015 by the Civil Aviation Authority of Nepal to regulate and systematize the operations of UAVs within the territory of Nepal. It was designed in a very short time and as a result it came out a bit too vague. Nevertheless, it was appreciable at the time owing to its utmost need in regulating the UAV operations post-earthquake. The directive required taking permission from multiple ministries and authorities for each project and restricted the flight operations at specific locations for specific periods as permitted (CAAN, 2015).

Different government agencies have different concerns from their aspect regarding the use of UAVs as follows:

- The Civil Aviation Authority of Nepal (CAAN) is concerned about the safety as they believe unregulated UAV operation possesses high level security threats to aircrafts, weakens air safety and encroaches personal privacy.
- The Ministry of Communication and Information Technology (MoCIT) is concerned about the regulated use of frequency by UAV's communication systems that might interfere with the communication devices used by national security personnel.
- The Ministry of Home Affairs (MoHA) is concerned with the security and safety of the general public, and the security of their privacy given the fact that high resolution images can detect very minute ground features. Since UAVs originated as military warheads and spying mechanisms, MoHA's concerns are commendable and necessary.

Although UAV permissions for almost two years remained tedious, post-2016 saw a rise in the number of private institutions and organizations using UAVs professionally. Later in February 2019, MoHA finally published a Remotely Piloted Aircraft/ Drone Related Flight Procedure, [23] which made it comparatively easier for professionals to use UAVs. The authority to provide flight permissions has since been delegated to the local government for the most popular categories of UAVs, hence making it much more convenient and faster for people.

3.2 UAV Registration

The MOHA Remotely Piloted Aircraft/ Drone Related Flight Procedure has categorized UAV into four specific types and has also introduced the provision for registration of UAVs from CAAN. As per the directive, all types of UAVs must be registered for a Unique Identification Number (UIN) with CAAN. UAVs are classified according to weight, purpose of flight and sensitivity of risk of flight operations viz. Category A, B, C and D (Dalamagkidis, 2015).

Table 1: Per category total number of UAVs registrations till March 2020 *information obtained from CAAN

.

	Weight of UAV	Risk of flight operations	Registered till Date
A	<250gm	Very low	15
B	250gms to 2 kgs	Low	129
C	2 kgs to 25 kgs	Regulated, Low	10
D	>25kgs	Regulated, High	0

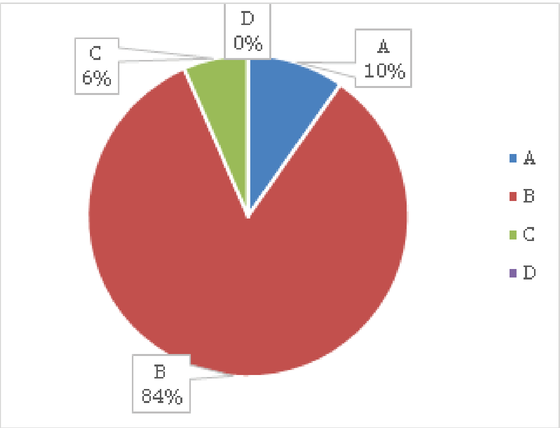

Chart 1 : Percentage of different category registered UAVs till date

An application needs to be submitted to the Flight Safety Standards Department, CAAN for the UAV registration for any one of these categories. The application package includes personal details or company documents with purpose of operation, details of purchase, custom clearance document and technical specifications of the UAV.

4. EXISTING AND PROSPECTIVE UAV APPLICATIONS IN NEPAL

4.1 Aerial Photography and Videography:

Nepal is home to many floras and faunas, and is the second richest country in water resources. Due to its diversity in topography, biology and climate, Nepal is considered as a rich country in terms of natural beauty. Aerial means of photo/videography is an effectively crucial means for capturing its true beauty. Use of UAVs in Nepal for photography and videography traces back to almost a decade, however, the rise in its popularity has been after the earthquake. Since then, the use of UAVs in photography, cinematography and media has risen exponentially.

Benefits: Aerial videos and photos help to capture bird's-eye-views of locations which is not possible and/or feasible with traditional methods. It's also much more flexible, cheaper, convenient and accessible than aerial photography using helicopters and planes.

Challenges: The process for securing permission for aerial photo/videography is the same as of any other professional application. Owing to the context and risk scenarios relating to the use of UAVs in photo/videography, the permission process needs to me more flexible and convenient since UAVs have democratized the professional aerial photo/videography, enabling not just media companies but also individual professionals to use them.

Licensing and regulation of UAV pilots is also required as the number of UAV pilots is rapidly growing without any quality check.

4.2 Surveying and Mapping:

About 70% of Nepal's topography is rough, and topographical surveying has a huge drawback owing to inaccessible locations, high risks to surveyors and equipment with the use of traditional tools and technologies. Also, being an underdeveloped country, Nepal has significant requirements for quality data driven development, hence giving rise to a need for a better intervention in surveying and mapping. As such, UAV technology has a huge scope in the said area in Nepal. The most popular types of surveys in Nepal are: land surveys, road surveys, hydropower surveys, as-built surveys, sewer and canal alignment surveys, transmission line surveys, etc. Also, a number of government agencies like the Survey Department, Nepal Electricity Authority, Department of Mines and Geology, Department of Roads and many newly formed local government units have prioritized use of UAVs in some of their projects, and recently in 2019, The National Surveying and Mapping Agency of Nepal also procured UAV for surveying and mapping.

Benefits: In comparison with traditional topographical surveying techniques, UAV photogrammetry (referring to capture of photos/videos along with measurement data) is cheaper, faster and more accessible, and helps generate several high-quality mapping products with details up to millimeters level

(Beretta, et. al., 2018). The UAV mapping could be delivered in less than 20% of the turn-around time that a conventional approach would have required (Volkmann, 2017).

Challenges: Most common and affordable UAVs in the market rely on RGB cameras/ sensors and are unable to provide quality data over areas with dense vegetation cover. In Nepal, a majority of areas are covered with vegetation, and the alternative lidar-based UAV technology to be used in such cases is highly expensive, hence making it challenging.

4.3 Disaster Response and Management:

Frequent multi-disasters in Nepal's difficult terrain makes disaster management a huge challenge and it is imperative to have up-to-date geospatial information. UAV enabled highly portable and quick-to-deploy alternatives for situational awareness to aid with efficient disaster planning and management. The high-resolution aerial imageries captured from drones can be utilized to create detailed maps that can in turn help in contextualizing the disaster management plans and responses.

Benefits: The high-quality maps and outputs produced from UAV based mapping enable efficient response plans and also encourage better coordination among various response teams and agencies.

Challenges: Using UAVs nowadays is much easier, but the unregulated use of UAVs without considering the privacy of people as well as the negative impacts of its use on people and communities leads to further damages in addition to the disasters themselves. We still lack a disciplined and regulated approach towards humanitarian responses using UAVs.

4.4 Rural Healthcare:

UAVs are far less time consuming than having to travel by foot, or through dangerous winding roads in mountains. It can be a very efficient tool to connect primary health facilities to more equipped hospitals by delivering patient information such as blood, urine and stool samples required for diagnosis from primary facilities to hospitals; and medicines from hospitals to patients in nearby rural locations in remote villages of Nepal. The problems with connectivity among health facilities, diagnostic laboratories and well-trained personnel, as well as with the access to basic medicines at the time of emergencies can be ameliorated efficiently and cost-effectively through UAVs. Different organizations have been trying to implement UAVs for rural health programs in Nepal.

Benefits: Efficient solution for connecting most rural communities in Nepal with essential medications and health services during emergencies where access to healthcare facilities by road is very difficult.

Challenges: Long range deliveries and delivery of larger payloads present technical bottlenecks in implementation of UAVs. Also, due to a lack of local maintenance facilities and enough skilled manpower for UAVs, sustainably implementing such projects is still hard in Nepalese context.

4.5 Urban Planning:

Nepal has only recently been federalized forming 7 provincial governments and 753 local governments, which are all prioritizing infrastructure development and planning. All these cases lead to a necessity of high-quality data and tools assisting in proper planning, and hence UAVs and related technologies possess huge significance in Nepal. Firstly, the dense urban clusters can be mapped in high resolution and spatial footprints of the utility structures could be derived that could help in proper planning development activities. Secondly, the urban sprawl could be made much more efficient through planning based on such high-quality data.

Benefits: High resolution spatial data from UAVs aids in proper planning in case of dense clustered areas. These data and utilities also reduce the redundancy of needing to conduct multiple kinds of surveys in the same area for different development purposes.

Challenges: Securing necessary permissions to fly over dense urban clusters is a huge challenge in Nepal, and also poses risks to people and infrastructures if done without proper security measures. Also, the UAV market is still in its infancy in Nepal, and hence creates hardships in scaling up mapping activities nation-wide.

4.6 Agriculture:

Nepal is an agricultural country with involvement of 65% of its total population in agriculture and contributing to almost 32% of its total GDP. The public in Nepal have agricultural land ownership mostly in segregated clusters here and there, resulting in a fragmented farming system. Their reliance is on traditional tools and technologies that age decades if not centuries, and hence have a dire need for disruption through technologies in many aspects.

UAVs equipped with different multispectral sensors can be used in collecting data that could help with better assessment of crop health, irrigation needs, farming management needs, etc. With the right government policies, programs and support to encourage advancements in agriculture, UAVs could really disrupt the way farming is done in Nepal, moving towards precision and data-driven farming from traditional farming.

Benefits: Detailed data from UAVs equipped with multiple sensors could help in higher yields through data driven farming and agriculture.

Challenges: Many farmers in Nepal have small land areas located in multiple locations also called as fragmented farming systems, which makes use of UAVs costlier. Also, the technical capacity of such farmers is much limited, hence making it difficult to implement locally sustainable UAV based approaches.

4.7 UAVs for Glaciological Studies:

Glaciers are an important indicator of climate change and changes in glaciers need to be monitored and studied on a regular basis. Satellite images are usually low in resolution due to cloud covers affecting the quality of data at such high altitudes, where glaciers are found. This establishes UAVs as important tools in data capture in such high-altitude areas to obtain high resolution images, thus helping a great deal in extracting different information of the glaciers and its surrounding like the rate of ice melting, changes in supraglacial lakes, changes in the geometry, area, etc.

Benefits: UAVs enable collection of data over large stretches of area in shorter time. They are operated below clouds hence solves the problems of data loss due to cloud covers in satellite imageries.

Challenges: Mapping very high-altitude locations requires special UAVs which are relatively expensive. Such drones are usually short-ranged, hence requiring the piloting team to be present at the site physically, hence making the mapping projects harder and time consuming as the teams need to trek for days just to reach the sites.

4.8 Biodiversity conservation and ecological monitoring:

Nepal is a richest country in biodiversity and hence regarded as a biodiversity hotspot. A lot of efforts and projects have been in the field of biodiversity conservation in Nepal since ages which is home to lots of floras and faunas, many endangered animals like one-horned rhinos and many unique to its environment like spiny babbler, Nepali Kalij, etc. UAVs equipped with different optical and multispectral sensors can be utilized in biodiversity and environmental studies for applications like wildlife monitoring, forest biomass estimation, counting and tracking various endangered species of animals in national parks and wildlife reserves, etc.

among others.

Benefits: UAVs provide quicker, cheaper and faster-to-deploy solutions to wildlife monitoring and conservation efforts.

Challenges: Multi-spectral sensors are expensive and also professional UAVs used in this kind of application are not readily available in Nepal.

