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Government of Nepal

मा. डा. शिवमाया तुम्बाहाङफे
मन्त्री
भूमि व्यवस्था, सहकारी तथा गरिबी निवारण

Hon.Dr. Shiva Maya Tumbahangphe
Minister
Land Management, Cooperatives and Poverty Alleviation

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Message from the Minister

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

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

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

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

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

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

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(...)

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Message from the Secretary

First of all, I would like to congratulate Survey Department for the continuation of its annual publication of the journal titled "Journal on Geo-informatics, Nepal" and coming up with it 21st issue. I feel honored to have an opportunity to put some of my views on this kind of academic activities through which research outputs, knowledge and information are shared. I am sure, this journal covers different aspects of Geo-informatics and I do have firm belief that this journal publication surely supports in sharing the information regarding, geo-informatics, surveying & mapping and other such related issues to the concerned stakeholders.

Survey Department has received some remarkable achievements in the field of Surveying, Mapping and Geo-information data generation which contribute to the overall national development and which also play crucial role in planning and execution of infrastructure development activities.

This department is conducting commendable activities in geographical information production, geodetic survey, topographical base map update, LiDAR survey, technical support in international boundary, cadastral survey and much more. Department is also adopting advanced technologies in surveying and mapping field to provide efficient service delivery to the citizens.

This is the department which conducted the Sagarmatha height measurement and shown its presence to the whole world with its capacity in the field of Surveying and Mapping and also started online service delivery system titled "Nepal Land Information System (NeLIS) and "*MeroKitta*" from the district survey offices.

NeLIS and "MeroKitta" system has been implemented in fifty district survey offices and hope that it will be replicated in remaining offices soon. I believe that this type of system will enhance the efficiency and transparency in the field of land administration services. I would like to assure full support from the Ministry to the Department's undertakings in the capacity of Secretary of the Ministry.

Further, I would like to strongly recommend all professionals in the field of Surveying, Mapping and Geo-information to gain benefits from the articles of the journal and also request to the professionals to contribute and share experience in the next issue of the journal. And also, would like to appreciate the efforts of Advisory Council and Editorial Board of this journal to bring out the 21st 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

Rpthapaliya
....

Ram Prasad Thapaliya
Secretary
Ministry of Land Management, Cooperatives and Poverty Alleviation
Government of Nepal

FOREWORDS

Survey Department has come with the 21st issue of its annual publication of "Journal on Geoinformatics, Nepal". I would like to congratulate entire staffs of the department and personnel who have contributed for the betterment of the Department and at the same time delighted to put few words in this issue of the journal.

Survey Department as the National Mapping Agency of Government of Nepal, it is continuously contributing in Land Administration services through its district level offices to the citizens. It is also providing technical support in international boundary, generating geo-information services, geodetic control strengthening and other surveying & mapping activities. 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.

Online based land administration service system termed as Nepal Land Information System (NeLIS) and "*MeroKitta*", which was inaugurated by Prime Minister of Nepal last year has been implemented in fifty district survey offices. The system has been the milestone and the turning point of the department in service delivery from Survey Offices at the district. Through this system, citizens can receive the service of map print, field book print, plot register print, request for field survey and online revenue payment and get the digital copy of map in hand without visiting the office. The service can also be received from the local level units which supports the objective of decentralization objective of the government. In order to support all these processes, government has already approved directive. Survey Department is planning to rollout the system in all district level offices in near future. Another major activity of the department is the LiDAR survey which generates a very high-resolution DEM useful for different development activities and disaster mitigation planning. Department is also planning to continue the LiDAR survey to cover the whole country. Besides these activities, department has also completed updating the topographical base maps and also heading with establishment of CORS.

Survey Department also focused on land ownership certificate distribution to the citizens of the village block who have been residing at that place since centuries back but deprived from the land tenure. In a single fiscal year, department succeeded to distribute more than forty thousand land ownership certificates which was always been less prioritized activity besides cadastral surveying and mapping.

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

Enjoy Reading!

Thank you!

Prakash Joshi
Director General
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EDITORIAL

"Journal of Geoinformatics, Nepal" is being published annually since 2058 BS (2002 AD) by Survey Department, the National Mapping Agency of Nepal. 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 these fields. This journal has been a platform for researcher to publish their knowledge in the field of Surveying Mapping and Geospatial technologies which is also playing key role in professional development through knowledge sharing.