4.9 UAV/Drone Journalism:

Journalism over the past few years has seen a rapid increase in the use of UAVs in Nepal, especially following the earthquake, where lots of national and international media used UAVs for news footage. Pahilopost.com, an independent news portal in Nepali language is the first media in the country to use UAVs for gathering news since April 2015. Ever since, a majority of news agencies have opted to use UAVs in at least a few of their coverages. The Nepal Flying Labs along with Photojournalist Club organised a one-day interaction session on UAV Journalism to sensitize around the use of UAVs in journalism. Use of UAVs is much more efficient and feasible for aerial media coverage instead of costlier alternatives like helicopters and balloons, and the ease of use of UAVs also makes it superior to other methods. While UAV journalism is still in infancy in Nepal, it has lots of scope and it is also growing day by day in use.

Benefits: UAVs provide aerial views with much higher flexibility in operation and reduced costs compared to other means of aerial photo/videography, which has enabled even small media companies to make use of UAVs.

Challenges: Nepal still doesn't have licensing policies for the regulation of UAV in journalism. Also, due to the democratization of aerial photo/videography by UAVs, we are prone to more privacy and security issues in lack of efficient regulations and monitoring systems.

Apart from the applications discussed earlier, there still are a few more applications in the context of Nepal. The national security agencies are using UAVs for surveillance. UAVs are being used most of the time during visits of VIPs and also for the surveillance of some busiest streets in the valley. Different innovation hubs, groups of young college graduates, student clubs in colleges and schools have started integrating UAVs as a part of their interest, educational assessments and have been trying to use it across different sectors. Many companies and organisations have also been using UAV generated data in combination with AI and other technologies to produce amazing results in many sectors.

5. MARKET CHALLENGE FOR DRONE INDUSTRY & SUGGESTIONS

While the applications of UAVs have gained momentum over the years, a lot of factors still pose great challenges to the UAV industry that need to be resolved in order to facilitate greater adoption of the technology in Nepal. Some of the challenges and corresponding suggestions could be summarized as follows:

Hardware issues: There are no UAV manufacturers in Nepal, and all the UAVs being used professionally are imported from abroad. Since UAVs are highly prone to damage owing to the undulating terrain, UAV accidents are very likely in Nepal. Since only few UAV repairing shops are available in Nepal that are able to handle just basic replacements, it's much tedious and costly to get the UAVs repaired in case of serious damages where the only option is to send UAVs abroad.

Manual Registration process: While there have been few positive changes in the recent UAV directives, few crucial mechanisms are yet to be implemented like the digital registration process, provision for monitoring and surveillance of UAV flights and approvals of UAV pilot institutions, registration of drones without purchase documents (those purchased way back, or the ones donated by foreign institutions/individuals).

Drone licensing policies: There are no provisions for UAV pilot licensing in Nepal, and no institution or individual can hold a license for UAV piloting. This has negatively impacted the market standard in terms of quality of drone services, as well as made it tedious for professionals to rapidly use UAVs.

Inefficient Permission Procedures: With the current permission regulations, there are many aspects that adversely impact the use of UAVs in Nepal. Firstly, lacking a one-door policy, the permission process is still tedious and time consuming in many cases. Although the permission process is more systematic than before, the entire process is manual which needs to be digitized and improved.

UAV insurance: Drone insurance is mandatory as per the guidelines for flight permission. Only 3rd party insurance is possible and feasible but it is extremely challenging and difficult to insure UAVs currently in Nepal.

Seeing the significant increase in the use of UAVs and its evolution in Nepalese Market, it is recommended to the government of Nepal to dedicate a priority unit to regulate the UAVs instead of distributing the authority to the CAAN and the MoHA's existing departments. Standardization in pricing- UAVs are very easy to fly, anyone with some online training could fly a drone. There is no competitive authority to set all the standard pricing, standard for human resources etc.

6. LIMITATIONS OF THE STUDY

This study is based on the documentations available over the internet and few publications. So the facts relating to UAVs that have not been publicly available could be missing. The limitations of this study could be briefly listed as:

1. In the case of exponential and disruptive technologies like UAVs, exactly predicting the trends and application areas is never possible as newer and better use cases keep emerging. While this study tries to portray the best possible representation of drone industry in Nepal, the context of the industry worldwide has taken higher leaps and hence this study doesn't portray the industry trends worldwide.

2. We haven't included the economic factor and availability of UAVs in the international market that also plays a role in the evolution of drone use cases in Nepal. A redundant issue with many application areas of UAVs in Nepal is due to the lack of proper infrastructure and skills to maintain and repair drones, which is not an issue in most of the countries.

3. This study lacks details on facts and figures relating to the Nepalese drone industry due to the lack of much data on the same.

7. CONCLUSION:

Prior to the April 2015 Earthquake, only a selected group of technology enthusiasts, researchers and organizations had been making use of the technology in Nepal. However, the use of UAVs during the disaster acted as a catalyst towards increasing UAV popularity and it significantly gave rise to its adoption in various applications, mainly by the private sector in Nepal. Even the government has started viewing UAVs as an imperative technology in some applications and has included its use in some ambitious projects of its own, while a large number of private, international and national organisations have been making use of UAVs as data collection tools for different applications. Currently, UAVs are used for aerial surveying, agricultural study, risks and hazards mapping, photography/videography, aerial surveillance, rescue efforts and medical cargo deliveries.

Though a new practice of decentralization can be witnessed in terms of giving local district governments the authority to permit flights of

UAVs, a proper system to track all permission requests and approved permissions all over the country is equally important. The beginning of a drone registration system to keep record of each and every drone in the country is a very important step in establishing drone industry but digitization of entire registration and permission process should be taken in parallel to properly document everything.

Additionally, in order to catch up with the fast-paced development of UAV technology, and ensure its contextualization and sustained application in Nepal, a much higher prioritization needs to be done in few of the areas such as proper technology transfer to the local people, capacity building of local people for sustainable UAV applications as businesses as well as for efficient surveying. Due to its rich diversity in topography, altitude, climate and biology, Nepal could be a central place for reverse innovation, helping countries and companies experimenting with cargo UAVs, drone deliveries, etc. Research, development and experiments are needed to be done for these various UAVs based solutions and to scale them to other regions.

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Author's Information

Name	:	Biplav Pageni
Academic Qualification	:	Bachelors of Technology in Mechanical Engineering
Organization	:	Nepal Flying Labs
Current Designation	:	Program Manager
E-mail	:	pbiplav@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.

Surya Lal Bhomi
Survey Officer,
Survey Department
2076/04/03.

Birendra Bista
Asst. Surveyor,
Survey Office Nuwakot
2076/03/29

Ayodhi Mahato
Asst. Surveyor,
Survey Office Solukhumbu

Improving Aboveground Carbon Stock Mapping Using Lidar and Optical Remote Sensing Data in Mountain of Nepal

Sajana Maharjan, Rajesh Bahadur Thapa
sajana.maharjan@icimod.org

KEYWORDS

LIDAR, Segmentation, Classification, Carbon Stock

ABSTRACT

There is a demand for methods to accurately estimate above ground carbon stock in response to climate change mitigation action. The study aims to develop a method to accurately estimate and map above ground woody carbon stocks using airborne LIDAR data (0.8 point/m2) and optical images (0.45m resolution) acquired over the mountains in Central Nepal. Canopy Height Model (CHM) was generated using LIDAR first return and last return. RMSE of 2.8m was obtained for LIDAR derived height. Object based image analysis (OBIA) and nearest neighbor classification methods were used to retrieve individual tree crown area and tree species (Shorearobusta and others) information. Segmentation accuracy was 76.2% based on 1:1 correspondence andthe overall classification accuracy was 75.86%. Multiple linear regression models which showed the lowest relative RMSE36.8% (Shorearobusta) and 32.4% (others)were used to estimate carbon stocks of the study area. The total amount of carbon stocks in the study area was approximately 89.45 MgCha-1.

1. INTRODUCTION

Forests play crucial role in global carbon cycle as they act as sink as well as source of carbon (Muukkonen et al., 2007). They hold more than 60% of the carbon contained in the aboveground biomass and about 45% of the carbon contained in soils, roots and litter at a global carbon scale (Dixon et al., 1993). Reducing deforestation,afforestation, and reforestation are therefore mitigation measures for global climate change (Hunt, 2009). Reducing Emissions from Deforestation and Forest Degradation (REDD+) implementation is one of the core component of Paris Agreement (COP 21) (UNFCCC, 2016) and is a climate change mitigation action. Reliable baseline statistics on national forest carbon stocks and sources of carbon emission is required to establish a national reference scenario and to implement REDD+. Therefore, there is a need to develop a robust method which can accurately estimate forest above ground biomass (AGB) and its carbon stocks (Thapa et al, 2015). Integrating remote sensing and field measured data provide important insights on AGB estimation of forest.

Several studies have already been done on estimation of ABG using remote sensing and field measurements (Saatchi et al., 2011, Thapa et al., 2016, Flores et al., 2019). NOAA AVHRR and MODIS (Dong et al., 2003; Baccini et al., 2004) have been used for biomass estimation at global and continental scale. Coarser spatial resolution data for forest AGB estimation was found to be unsuitable due to mixed pixels and the huge difference between the support of ground reference data and pixel size of the satellite data (Muukkonen et al., 2007).AGB estimation using medium resolution satellite imagery such as Landsat TM at national and regional level showed data saturation, mixed pixels and cloudy weather problems (Lu,2005; Steininger, 2000). Very high resolution (VHR) images such as aerial photograph, satellite images such as Quickbird, IKONOS, WorldView and GeoEye images can detect individual tree crowns (Gonzalez et al., 2010). In addition, crown density and species identification had been done using high resolution data (Katoh et al., 2009) while some studies reported AGB estimation relating DBH to tree crown area delineated using VHR images (Hirata et al., 2009; Song et al., 2010). However, models based on onlycrown area (CPA) and DBH are often insufficientto estimate biomass accurately because these models missed tree height information which is crucial parameter for biomass estimation. Height varies for same DBH of trees which eventually misguides AGB estimation. Thus, height of trees should be considered for accurate estimate of biomass. In addition, intermingled trees cannot be separated even with high resolution images which cause error in individual tree crown delineation and eventually leads inaccurate AGB estimation (Hirata et al., 2009; Palace et al., 2008). If the intermingled trees are of the same species, this might have less impact on AGB as wood density remains same. However, this might not always be the case in mixed sub-tropical forest. LIDAR data can separate intermingled tree crowns based on their tree tops as it gives tree height information (Thapa et al., 2015).

Optical remote sensing data lacks height information. To overcome this, airborne LIDAR data can be used which provides tree height information. Severalstudies (Asner et al., 2012; Kronsederet al., 2012; Thapa et al., 2015) found accurate estimation of AGB using LIDAR data. Integration of LIDAR data with optical images have shown further improvement in accuracy of AGB estimation thereby improving individual tree crown delineation and forest type classification (Leckieet al., 2003; Holmgren et al., 2008; Karna et al., 2015, Wangda et al., 2019).More studies on AGB mapping are required over varying geographic areas as forest structure and associated environment varies in large geographic space. Such studies are still lacking in the unique geographic characteristics of Nepal, therefore, the study aims to develop a method to accurately estimate and map above ground woody carbon stocks using airborne LIDAR and optical images acquired overthe mountains in Central Nepal.

2. STUDY AREA AND DATA USED

Our study area is located in Ludikhola Watershed which lies in southern part of GorkhaDistrict, Nepal (Figure 1). The watershed covers 1888 ha of forest area with elevation ranging from 318 m to 1714 m (Shrestha et al., 2014; REDD, 2011) having sub-tropical forests. The watershed consists of 31 community forests (CFs). The study was carried out only in five CFs, i.e.,Ludidamgade, Birenchok, Kuwadi, Chisapani and Shikhar. These CFswere chosen as representative of sub-tropical forests of Nepal, and based on data availability and accessibility.

LIDAR data was acquired within 16 March to 2 April 2011 with point density of 0.8 point/ m^2 on average. High resolution optical camera was mounted in the same platform as LIDAR which acquired optical images at 0.45 m resolution (Arbonaut 2012).

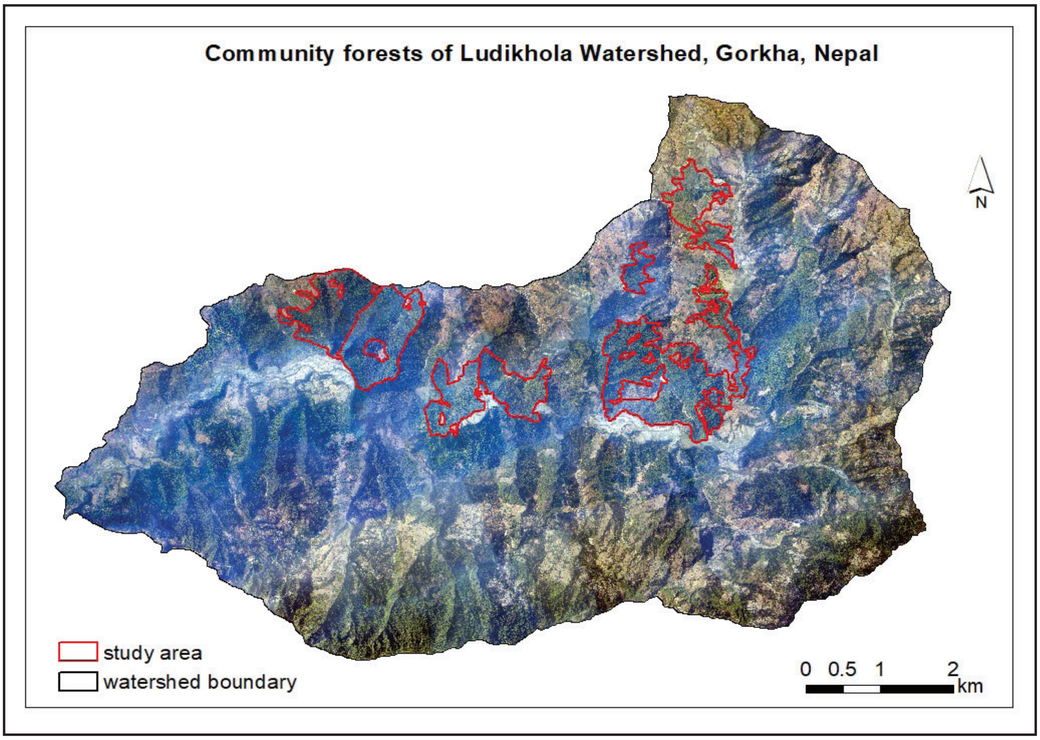


Figure 1: Location of study area

3. METHODS

3.1 Field work

Stratified random sampling, as per the Community Forest Inventory Guideline of Nepal 2004was adopted for this research as it ensures samples are being spread out over the entire study area and gives more precise estimates of forest parameters (Husch et al., 2003). The field work was carried out in September-October 2011. Circular plots with radius 12.62 m and plot area of 500 m^2 were used. Information on intermingled trees and forest parameters such as DBH, height, crown diameter, crown density and species were collected for each plot in the field.

3.2 Trees delineation

Trees identified on the field were manually delineated on 3×3 low pass filtered in the optical image. Crown diameter measured in the field was used as reference to correctly delineate the tree.Only 294 trees were recognized on the image and were manually delineated. The delineated tree crown areas were used to extract the height of the trees from the LIDAR data.

3.3 Canopy height model development and validation

Canopy height model (CHM) can be generated by subtracting Digital Terrain Model (DTM) from Digital Surface Model (DSM) which can be directly related to the height of the trees (Asner et al., 2012; Kim et al., 2010; Thapa et al., 2015). DTM represents bare ground surface whereas DSM represents ground surface including all objects on it (Heritage et al., 2009). The DTM was generated from the last returns of the LIDAR pulse which describes ground surface. Similarly,the DSM was generated from the first canopy return of the LIDAR pulse which describes the canopy surface. The available LIDAR data was in the form of point cloud which was processed using Lastoolsto develop DTM and DSM.The obtained CHM was then filtered to surpass the outliers.LIDAR derived height was validated with field measured heightinformation by computing regression coefficient of determination (R^2) and root mean squared error (RMSE).

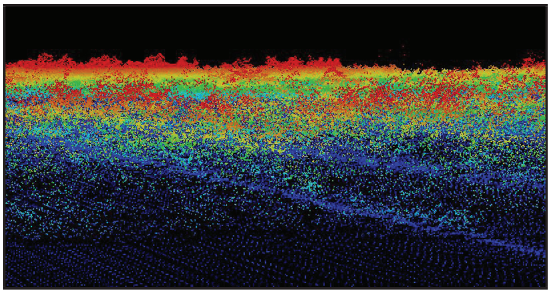


Figure 2 Point cloud (different color shows height variation of the object)

3.4 Optical image segmentation and validation

Optical image segmentation was required to obtaincrown projection area (CPA) of individual tree. Several studies (Kim et al., 2010; Leckie et al., 2003; Song et al., 2010; Karna et al., 2015) have shown individual tree crown delineation using high resolution images with segmentation techniques. We have chosen chessboard segmentation and region growing segmentation methods in eCognition Software. Grid size of two by two pixels was used for chessboard segmentation. Window size of 5×5 was given for region growing as average crown diameter measured in the field was approximately 4 m. Basic and advanced reshaping of tree crown segments were done using watershed transformation and morphology techniques to refine individual tree crown delineation. In this study, two segmentation accuracy measures were applied i.e. Relative Area Measures (Clinton et al.,2010) and 1:1 correspondence (Zhan et al., 2005). These measures wereused when manually delineated and automatic segments are available. Over segmentation, under segmentation, and segmentation goodness (D) weredefined according to Clinton et al. (2010).

3.5 Segmentation assessment for intermingled trees

Segmentation using both images (CHM and optical image) separates intermingled tree accurately. However, segmentation were visually checked with reference to field data. If there are two segments for two trees which were found to be intermingled in the field, then intermingled trees are considered separated.

3.6 Tree species classification and accuracy assessment

Nearest neighbour classification algorithm was applied for tree species classification. Though *Shorearobusta*, *Schimawallichii, Castanopsisindica*and *Rhuswallichii*tree species were found in the study area, classification was done only into two classes i.e. *Shorearobusta*and others. This is because most of the trees identified on the image were *Shorearobusta* and there were not enough samples for *Schimawallichii, Castanopsisindica*and *Rhuswallichii*on the image. About 70% of the samples were used for classification and remaining 30% were used for validation.

3.7 AGB and carbon stock calculation

Allometric equation (Eq. 1) developed for tropical moist forest by Chave et al. (2005) was used to calculate AGB as site specific allometric equations were not available.

…………(1)

Where,

AGB = above ground biomass [kg]

ρ = wood specific gravity [gm/cm^3]

D = tree diameter at breast height (DBH) [cm] and

H = tree height [m]

Wood specific gravity for *Shorearobusta* is 0.88 gm/cm^3 and for others is 0.72 gm/cm^3 (Shrestha et al., 2014). Then, carbon stock of the tree was calculated from AGB using conversion factor 0.47 (IPCC, 2003).

3.8 Regression models and validations

Models based on linear relationships between carbon and CPA, carbon and height, and carbon, CPA and height were developed. Variation Inflation Factor (VIF) was calculated to checkmulticollinearity among the variables. VIF value above 10 indicates that there will be effect of multicollinearity on the model (Obrien, 2007). Only trees which had one to one matching of the segments and correctly classified were taken for model development and validation. Outliers were removed which is the prerequisite of the regression models (Mora et al., 2010). Thus, total number of sample data becomes lesser than the trees that were initially identified on the image. Only 239 trees were used for model development and validation. Carbon calculated from the field data and carbon predicted by the model were compared to validate the models. Models performance were evaluated with coefficient of determination (R^2) and root mean squared error (RMSE).

3.9 Carbon stock mapping

Multiple linear regression models were developed for both *Shorearobusta* and other species to estimate the amount of carbon stocks in the study area. Relative RMSE for each model was reported.

4. RESULTS AND DISCUSSION

4.1 CHM preparation and accuracy assessment of LIDAR derived height

CHM showed that the tree height in the study area is upto40 m. LIDAR derived height was compared with field measured height using linear regression modelin whichcoefficient of determination (R^2) was 0.74 and RMSE was 2.8 m. LIDAR derived tree height underestimated field measured tree height by 0.98 m on average. The error could be because of low point density (0.8 point/m^2 on average) or tree height measurement errors induced by the equipment in the field. Due to the low point density, there is less probability that laser returns hit the true tree top of a tree (Suarez et al., 2005). This leads to the variation in LIDAR derived height with field measured height. Other studies also reported underestimation of ground measured tree height (Leckie et al., 2003; Saurez et al., 2005) although these studies used higher point density LIDAR data compared to the data used in this study.This could be due to coniferous forests which were their study areas in both cases. The crowns of coniferous trees have a triangular shape (Figure 3a). Compare to this, the crowns of deciduous trees found in CFs of Ludikhola Watershed are relatively flat leading to less variation in height from tree top to the edges of the crowns (Figure 3b). Due to the crown shape in coniferous trees, laser returns hitting the true tree top and those hitting the edges have a higher variation in height than in deciduous trees. Thus, in this study with low point density the underestimation is not high compared to the studies (Leckie et al., 2003; Saurez et al., 2005). In addition, the gridding process might introduce error into the CHM through the interpolation method and the grid spacing chosen (Smith et al., 2004). Canopy height underestimation might be due to the laser pulse penetration into the canopy before reflecting a signal and the signal might not be detected by the scanner as a first return (Gaveau et al., 2003).

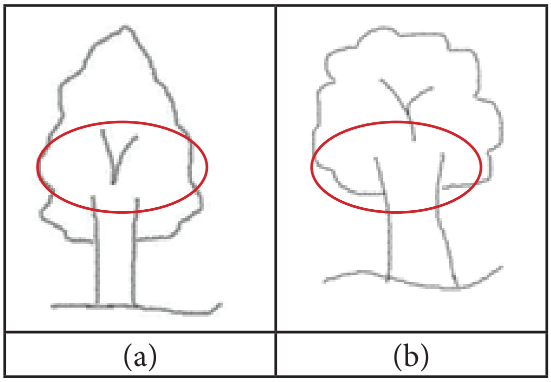


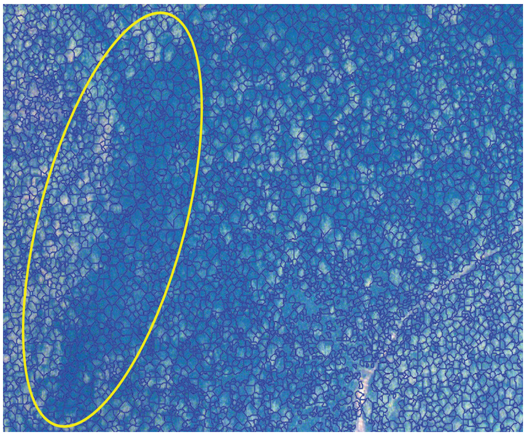
Figure 3: Crowns shape (a) coniferous tree (b) deciduous tree

4.2 Tree crown delineation and accuracy assessment

For the all delineated tree crowns of the study area, over segmentation was 0.29, under segmentation was 0.33 andD value was 0.31. For the accuracy measures of 1:1 correspondence, manually delineated tree crowns and automated segments from segmentation were assessed by matching on one to one basis. On the basis of this accuracy measures, overall segmentation accuracy was 76.2%.