The coverage of more than 100 articles since the first publication till this 21st issues in various topics dealing with historical to latest technologies emerging in geospatial field has been the source of information in the field of Surveying and Mapping. I would like to express sincere thanks on the behalf of editorial board to all those incredible authors for their contributions in journal publication by providing the valuable papers. Special thank goes to members of Advisory Councils and Editorial Boards of all those issues of the journal for their valuable contribution to publish the journal. This 21st issue of the journal contains variety of interesting and worth reading articles on different topics related to geospatial domain.

I am thankful to Survey Department for providing me the responsibility of the Editor-in-Chief for this 21st issue of the journal. With Continuous guidance and advice of Advisory Council, this Editorial Board have been able to bring this issue of the journal for readers. On behalf of all the members of the Editorial Board, I would like to express sincere thanks to all contributing authors, paper reviewers, members of Advisory Council and all other persons who have contributed for the publication of 21st issue of the journal.

At last, on the behalf of Editorial Board, let me humbly request all of you to contribute your valuable articles, research papers, review papers for the upcoming issue of this journal.

Karuna K. C.,
Editor-in Chief,
Ashad, 2079 (June 2022)

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Accuracy Assessment of UAV for Cadastral Application

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KEYWORDS

Unmanned Aerial Vehicles, Point clouds, Orthomosaic, Digital Elevation Model, Digital Terrain Model

ABSTRACT

This study aims to produce accurate geospatial 3D data from unmanned aerial vehicle (UAV) images. An image of approx. 1 km2 area of the Banepa-10, Kabhrepalanchok district was captured using a DJI Mavic Pro drone. Pix4dmapper programs were used to generate the solution. The horizontal and vertical accuracies of the obtained UAV solution were computed by comparing the coordinates of 5 Ground Control Points (GCPs) with coordinates measured using the static DGPS observation method. The root mean square error (RMSE) was calculated during geo-referencing of Orthomosaic and obtained a value of 0.006.Mainly, three comparisons were made for parcels digitized from the Orthomosaic image w.r.t to Total Station and Tape measurement ; Area, Perimeter and Centroid Position. Cadastral survey using Total station, UAV and Tape measurement were confirmed to be comparable in terms of accuracy, completeness, and expenditure of time. From the result of this study, the area as well perimeter of parcels obtained from georeferenced orthorectified UAV image seems to be closer with the area as well as perimeter from total station survey compared to those obtained from tape measurement. If the area is pre-demarcated and clearly visible in Orthomosaic image, then information can efficiently be gained. Some ambiguity could be seen in the comparison of digitized parcels whose boundary information was not clear.

1. INTRODUCTION

1.1 Background

The land survey of Nepal dates back to 1930 B.S; with the gradual development in land administration, the cadastral mapping and land recording system in Nepal was started in 1980 B.S. (Dangol and Kwak, 2013). With the formulation of the Land Survey and Measurement Act, 2019 B.S. up-to-date land ownership and records were formalized with the maintenance of a map-based land record system. Cadastral mapping of entire Nepal was prepared through the traditional plane table survey where 38 districts are mapped in grid sheet and remaining at free sheet. However, due to the advancement in technologies Survey Department began to use the Total Station, an electronic instrument for cadastral mapping. A concept for conducting the survey using a Total Station has been devised to reduce the number of conflicts, improve mapping accuracy, and facilitate the implementation of a land information system. Since 2006 A.D., the initiative has been conducted in two municipalities (Banepa and Dhulikhel) (Dangol and Kwak, 2013). In comparison to traditional plane table surveying, this technique for obtaining spatial data proved to be quite efficient. There was additional study into using GPS technology and high-resolution satellite photos to capture datasets for cadastral surveys. However, these strategies have yet to be put into effect on a broader scale.

Unmanned Aerial Vehicles (UAVs) are remotely controlled or fly with complex automation system aircraft. With the recent development in UAVs and the improvement in automatic navigation technology and stable imaging devices, UAVs can perform aerial operations at different altitudes, according to the mission requirements, and they are able to obtain high-spatial-resolution images and produce ortho-photos, digital surface models, and topographic maps. In addition, UAV aerial photogrammetry has been studied in relation to its application in cadastral surveys in recent years (Chio and Chiang, 2020). Many attempts have been made to use aerial photography for cadastral surveys. UAV has emerged as the most efficient technology for mapping large areas for cadastral surveys and many attempts are being made to use aerial photograph (UAV imageries) for cadastral surveys in which countries like Bhutan, Srilanka, India and Cyprus have applied this technique for updating the existing cadastral maps (Tamrakar, 2012). Manyoky et al. (2011) performed a study on UAV in cadastral application and found that UAV delivers comparable results with respect to data acquisition, processing and evaluation, and time of survey and provides a valuable alternative to other traditional methods. Studies by the ortho-mosaics generated from the high-resolution UAV photos are at least as accurate as conventional terrestrial surveying methods that showed geometrical accuracies with a maximum of 3 centimeters (Rijsdijk and van Heinsberg (2013).