Both images (CHM and optical image) were used in order to assign the classes trees and others (shadow, bare land). The use of CHM in this step helped to extract trees in shadow area (Figure 4) which would be missed if only reflectance values were used. The use of height information helped to separate trees from other vegetation (shrubs and herbs). In this regard, the use of height information for tree crown delineation helped to eliminate most of the commission errors (delineating shrubs or other ground vegetation as trees) that often occur in open forest area with optical imagery. Lopped trees were filtered using height information.

a. Shadow area



b. Segments on shadow area

Figure 4: Digital camera image showing shadow area and segments on the shadow area

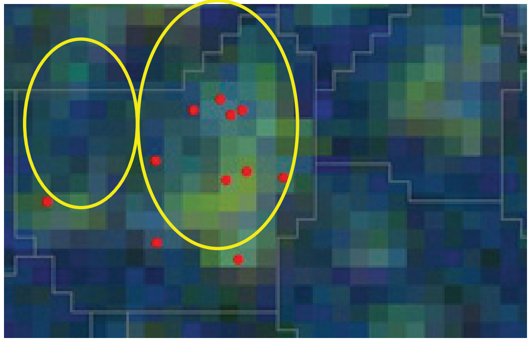
Both commission and omission errors were found in the segmentation. Omission errors occurred due to intermingled trees whereas commission errors were due to irregular shape of the tree crowns where an individual branch may create falsetree tops, so there seems to be two trees instead of one. Segmentation accuracy in this study was improved as compared to Shah (2011).The improvement could be due to the addition of height information in the segmentation as similar to Kim et al. (2010).

4.3 Image classification and accuracy assessment

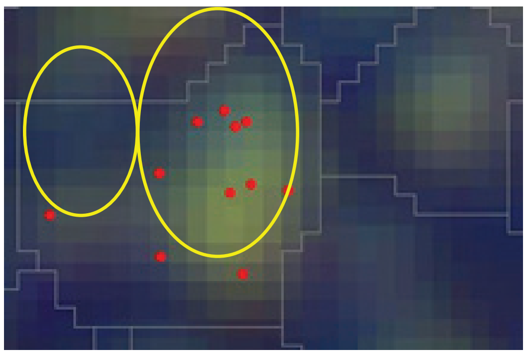
Trees were classified into two groups i.e. Shorea robusta and others. Overall classification accuracy was 75.86%. The accuracy might be affected by quality of crown delineation (Ke et al., 2010), the spectral information being used (ITC, 2010) and shadow due to high hills. Shadow was prominent due to the topography of the study area which led to variation in brightness values of trees even for same species. Eventually, this has affected in crown delineation and classification. The accuracy is lower than Ali et al. (2008) which achieved 86% overall classification accuracy for two species using different multi-spectral imagery (4 bands) and higher resolution LIDAR data (16 points/m2).

4.4 LIDAR data in separating intermingled tree crowns

In this study, intermingled trees were not separated even using LIDAR data with point density of 0.8 point/m^2. In region growing segmentation, a region grows from the tree top until it reaches to local minima. In intermingles trees, there are two trees but there are not enough points with brightness values that are sufficiently different due to which the algorithm cannot separate two intermingled trees (Figure 5). In addition, the points are irregularly shaped. However, this logic is applicable for low degree of intermingling, as trees can be intermingled in different degrees in nature (Figure 6).



a. Multipoint on the image



b. Multipoint on the smoothen image

Figure 5: Showing multipoint (from point cloud) (yellow oval shapes show 2 trees that are intermingled)

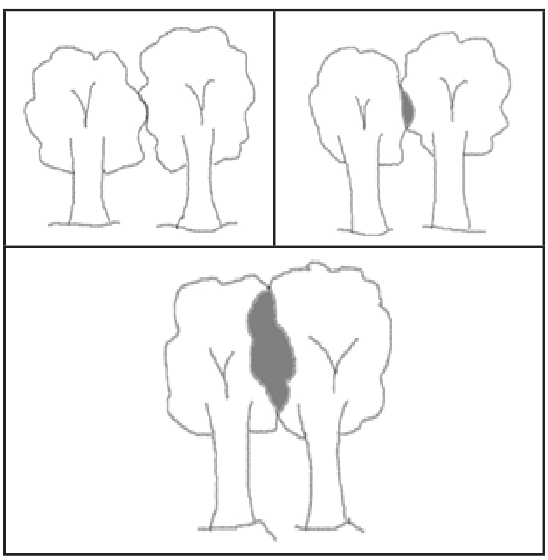


Figure 6: Different degree of two intermingled canopy trees

In this study, data on the degree of intermingled trees were not collected. If crowns have a high degree of intermingling there would be no local minima or valleys between tree tops and the crowns are considered to be one. There were more omission errors observed in deciduous trees due to densely growing trees with homogenous height distribution resulting in inability to separate neighboring trees.

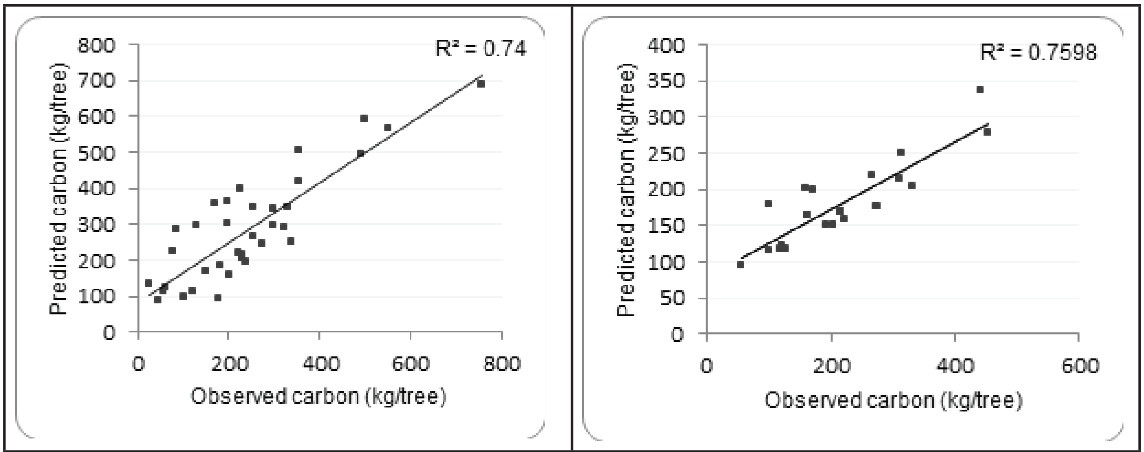
4.5 Regression models and validations

Relationships of field measured carbon with CPA and CHMfor both *Shorearobusta* and other species were obtained using multiple linear regression model (Eq. 1 and 2).132 measurements were used for model development for *Shorearobusta*and 47 measurements were used in case of the other species. In general, all models were explaining well the relationship of carbon with CPA and CHM. In this relationship, the VIF was less than 1. The multiple linear regression models had relative RMSEs,i.e. 36.8% and 32.4% for both *Shorearobusta* and other species, respectively.

$$Carbon\ stock\ (Shorea\ robusta) = -163.07 + 10.58 \times CPA + 11.58 \times CHM \ldots\ldots\ (2)$$

$$Carbon\ stock\ (Others) = -102.2 + 6.2 \times CPA + 9.48 \times CHM \ldots\ldots\ (3)$$

Result showed that there were improvements in the models using two explanatory variables (CPA and the canopy height). Height and CPA are important biophysical parameters to estimate biomass of a tree using remote sensing. Moreover, biomass depends on volume and volume can be calculated from height and DBH. Since there is relation between CPA and DBH (Hirata et al., 2009; Shimano, 1997), it is expected that CPA and height will give a good estimate of biomass. Consequently, these two variables i.e. height and CPA can explain more about variability of biomass than using either of variables alone. Coefficient of determination (R^2) were 0.74 and 0.76 for *Shorearobusta* and others, respectively (Figure 7).



a. *Shorearobusta*	b. Others

Figure 7: Scatterplots of predicted versus observed carbon

4.6 Carbon stock mapping

The carbon stock models (Eq. 1 and 2) were used for both *Shorearobusta* and other species to extrapolate the amount of carbon stock spatially and mapping the carbon stock in the study area (Figure 8). The study area has approximately 89.45 $MgCha^{-1}$.

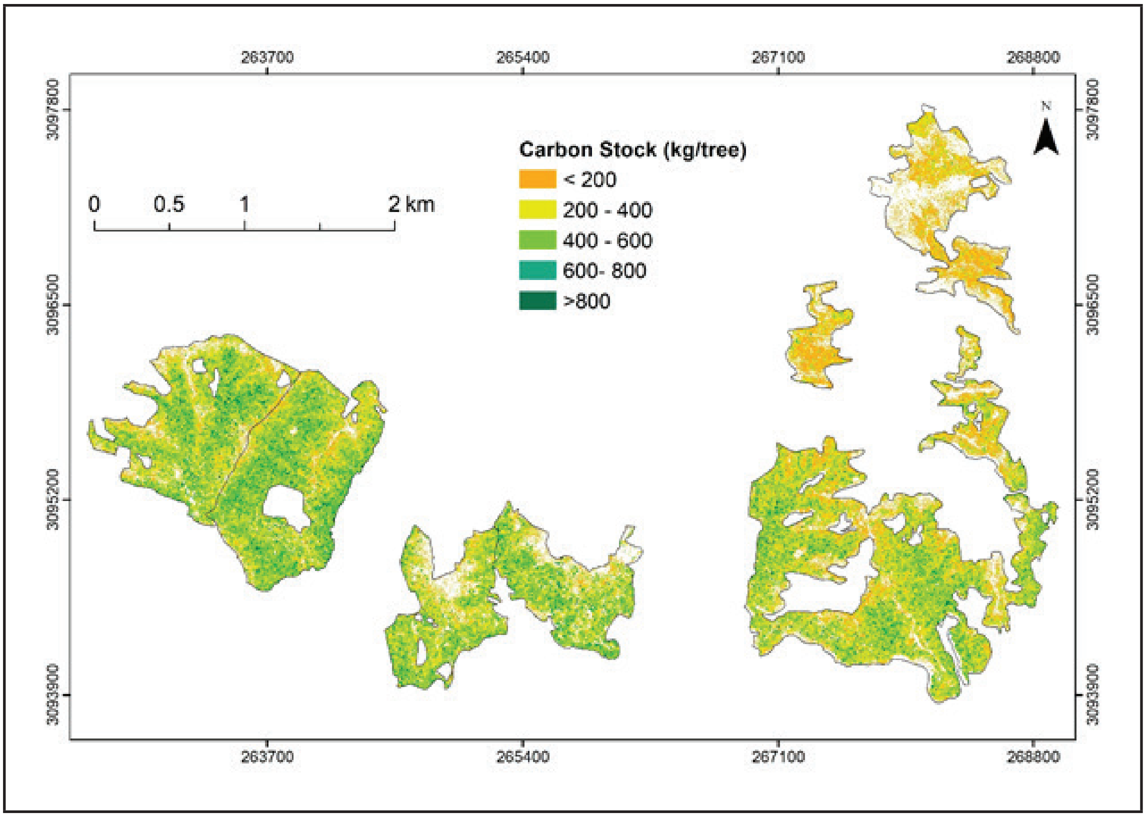


Figure 8: Carbon Stock Map of the Study Area

5. CONCLUSIONS

Although, numerous studies to estimate forest carbon stocks from LIDAR were documented, there are limited examples in the literature that address the combination of the LIDAR pulse returns and the very high resolution optical imagery in such varied topography. This study has demonstrated the development forest carbon stock estimation model using LIDAR and the optical imagery at species level accurately. Employing field and airborne LIDAR measurements, forest-specific models were developed, capturing major variety of forest species. Because of the structural differences and associated carbon content between the forest types, the forest specific models provided improved results with reduced uncertainty.The modeling outcomes has provided more options for forest carbon assessment in the Nepal where topography matters.Using height information in mountain region is crucial as the information not only help to improve the model but also extract trees information even in shadow area which would be missed if only reflectance values were used. The methodology for measuring carbon stock in sub-tropical forests will contributein response to climate change mitigation action.

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Author's Information

Name	:	Sajana Maharjan
Academic Qualification	:	MSc. in Geoinformation Science & Earth observation
Organization	:	ICIMOD
Current Designation	:	Remote Sensing and Geoinformation Analyst
Work Experience	:	5 Years
E-mail	:	sajanamaharjan87@gmail.com

Realization of Geocentric Datum for Nepal: Ingredients, Recipe and the Cooking

Er. Mahesh Thapa, Er. Bigyan Banjara
mahesh.thapa@nepal.gov.np, bigyan.banjara@nepal.gov.np

KEYWORDS

Geocentric Datum, CORS, GNSS

ABSTRACT

The existing classical geodetic datum of Nepal called as Nepal Datum was developed and realized almost 40 years ago through the concerted surveying involving astronomic measurements by Czechoslovakian team along with Doppler observations and Trigonometric Surveying by British team. Since the realization of this geodetic datum by establishment of First Order Control Network at 68 locations, secular and co-seismic crustal movements has potentially disturbed the integrity of the network. Any survey activities based on use of existing datum without proper understanding and discretion can potentially compromise the outputs of surveying. On another hand, the classical datum is not directly compatible with the current surveying trends based on GNSS technologies. In order to ensure access to precise and GNSS compatible datum, there is an urgent need to develop geocentric datum. . In this article, we examine and recommend ways to realize geocentric datum by maximal utilization of already existent and necessary components for a functional geocentric datum. This paper is divided into three sections: Ingredients, Recipe and the Cooking. The ingredients section discusses the infrastructure for geocentric datum, the recipe section discusses the procedures to defining geocentric datum and the Cooking section discusses on the part of capacity development.

1. INTRODUCTION

With the advent of Global Navigation Satellite System (GNSS), nations have transitioned from classical datum to geocentric datum based on International Terrestrial Reference System (ITRS) and its realization International Terrestrial Reference Framework (ITRF). A geocentric datum is defined with its center as the mass center of the Earth. While there are several advantages of transitioning to a geocentric datum, the most pronounced is easier access to a precise datum which is directly compatible to GNSS technologies. GNSS technologies have been the choice of surveyors for surveying specially for establishing control points, thanks to rapidly dwindling price of such instruments. However, for Nepal, the larger advantage is to replace the existing datum that was established as early as 1980's. The location of Nepal between two converging tectonic plates causes considerable plates motion. Study by (Avouac, Jouanne, Flouzat, & Bollinger, 2006) showed stations at Simara, Daman, and Nagarkot with velocities in North component of 32.7 mm, 31.9 mm and 30.1mm per year respectively and the same in East component was 37.9 mm, 37.1 mm and 30.1 mm in between 1990 and 2004. This indicates there is significant change in position of the control points in absolute terms. The difference in velocities between the stations is indication that the internal consistency of the stations is disturbed. The role of national mapping agency is to define a geodetic datum which is precise, accessible and compatible to existing technologies. In this context, we present ways to define and develop realization of geocentric datum by maximal utilization of existing facilities.

2. NEPAL DATUM

The existing official datum of Nepal is a classical datumreferred as Nepal datum with its origin at Nagarkot. There is some confusion among user community regarding whether the datum is based on Everest 1830 ellipsoid or Everest 1937 Adjustment ellipsoid. Although, conceptually these are similar, there are differences. Originally, the Everest 1830 ellipsoid was defined in terms of foot. In order to adopt it to metric system, a conversion factor of 0.30479841 for foot to meter was adopted in 1937 for readjustment of Indian triangulation network (Georepository, 2020), hence the name Everest 1937 Adjustment. This foot to meter conversion factor meant the semi-major axis of this ellipsoid is6377276.345 meters and semi-minor axis is 6356075.413 meters. This is the ellipsoid used in definition of Nepal datum (SD, 1976). The realization of Nepal datum was accomplished by establishment of First Order Triangulation Network as a combined effort of Astronomic observations during 1976/77 by Czechoslovakian team, Doppler observations during 1981 by 512 Specialist Team Royal Engineers, UK and trigonometric surveys by 19 Topographic Squadron Royal Engineers UK.In order to avoid confusion, it is recommended that this datum be Nepal1981 datum. This is justified since the realization of the Nepal datum started with Doppler observations in 1981 on First Order Stations.

3. INGREDIENTSFORGEOCENTRIC DATUM

In this section, the major components necessary for a functional geocentric datum are introduced. In succeeding sections,the existing status of each of these components are examined with discussion of prospective future developments.

Realization of geocentric datum requires at least three major components a) CORS stations b) Data and Monitoring Center c) Networking. Each of these are briefly described here.

3.1. CORS (Continuously Operating Reference System)

In principle, CORS are very similar to GNSS/ GPS instrument that capture signals from GNSS satellites. However, in practice, these are designed in a much rugged manner to be able to operate continuously considering factors such as security, power supply, storage, weather, etc. More importantly, communication facilities is installed for data transfer as well as monitoring of the stations. Figure 1 shows a typical CORS station. This station is established within the premises of Survey Department, Nepal.

Figure 1: CORS Station at Survey Department, Nepal

Establishment of CORS stations is the most challenging as well as time consuming process for development of a functional geocentric datum. In terms of the total budget, the maximum proportion of budget has to be allocated for establishment of these stations. However, this can be avoided to large proportion. Thanks to the interest shown by international scientific communities towards study of secular and coseismic crustal movement of highly dynamic and converging tectonic plates of Nepal, there are already considerable number of CORS stations. While an exact figure is not available, it was estimated that there were already more than 50 stations in 2015 (LS, 2015). There has been further increase in this number. Most of these stations are established with collaboration between international scientific communities and Department of Mines and Geology, Nepal. Survey Department operates three stations, two at Nagarkot and one within the premises of department at Kathmandu. The distribution of the CORS station is shown in Figure 1. This is in not an exclusive list.

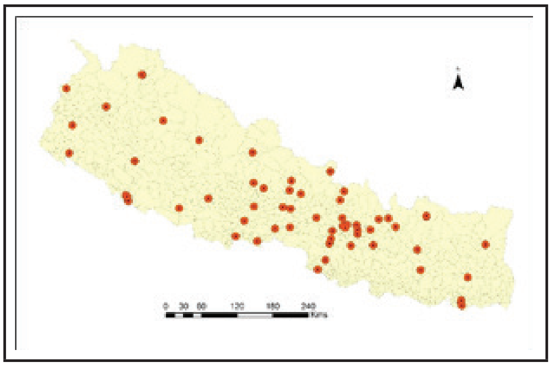

Figure 2: Distribution of CORS stations of Nepal

Considering there are several other stations missing in Figure 1, there already exists a good distribution of CORS stations good enough for development of a Fiducial Network. However, not every station can be part of this Fiducial network and a careful selection has to be made. This is discussed in the succeeding section.

3.2. Data and Monitoring Center

The data and monitoring center performs the following functions:

- Collection, Storage and Processing of GNSS observations obtained from individual CORS stations
- Monitor the health of CORS stations
- Provide access to GNSS raw observations and/or post processing facilities
- Generates and stream corrections for RTK surveying generally in form of NTRIP

While there is no dedicated data and monitoring center at present, the government to a large extent already has facilities to establish it within a short time period. This is discussed in the following section.

3.3. Networking

A secured networking is essential to transfer data and corrections between CORS stations, Data and Monitoring Center and the user community. The ways to develop this is discussed in the following section.

4. RECIPE FOR GEOCENTRIC DATUM

As discussed in preceding section, a functional geocentric datum requires CORS stations, Data and monitoring center and CORS Network. In this section, we discuss the recipe to bring these together.

4.1. Forming a Fiducial Network of CORS Stations

As discussed in the ingredients section, there already exists considerable number of CORS stations in Nepal. However, many of these stations are retired and some of these are established over roofs which is not the best condition for a station to be part of the Fiducial Network.Only stations that are in operational condition and established with highly stable monument type can be part of the Fiducial network. CORS stations having either shallow-drilled braced monument or deep driven rod braced are the most stable monuments. Our examination of existing stations shows that there is a well-distributed stations with stable monument types. Figure 3 shows the stations which are active and have highly stable monument types. These stations are feasible to be part of fiducial network for realization of geocentric datum. There are at least 27 such stations. The station code and location of these stations are : BMCL: Bhimchula; BRN2:Biratnagar; CHLM:Chilime; CHWN: Chitwan; DLPA: Dolpa; DNGD: Dhangadh; DRCL: Darchula; GNTW: Ghanteshwor; GRHI: Ghorahi; HETA: Hetauda; JMLA: Jumla; JMSM: Jomsom; KKN4: Kakani; KLDN: Koldana; KUGE:Kavrepalanchok; LMJG: Lamjung; NAST: Kathmandu; NPGJ: Nepalganj; ODRE: Odare; PYUT: Pyuthan; RMJT: Rumjatar; RMTE: Ramite; SIM4: Simara4; SMKT: Simikot; SNDL:Sindhuli; SYBC: Syangboche, TPLJ: Taplejung.

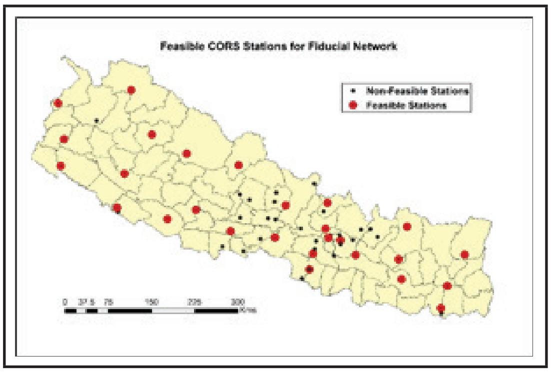

Figure 3: Stations with highly stable monuments that could form part of Fiducial CORS Network

There are some areas which lack sufficient CORS stations. Further investigation has to be done to assure if indeed there are no stations. In case, there are no stations, Survey Department can take initiatives to establish new CORS stations in those areas.

It is to be noted that we have only considered Fiducial stations that are necessary to realize geocentric datum. For providing Network RTK solution, a much denser network of CORS is necessary. Existing stations that are not considered as Fiducial CORS stations can also be utilized for this purpose along with establishment of newer CORS stations. However, this is not within the scope of this paper.

4.1.1. Mechanism for operation and maintenance of CORS stations

The existing CORS stations are owned by several different agencies of Nepal and majority of these stations are established in partnership with international agencies.In order to ensure smooth operation and maintenance of these stations, a mechanism has to be established which involves all the agencies. The roles of each agencies can be redefined in agreement with these agencies including modality of data distribution.

4.2. Data and Monitoring Center

While there is no dedicated Data and Monitoring center, Government Integrated Data Center (GIDC) could be used as data center. For monitoring of the CORS stations, a facility can be developed at Nagarkot Observatory and Survey Museum (NOSM) which is a part of Geodetic Survey Division, Survey Department. In addition to being a monitoring center, NOSM can be further developed as a center of excellence for geodetic research.