In this regard, in the case of Nepal, the development of the cadastral system is very gradual with the use of plane table survey and introduction of the total station survey; so a shift in feasible technology is necessary for the efficient development of the cadastral system. In Nepal, unprecedented population growth and internal migration coupled with unplanned developmental activities has resulted in urbanization, which lack infrastructure facilities. (Karna et al., 2013) Thus, UAV techniques can be employed as modern technology for more efficient and effective improvement and addressing related issues regarding the cadastral system of Nepal. The technology can have priority according to the accuracy, time, cost, and security of the system. So with this advent, the feasibility study of UAV application regarding cadastral mapping was accomplished in Banepa municipality ward no. 10 from 2078/10/26 to 2078/11/1, according to the approval program of Survey Department in fiscal year 2078-79. In this study, our attempt is to find out the feasibility of orthophoto collected from UAV to update cadastral maps and databases in Nepal and to compare and analyze area of parcel obtained from total station as well as tape measurement with digitized UAV ortho-rectified image.

1.2 Objective

The main objective of this research is to assess ac curacy of orthophoto using UAV and its potential application on cadastral mapping. The other objectives are:

i. To prepare ortho-photo of the study area and assess its accuracy using check points

ii. To create a digital cadastral boundary map of the study area

iii. Compare and analyze digital cadastral boundary data with existing cadastral data of the study area

1.3 Study Area

The proposed study area lies in ward 10 of Banepa Municipality of Kavrepalanchok District. The study covers an area of approx. 100 Ha. and is selected so as to cover different topographic variations such as low land, gently sloping and steep hills and land use types such as residential, commercial, agricultural, forest, water bodies etc.

Figure 1: Study Area (part of Banepa-10, Kavrepalanchok)

2. METHODOLOGY

2.1 DGPS survey

DGPS Survey was performed using 4 highly precise Trimble R7 GNSS Receivers. A total of 5 ground control Points (GCPs) and 3 Check Points was established during the Survey. A minimum observation of 8 hours for base stations and 2 hours for Ground Control points was taken. DGPS Observation was done forming triangular network for network correction which gives relatively higher accuracy during the processing. An observation frequency of 1second and a cut-off angle of 15° was set.

2.2 Link with national network

DGPS Survey have been linked with two Third Order National Trig. Points available at Cihandada at Banepa Municipality and Point no. 120 Kavre Devisthan at Dhulikhel Municipality.

2.3 Traverse by total station

Traverse Survey was performed using angle-distance method for precise calculation of GCPs using 5" Geomax Total Station.

2.4 Error adjustment

Standard Error adjustment methods have been applied for Traverse calculation. The tolerance limit set by Standards of Procedure for Cadastral mapping purpose is ±60ccg. The angular closure error of the traverse computed was 47ccg within the tolerance limit.

The sum of interior angles of a closed traverse was calculated using the formula

$(n - 2)*(200^g)$.where n=5 is the number of sides of the traverse observed.

2.5 Coordinate obtained from traverse and DGPS

Coordinates calculation have been performed using standard software for DGPS observation data. Trimble Business Centre (TBC) was used for precise processing of the GCPs and linked with the National Trig. Points. The details of the processing have been attached in the annex.

2.6 Digital cadastral

Digital Cadastral Survey was performed using 5" Geomax Total Station. Precisely Calculated Ground Control Points was used as reference during the whole survey. Some offset points were also used to observe the details during the cadastral survey. For verification using ground measurement, tape survey was also done for some visible and distinct features.

2.7 UAV flight and image acquisition

Image acquisition was done using Mavic2Pro UAV. A flying height of 100m. and an overlap of 70% was maintained during the whole flight. The whole study area was covered in series of flights taken from various station.

2.8 Field Team for Surveying

For the field observation, different teams were mobilized according to the field activity. The field work was started on Magh 24,2078 and completed by Falgun 1,2078. All the technical teams were from the Survey Department. Separate teams were mobilized for separate field work like UAV Flight Survey, GNSS survey, Total Station Survey and Tape Measurement. Following table shows the list of technical staff involved for different field work.

Table 1: List of Team Members.