5. COOKING

All the best ingredients and the best recipes in the world do not turn to a dish unless prepared by a professionals. In order to ensure a functional geocentric datum is realized, the following issues must be addressed:

5.1. Capacity Development

It is quite laudable that Survey Department has invested in capacity development in geodesy specifically by funding employees to receive higher education in geodesy. The fruit of this sowing is just bearing its fruit. As part of second phase, the department must prioritize its missions and accordingly conduct technical workshops and training programs, possibly welcoming professionals from abroad to collaboratively work with professionals at the department.

5.2. Retaining Human Resources and Preserving Institution Memory

Development of geodesy within bureaucracy is challenging. Professionals spend years, if not decades to gain expertise in one of the domains of geodesy. The existing bureaucratic system does not recognize this. The department should bring about changes to encourage professional who have acquired expertise in the field to continue doing so. In addition, concrete efforts to preserve institutional memory has to be initiated.

5.3. Partnerships

Review of the history of geodetic development in Nepal, except for handful of achievements, all of these have been realized through partnerships with international agencies. As a matter of fact, geodetic developments involve participation of all nations working collaboratively. This is quite conspicuous from the fact that ITRF stations which is necessary for defining geocentric datum is established and maintained through partnerships among several nations. Rejecting partnerships is avoiding development of geodesy.

6. CONCLUSION

A house without a strong foundation is a disaster waiting to happen. It is the same for all surveying and mapping activities. The priority sector of national mapping agency should be development of geodetic datum. In this article, we have discussed how this can be realized by maximizing utilization of already existent facilities particularly the CORS stations. The national mapping agency should take leadership on forming a mechanism for operating CORS within Nepal in order to define and develop realization of geocentric datum. It also should realize the existing that geodesy is a pure science but currently established within a bureaucratic framework. In order to develop it, there is no other ways than focus on capacity development, encourage collaboration and partnerships and bring about policy reforms to retain human resources.

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Author's Information

Name	:	Er. Mahesh Thapa
Academic Qualification	:	M.Sc. in Geospatial Technologies (Erasmus Mundus), Spain and Germany
Current Organization	:	Survey Department. Geodetic Survey Division
Current Designation	:	Survey Officer
E-mail	:	mahesh100thapa@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

Spectral Analysis of Worldview-2 Imagery in Detecting Invasive Plant Species (mistletoe) in Scots Pine Forest

Sunil Thapa
sunilmagar@gmail.com

KEYWORDS

Biological invasion, Remote Sensing, NDVI, Optical satellite imagery

ABSTRACT

Mistletoe (Viscum album), a hemiparasite of Scots pine (Pinus sylvestris), is one of the major problems in the conservation of Scots pine forest in the Alps. The study area covered with coniferous plantation, a part of Bois Noir in the South Western French Alps is highly affected by mistletoe. Consequences of mistletoe infection include branch swelling and bending of the tree structure. The coniferous plantation in the study area, located in Bois Noir in the south-western French Alps, is experiencing an alarmingly high rate of tree mortality due to mistletoe infection. This study aims to assess the spectral distinctness of Scots pine in the presence and absence of mistletoe. For the management and minimization of biological invasion, detection and mapping plays a key role in forest conservation. Advancement of very high resolution (VHR) satellite imagery and aerial imagery with application of remote sensing and GIS technologies has shown a promising result in detecting, mapping and monitoring forest health. In this research, very high resolution satellite imagery WorldView-2 (panchromatic 0.5m and multispectral 2m) was used. Scots pine with mistletoe presence has low spectral reflectance in all bands, but NIR1, NIR2 and Red edge of WorldView-2 have higher ability to discriminate the mistletoe. Similarly, the vegetation index NDVI 2 (band combination of Red and NIR2) has the potential to discriminate the mistletoe. Detection of such biological invasions provides good information for effective conservation and better management of forests.

1. INTRODUCTION

Biological invasion poses a serious threat to global biodiversity and adversely affects native plants, ecosystem structure and function (Peerbhay et al., 2016; Thapa et al., 2018). *Viscum album austriacum* commonly known as mistletoe, is a threat to its host species and its widely growing infestation in various forests is exacerbating loss of tree species (Varga et al., 2012). By extracting water and carbohydrate from their hosts, mistletoe causes water and nutrient deficiency (Dobbertin et al., 2005a; Rigling et al., 2010). During the drought period, mistletoe effect can be as it increases the risk of drought induced mortality of its host species (Rigling et al., 2010). Eventually it disrupts the stomatal system including gas exchange effect (Zweifel et al., 2012) and thus reduces the photosynthesis phenomenon of the host species (Glatzel & Geils, 2009).

Mistletoe has a wide range of distribution in Asia and Europe (Hawksworth & Scharpf, 1986). It is widely distributed in the Alps and the dry inner alpine valleys to the north in Bavaria, where it has contributed to the decline of pine trees in the forests of Terul (Eastern Spain), France, Switzerland, Italy, Greece, Austria, Germany, Sweden, and Great Britain (Dobbertin & Rigling, 2006; Peršoh et al., 2010; Sanguesa-Barreda et al., 2012). Similarly, in Mexican cold mountain forest (evergreen coniferous forest), mistletoe is the second most destructive pest after the bark beetle (Clark-Tapia et al., 2011). In South-western French Alps, the tree mortality rate of planted *Pinus nigra* is also alarming due to mistletoe (Vallauri et al., 2002).

Pinus sylvestris (Scots pine) has been widely affected by mistletoe *and* is one of the major causes for its mortality (Mutlu et al., 2016). Crown degradation, ramification and radial increments are some of the impacts caused by the mistletoe to the host Scots pine (Rigling et al., 2010). The mortality rate of Scots pine infested by mistletoe is twice higher than that of non-infested trees (Dobbertin & Rigling, 2006). Swelling, bending of tree structure, and defoliation are some of the impacts which can be visually assessed in Scots pine with mistletoe. Furthermore, mistletoe is considered as an indicator species for changes in temperature as it causes drought stress in the host species (Dobbertin et al., 2005b).

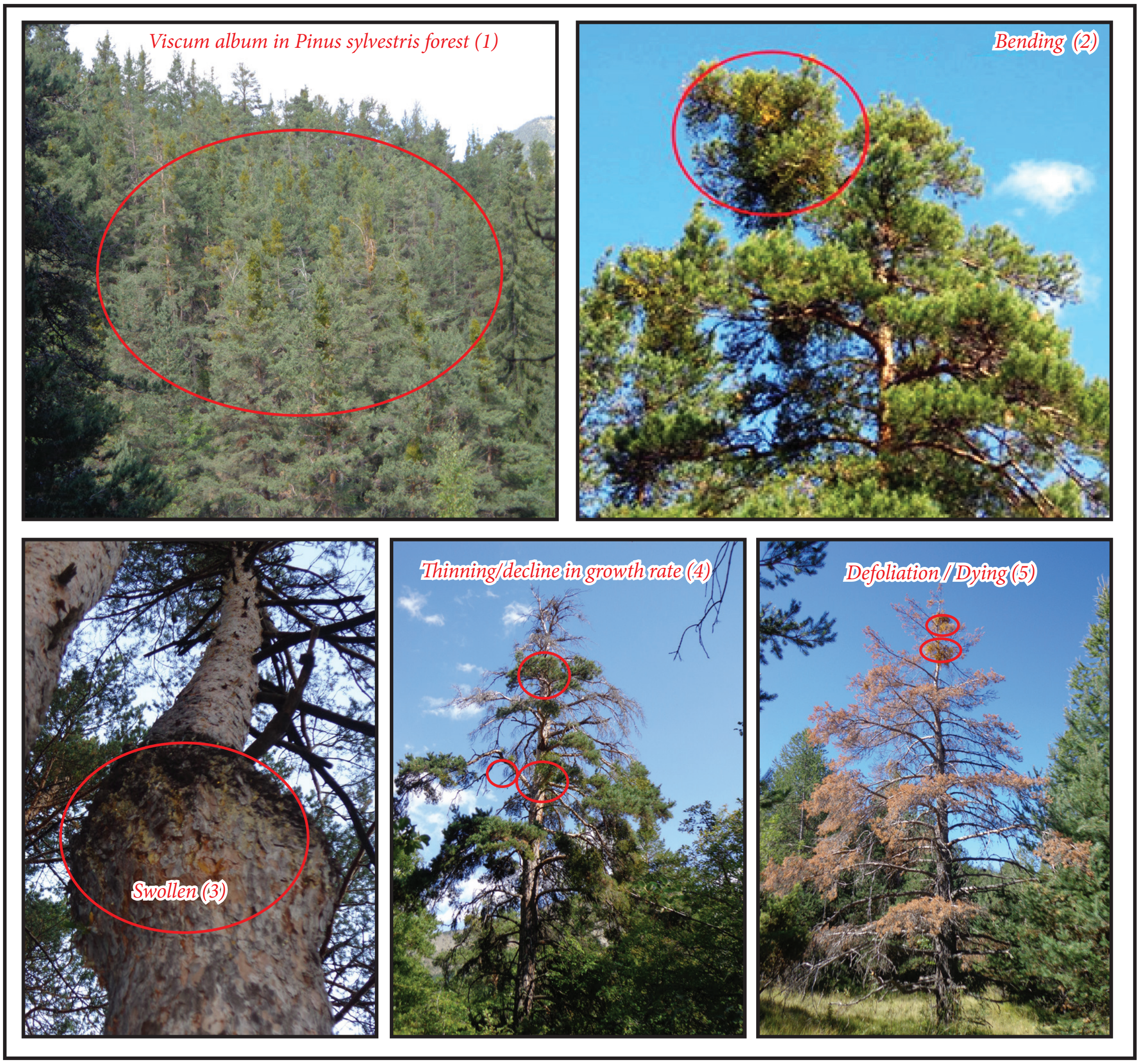

Figure 1: Impacts of mistletoe in scots pine trees in study area (Bois Noir, Barcelonnette France)

Remote sensing tools and technologies have been widely used in forestry. Remote sensing is an effective tool for detecting, monitoring and mapping forest health, pests and biological invasive species in forest (Joshi et al., 2006; Ismail et al., 2007; Peerbhay et al 2016). Twenty first century digital aerial imagery has the potential to capture the image between 5 cm and 1 m pixel size (Wulder et al., 2012) and the very high resolution satellite sensors have the ability to take imagery of spatial resolution 50 cm for panchromatic and 2 m for multispectral. According to Hussin et al. (2006) besides high spatial resolution, aerial images (TETRACAM) can show similar spectral characteristics as satellite (IKONOS) imagery can provide. However, both sensors (airborne and satellite) have their unique potential for forest classification and monitoring.

Spectral reflectance and vegetation indices are the key indicators used for assessing and monitoring health of plants from remote sensing data. Spectral reflectance of each plant species has its own unique characteristics which vary with wavelength and can be observed in the spectral reflectance plot (Carter & Knapp, 2001). The same species can respond differently according to their health condition (Carter & Knapp, 2001; Xie et al., 2008). Vegetation indices are dimensionless radiometric measures which are computed from reflectance values and widely used to assess the health status of the plant species (Jackson & Huete, 1991). Normalized difference vegetation index (NDVI) is one of the most intensively used spectral vegetation index to analyse plant stress (Eitel et al., 2011), plant health (Xie et al., 2008), biomass (Mutanga et al., 2012), and crop production (Psomiadis et al., 2017). NDVI is first used by Rouse et al. (1974), it is calculated on the basis of spectral reflectance in NIR and Red band of the spectrum. The main purpose of the vegetation indices is to enhance the vegetation reflectance/signal and lower the reflectance of other effects like soil and solar irradiance (Jackson & Huete, 1991). Several vegetation indices like NDVI, enhanced vegetation index (EVI) are widely used to assess the health status of plants. The study done by Falkenström and Ekstrand (2002) in an evergreen coniferous forest (Norway spruce and Scots pine) verifies that the analysis of spectral reflectance from high resolution satellite data were able to detect pine defoliation in the near infrared (NIR) band. Furthermore, "high NDVI values would be associated with increased photosynthetic activity and would serve as a useful proxy for identifying stressed trees" (Wulder et al., 2006).

2. MATERIALS AND METHODS

2.1. Study area

The study area is a part of Bois noir catchment located in the South Eastern part of France in the district of Barcelonnette. The study area is located between 44°25' 22.87''N latitude

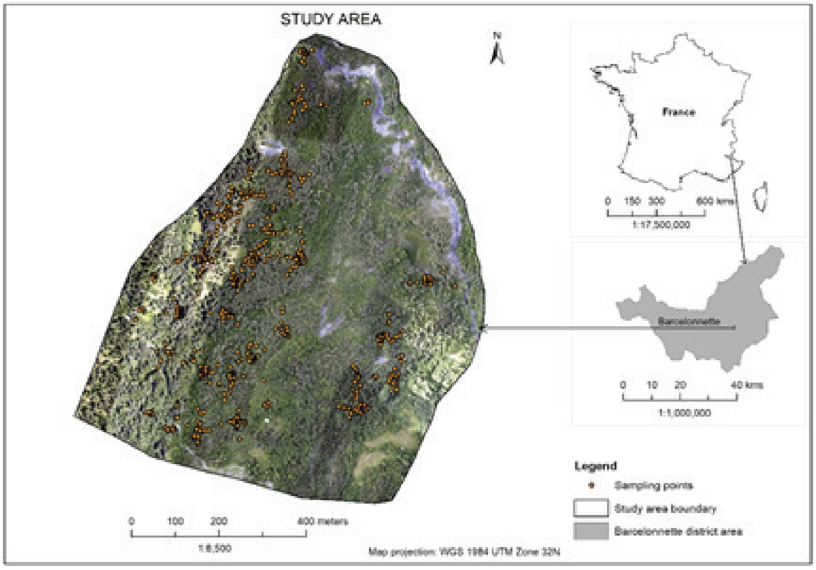

Figure 2: Study area showing distribution of sampling points

to 6°40’ 22.43’’E longitude with elevation ranges from 1100 to 3000 m. The climate of the study area is dry mountainous and inter annual rainfall strongly varies from 400 to 1400 mm and the mean annual temperature is around 7.5°C (Maquaire et al., 2003). The area has an irregular rugged topography with slope gradients ranging from 10° to 35° and scree slopes (Thiery et al., 2007; Saez et al., 2012).

The vegetation of the study area is a century old plantation of coniferous trees with pockets of broadleaf forests. In 18th and 19th century, the Bois Noir area suffered from heavy deforestation (Kappes et al., 2011). To control deforestation and debris flow, reforestation and construction of check dams were initiated (Kappes et al., 2011). The area has relatively homogenous forest stands mostly dominated by conifers including Scots pine (*Pinus sylvestris*), Mountain pine (*Pinus uncinata*) and European larch (*Larix decidua*) along with some varied patches of mixed and broadleaved species.

2.2. Data

The WorldView-2 (WV-2) satellite is the first high resolution commercial satellite with 8 spectral bands (Digital Globe, 2009). It has a spectral diversity of 4 standard bands (Blue, Green, Red and NIR1) and 4 new bands (Coastal, Yellow, Red edge and NIR2). The multispectral resolution of this imagery is 1.85 m and it can provide 46 cm panchromatic resolution (Digital Globe, 2009). Very high resolution satellite imagery WorldView-2 (WV-2) of having 8 bands spectral resolution of 2m and panchromatic resolution of 0.5 m was used for this study. The imagery was acquired in September 2010.

The airborne Ortho imagery and airborne LiDAR data acquired in July were also used. The LiDAR derived canopy height model (CHM) and digital terrain model (DTM) were used.

2.3. Sampling design

A random set of 40 location points were generated in the study area. From the centre, the circular plot having 500m^2 areas was established to collect the data after slope correction (Husch et al., 2003). In order to increase the mistletoe incidence data 27 transects were sampled. Due to topographic constraints (steep slop and rugged terrain) 7 circular sample points were discarded and 2 plots without Scots pine trees were also removed from the sampling set. Only circular sample points were used for assessing the forest structure parameters like tree density and basal area (Boakye et al., 2012).

Field data collection was carried out from 11 to 27 September 2012. The iPAQ and Hand held GPS were used to navigate to the selected plot centre. However, due to canopy obstructions it was impossible to locate plot centres precisely. To minimize the error, the available LiDAR derived canopy height model (CHM) (Kumar, 2012) was used to determine the centre of the plot. Using the CHM, at least two landmark features were identified in the surroundings of the centre plot as seen on the CHM to confirm plot centres. The centre point and individual locations of trees were subsequently determined by measuring the bearing and distance using the Sunnto compass and measuring tape respectively. Differential Global Positioning System (DGPS) was also used to record the geographic coordinates of the centre point of the plot.

Each Scots pine tree in the plots were visually assessed on the ground and incidence of mistletoe recorded. Crown coverage of the plot was measured using a spherical densiometer from five different locations within the plot and the canopy cover averaged. After sampling a circular plot, four 50 m perpendicular line transects were laid from the same centre point. The presence (P) and absence (A) of mistletoe in Scots pine trees was recorded at 5 m intervals.

2.4. Image preprocessing (Geometirc Correction)

The WorldView-2 image was delivered without any cloud cover, and both atmospherically and radiometrically corrected. Geometric correction was performed in two stages; (i) sensor specific geometric correction without ground control points and (ii) ortho-rectification using ground control points (Kukunda, 2013).

2.5. Extraction of canopy spectra of Scots pine in presence and absence of mistletoe from WV-2 image

Training samples of presence and absence of mistletoe in Scots pine were obtained using field observations as a reference. Pixel value of sample Scots pine trees was extracted from the spectral profile. The mean pixel values of Scots pine trees with and without mistletoe were plotted in Y axis and the eight spectral bands of WV-2 were plotted in the X-axis.

In order to minimize the error in the analysis of WV-2 imagery spectral reflectance of Scots pine with mistletoe presence due to the gap in the imagery acquired date and field data collection date, the field data was labeled on the density of mistletoe in scots pine which was given as follows:

Density class of mistletoe:

0=No mistletoe; 1=Low mistletoe;

2=Medium mistletoe; 3=High mistletoe

The spectral profile of each density class of mistletoe was extracted and analyzed.

2.6. Computing and analysis of spectral vegetation indices

Three equations using different band combinations for Normalized Difference Vegetation Index (NDVI) (Rouse et al., 1974) were computed (Table 1) in the model maker. Three different NDVI maps were generated. Field points of presence and absence of mistletoe were overlaid on the three NDVI images. To extract pixel values from the NDVI images for spectral signature development an inquiry box of minimum of 6 pixels was used. The pixels values at the determined geographic location were exported to ASCII file. The mean value of those exported presence and absence of mistletoe in Scots pine was plotted in Excel and the analysis was conducted.

NDVI was calculated as follows:

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

NIR - reflection in the near-infrared spectrum

Red - reflection in the red range of the spectrum

Table 1. *NDVI Vegetation Indices*

S.N.	Abbreviation	Equation
1	NDVI 1	[(NIR1-Red edge)/(NIR1 +Red edge)]
2	NDVI 2	[(NIR2-Red)/(NIR2 +Red)]
3	NDVI 3	[(NIR2-Red edge)/(NIR2 +Red edge)]

3. RESULTS AND DISCUSSION

The overall density of Scots pine tree is 618 trees/ha whereas the density of Scots pine having mistletoe *is* 40 trees/ha. Around 3.5 ha of basal area is covered by Scots pine trees having mistletoe. The presence of mistletoe is low in Scots pine having low DBH, while those with big DBH have high mistletoe presence. In the sampled trees, 10% of Scots pine with mistletoe presence have DBH more than 30 cm while only 0.3% of Scots pine with mistletoe have DBH less than 15 cm.

3.1. Spectral analysis of Scots pine in the presence and absence of mistletoe

Spectral reflectance values convey information on biophysical, biochemical and physiological characteristics of vegetation features and therefore can be used to distinguish vegetation along the spectrum. Spectral distinctness of Scots pine in the presence and absence of mistletoe is clearly observed in all eight bands of the WV-2 image. All bands showed a similar trend of spectral curve for both presence and absence of mistletoe in Scots pine. The WV-2 imageries have four extra spectral bands that support vegetation identification. These include the coastal band that supports vegetation identification based upon its chlorophyll and water penetration characteristics. The yellow band which enhances identification of "yellow-ness" characteristics of targets (Digital Globe, 2009) and the red edge band that aids in the analysis of vegetative condition (Mutanga & Skidmore, 2004). With these extra spectral bands, the spectral signatures of Scots pine with and without mistletoe are clearer in the WV-2 imagery. NIR1, NIR2 and Red edge have the highest spectral distinctness compared to other bands. In the Red edge, there is a sharp rise in the reflectance curve in both presence and absence of mistletoe. However, mistletoe presence shows a short sharp rise compared to Scots pine with mistletoe absence. The mean reflectance of the healthy Scots pine in the visible range (400-700 nm) was slightly higher than that of Scots pine with mistletoe whereas there was much higher mean reflectance in 700-1000 nm than that of mistletoe infected pine trees. Li et al., (2014) study on detecting citrus greening disease, also reflect that healthy samples reflectance is much higher in 700-1000nm than infected samples. Spectral reflectance of Scots pine trees in the presence and absence of mistletoe.

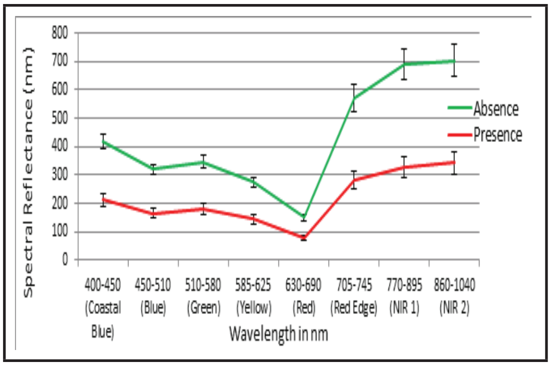

Figure 3: Spectral reflectance of Scots pine trees in the presence and absence of mistletoe

Photosynthetically active vegetation has a higher reflectance in the NIR band than stressed and photosynthetically inactive vegetation (Beeri et al., 2007; Carter & Knapp, 2001) thus, Scots pine with mistletoe presence may be under stress and photosynthetically less active compared to Scots pine with mistletoe absence. A study by Eitel et al. (2011) has shown that the Red edge band has the capability to detect plant stress due to changes in Chl_{ab};. According to Carter and Knapp (2001), transmittance, reflectance and absorptance of the stressed and healthy vegetation can be better distinguished in NIR. Red edge, NIR1 and NIR2 of WV-2 image plays a key role in class separability (Immitzer et al., 2012a) and additional spectral band of WV-2 detected coniferous and broadleaf trees with 99% accuracy (Immitzer et al., 2012b). Similarly, in this research the Scots pine with mistletoe resulted in a decrease in absorption in the red band and a shift to the Red edge and a larger difference in band NIR1 and NIR2.

3.2. Analysis of vegetation indices (NDVIs)

The mean NDVI pixel value of presence and absence of mistletoe was calculated (Table 2). In all three calculated indices, the NDVI ratio value is lower for Scots pine with mistletoe presence. However, NDVI ratio value (presence=0.61, absence=0.70) obtained from band combination of 8 and 5 (NIR2 & Red band) is able to detect the presence of mistletoe better compared to other two indices.

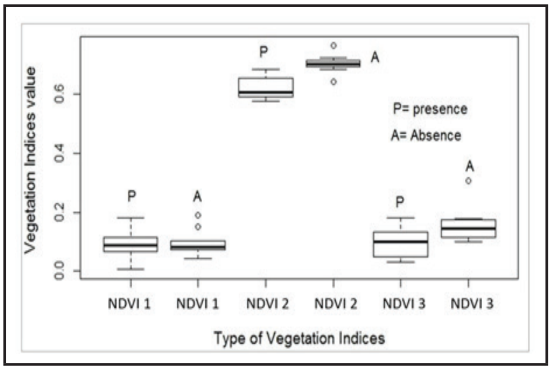

Figure 4: Boxplot of reflectance value of three different vegetation indices for presence and absence of mistletoe in Scots pine

Table 2.*Reflectance value of three vegetation indices*

	Mistletoe	
NDVI	**Presence**	**Absence**
NDVI 1	0.09	0.097
NDVI 2	0.619	0.704
NDVI 3	0.1	0.155

NDVI 2 was significant at (alpha=0.05, p-value<0.00) for discriminating the presence and absence of mistletoe in Scots pine. However, NDVI 1was not significant at alpha of 0.05. Furthermore, a Kruskal-Wallis test showed NDVI 2 was significantly different (p<0.0167) from NDVI 1 and NDVI 3. NDVI 2 had highest discrimination and was significantly different from other two vegetation indices. Ismail et al. (2006; 2008) also revealed that NDVI shows better performance compared to other vegetation indices in detecting Pinus patula tree infestation by Sirex noctilio. Similarly, previous research done by Bhattarai et al. (2011) has obtained a significant result (p-value =-0.09) to discriminate Sirex wood wasp infested Scots pine in WV-2 by using NDVI 2. NDVI 2 value of Scots pine trees was lower in the presence of mistletoe which indicates a reduction in the total green biomass (chlorophyll) or leaf area index (LAI) of the Pinus trees. According to Adams et al. (1999) there is less absorption by chlorophyll and less reflectance in the near infrared region in the stressed vegetation.

4. CONCLUSION

From the analysis of spectral characteristics of Scots pine in WV-2 image, it was revealed that there is a distinct spectral reflectance of Scots pine in the presence and absence of mistletoe. The Red edge, NIR1 and NIR2 bands of WV-2 show better separability. Among three vegetation indices, NDVI 2 showed the highest performance in distinguishing mistletoe in Scots pine. This kind of research is very limited in Nepal's forest so assessing the spectral distinctness of biological invasion in Nepal's forest could be beneficial.

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Author's Information

Name	:	Sunil Thapa
Academic Qualification	:	M.Sc. in Geoinformation Science and Earth Observation
Current Organization	:	ICIMOD
Current Designation	:	Remote Sensing & Geoinfromation Analyst
E-mail	:	sunilmagar@gmail.com

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Date: 13-16 July 2020
Country: Online Meeting
Website: https://www.cipa2019.org/

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Date: 16-25 August 2020
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Country: Nice, France
Website: https://www.udms.net/

The 5th International Conference on Smart City Applications
Date: 7-9 October 2020
Country: http://www.medi-ast.org/SCA20/
Website: http://www.medi-ast.org/SCA20/

3rd International Conference & Exhibition Advanced Geospatial Science & Technology
Date: 20-22 October 2020
Country: Tunisia
Website: http://www.teangeo.org/En/

Second International Conference on Unmanned Aerial Systems-2020
Date: 31 October - 02 November 2020
Country: Greater Noida, India
Web site: https://www.iitr.ac.in/uasg2020/

23rd ICA Workshop on Map Generalisation and Multiple Representations
Date: 5 - 6 November 2020
Country: Delft, The Netherlands
Website: http://varioscale.bk.tudelft.nl/events/icagen2020/

Pacific Islands GIS & Remote Sensing User Conference 2020
Date: 23 - 26 November 2020
Country: Fiji Islands
Website: http://www.picgisrs.org/

20th International Scientific GeoConference SGEM Vienna Green 2020
Date: 08-11 December 2020
Country: Vienna, Austria
Website: https://www.sgemviennagreen.org/

43rd Scientific Assembly of the Committee on Space Research (COSPAR) and Associated Events
Date: 28 January - 4 February 2021
Country: Sydney, Australia
Web site: http://www.cospar2020.org/

11th IAPR Workshop on Pattern Recognition in Remote Sensing
Date: 10 - 15 January 2021
Country: Milan, Italy
Website: http://iapr-tc7.ipb.uni-bonn.de/prrs2020/

The 12th International Conference on Mobile Mapping Technology
Date: 26-28 May 2021
Country: Padua, Italy
Website: http://iapr-tc7.ipb.uni-bonn.de/prrs2020/

40th EARSeL Symposium 2020
Date: 7 - 10 June 2021
Country: Warsaw, Poland
Website: http://symposium.earsel.org/40th-symposium-Warszaw/home/

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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
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2. Human Resource Development Policy in Space Technology Sector in Nepal
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3. Registration of 3rd Dimension: the Context of Nepalese Cadastre
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4. Spatial Data Infrastructure for Prosperous Nepal
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4. RS/GIS For Hazard Mapping & Vulnerability Assessment, Earthquake Disaster Management, Kathmandu, Nepal
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5. Technical Deficiencies and Human Factors in Land Disputes: In the Context of Nepalese Cadastral Surveying
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5. Customer satisfaction model and organisational strategies for Land Registration and Cadastral Systems
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5. Road Network Planning for Sustainable Urban Development in Kirtipur Municipality, Nepal
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6. Technical Aspects of Digitization of Cadastral Maps
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7. Use of Geo-Informatics in Flood Hazard Mapping: A Case of Balkhu River
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3. Connecting space to village SERVIR Himalaya at work for bringing earth observation to societal benefits
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4. Education and Research Enhancement in Land Administration Sector at Kathmandu University
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5. Data Acquisition For Search, Rescue And Relief Operation In Affected Areas Caused By Natural Disaster
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6. Exploring Spatial Data Sharing Factors And Strategies For Catchment Management Authorities In Australia
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7. Identifying Spatial Scale And Information Base: An Essential Step For Watershed Management And Planning
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8. Necessity Of Disaster Mapping Unit In Survey Department: The Context Of 2015 Gorkha Earthquake And Disasters In Nepal
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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
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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*

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Er. Amrit Karmacharya

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

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Sanjeevan Shrestha & Tina Baidar

7. Cadastre 2014: Performance of Nepal
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8. GNSS Practice In Survey Department
Sushmita Timilisina, & Bibek Nepal

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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
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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

Nepal Remote Sensing and Photogrammetric Society (NRSPS)

New Executive Committee Officials

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

Basic Remote Sensing Training

Kathmandu Forestry College (KAFCOL) in collaboration with **NRSPS** organized a "**Basic Remote Sensing Training"** was organized from March 3-9, 2019 (Falgun 19-25, 2075) at KAFCOL in which 8 trainee from different disciplines were participated. Some of the resources persons of the programme were from the members of NRSPS. They were Dr. Him Lal Shrestha, Dr. Umesh Kumar Mandal and Mr. Raj Kumar Thapa. On 3rd March, 2019, an introduction programme was conducted in which Dr. Ambika Poudel, Principal, KAFCOL introduced activities of KAFCOL and Mr. Rabin K. Sharma, President, NRSPS presented the information on NRSPS.

Global Surveyor's Day

On 21st March 2019 (7th Chaitra 2075), **Global Surveyor's Day** was observed with varieties of programme. The event was jointly organized by Nepal Geomatics Engineering Society (NGES), Nepal Surveyor's Society (NESA), Nepal Institutions of Chartered Surveyors (NICS) and Nepal Remote Sensing and Photogrammetric Society (NRSPS). The workshop was inaugurated by Hon. Padma Kumari Aryal, Minister, Ministry of Land Management, Cooperatives and Poverty Alleviation who had delivered the inauguration speech as well.

In the opening ceremony Mr. Rabin K. Sharma, President, NRSPS gave welcome remarks and highlighted the programmes of the event and Mr. Sarad Mainali, President NGES presented the importance of the event. A Keynote speech was delivered by Hon. Sushil Bhatta, Member, National Planning Commission.

The event was organized with the varieties of programmes such as Exhibition, Futsal competition and Map making competition. The main attraction of the event was the panel discussion on Five generation surveyors: From Chain Survey to Drone. Five generation surveyors were identified as Mr. Buddhi Narayan Shrestha, Mr. Babu Ram Acharya, Mr. Ganesh Prasad Bhatta, Ms. Bhuwan Ranjit and Mr. Uttam Pudasaini. They presented their views on the basis of their experiences and expectations in the future to come. The closing ceremony which was chaired by Rabin K. Sharma, President NRSPS in which the speakers were Mr. Amba Dutta Bhatta, Acting President, NESA and Mr. Gopi Nath Mainali, Secretary, Ministry of Land Management, Cooperatives and Poverty Alleviation

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.

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

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.

Executive Committee

President
Er. Sharad Chandra Mainali
Vice-President
Er. Umang Raj Dotel
Secretary
Er. Poshan Niraula
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
Er. Prem Thapa

NGES organized a program for exchanging the **greetings of Tihar and Chhat festivals** on November 3, 2018 as its first program after the formation of current executive committee on 26 October, 2018.

International Relations: NGES and PIESAT (China) meeting on possible collaborations in the field of surveying and Mapping.

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

NGES voluntarily supports Dhurmus Suntali Foundation in Construction Survey of **Gautam Buddha Cricket Stadium** in Chitwan. (Lead- Er. Ashish Giri)

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

Celebrating **Global Surveyors' Day** - March 2, 2019

Volunteer Surveying by NGES for possible Cycle-lane in Kathmandu Valley as per request of Nepal Cycle Society.(Lead- Er. Ashim Babu Shrestha)

NGES President delivering notes on unified Land Act

Call for papers

The editorial board requests for papers related to geo-information science and earth observation for the publication in 20th issue of the Journal on Geoinformatics, Nepal.
Last date of submission is 30th March 2021.
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

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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.

Chief Survey Officers **Mr. Susheel Dangol, Mr Khimlal Gautam** and **Mr. Sudeep Shrestha** participated Southeast Asian Satellite Application Workshop held in Xian China.

Survey officers **Mr. Prakash Dulal, Mr. Bigyan Banjara, Mr. Prabesh Yagol, Mr.Sumeer Koirala, Mr. Bhanu Bhatta, Mr. Ananda Paudel** and surveyor **Mr Shahadev Ghimire** participated in training on GNSS data processing held at University of Bern, Switzerland.

Survey Officers **Mr Suraj Bahadur KC, Mr Mahesh Thapa, Ms Jyoti Dhakal, Mr Shanker KC, Mr Stalin Bhandari, Mr Rabin Karki,** Surveyor **Mr. Ishwor Aryal, Mr Jeeban Thapa** and **Mr Prabhash Yadav** participated on gravity data processing and GEOID determination at Technical University Denmark.

Officials from Land Satellite Remote Sensing Application Center, Ministry of Natural Resources of P.R.China (LASAC) visited Survey Department regarding scope of future collaboration in the field of application of Remote Sensing.

Survey Officer Mr **Deepak Ratna Shakya** and Mr **Ram Prasad Thusa** conducting Precise Leveling during the program execution of Mt Everest Height Measurement activity.

Beacon over the Wild T3 Theodolite ready for Trignometrical leveling and triangulation and weather station during the program execution of Mt Everest Height Measurement activity.

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

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