UAV Survey	
S.N.	**Name**
1	Prabesh Shrestha
2	Hemraj K.C.
GNSS survey	
1	Buddha Lama
2	Sundar Devkota
Total Station and Tape Measurement Survey	
1	Girija Pokhrel
2	Bikram Shrestha
Field Data Computation	
1	Prabesh Shrestha
2	Girija Pokharel
3	Sundar Devkota

3. ACCURACY ASSESSMENT

3.1 Area Comparison

The outputs are generated as per the survey and observation done during the Field work. The comparisons between area computed from Total Station survey, Tape measurement and area digitized from orthorectified geo-referenced UAV Image of 23 parcels selected over the study area has been presented in Table 2:

Table 2: Comparison of Image Parcel Area w.r.t Total Station and Tape Measurement.

Parcel Number	Area (Sq. m.)			Difference of Image w.r.t (Sq. m.)		% Error Image w.r.t	
	Image	Total Station	Tape	Total Station	Tape	Total Station	Tape
1	160.253	161.617	160.390	-1.364	-0.137	-0.851	-0.086
2	350.658	349.636	341.560	1.022	9.098	0.292	2.594
3	127.192	131.034	117.590	-3.841	9.602	-3.020	7.550
4	108.769	111.495	107.340	-2.726	1.429	-2.506	1.314
5	142.773	140.864	139.130	1.909	3.643	1.337	2.552
6	109.939	115.036	113.620	-5.097	-3.681	-4.636	-3.348
7	14.734	15.378	15.100	-0.644	-0.366	-4.371	-2.487
8	96.542	91.933	92.490	4.609	4.052	4.774	4.197
9	189.929	187.546	185.720	2.383	4.209	1.255	2.216
10	127.356	123.227	126.360	4.130	0.996	3.243	0.782
11	106.588	107.994	104.860	-1.406	1.728	-1.319	1.621
12	95.617	92.670	90.350	2.947	5.267	3.082	5.508
13	90.081	89.297	98.250	0.784	-8.169	0.870	-9.069
14	1011.370	1020.597	996.830	-9.226	14.540	-0.912	1.438
15	88.186	81.992	86.400	6.194	1.786	7.024	2.026
16	1484.570	1493.773	1491.200	-9.203	-6.630	-0.620	-0.447
17	101.578	99.470	98.400	2.108	3.178	2.076	3.129
18	211.843	209.613	207.210	2.231	4.633	1.053	2.187
19	86.604	83.047	84.700	3.557	1.904	4.107	2.199
20	107.725	105.343	104.700	2.382	3.025	2.211	2.808
21	72.755	69.528	69.740	3.227	3.015	4.435	4.145
22	128.136	122.284	118.450	5.852	9.686	4.567	7.559
23	148.752	149.368	152.230	-0.616	-3.478	-0.414	-2.338

The parcels derived from georeferenced ortho image of UAV were used for analysis and compared with the parcel obtained from total station survey as well as the parcel area from tape measurement. Due to time limitations, a total of only 23 parcels were digitized from UAV image and same parcel from total station survey and tape measurement were used. Among 23 parcels, 1 parcel obtained from Image and Total station survey was greater than 5% differences in area. It indicates that only 4.3% parcels were found with more than 5% area differences. It seems that there is low mismatch in area between parcel from image and parcel obtained from total station survey. Similarly, out of 23 parcels, 4 parcels obtained from Image and tape measurement were greater than 5% differences in area. It indicates that only 17 % parcels were found differences greater than 5 %. The above statistics shows that the area of parcels obtained from georeferenced orthorectified UAV image is closer with the area obtained from Total station survey than area obtained from tape measurement.

Figure 2 shows the plot of difference (in sq. meters) in area of each parcel measured in Orthomosaic image with respect to Total Station and Tape measurement. The x-axis shows the number of parcels, and the y-axis shows the positive and negative differences in square meters. As seen in the graphs, the minimum deviation seen with respect to Total Station measurement is in parcel number 23 and with respect to Tape measurement is seen in parcel number 1. The maximum deviation seen with respect to Total Station measurement is in parcel number 14 and with respect to tape measurement is also seen in parcel number 14.

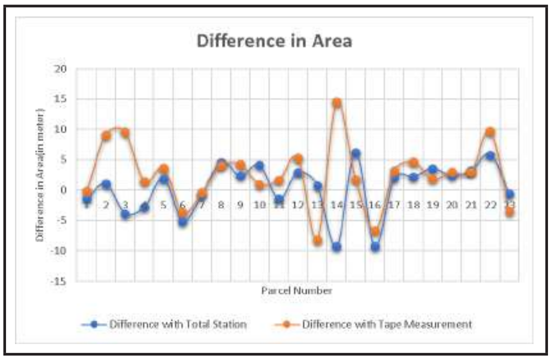

Figure 2: Plot of deviation of parcel area of image with total station and tape measurement

3.2 Perimeter Comparison

The perimeter of land parcels obtained from digitization of UAV images along with the perimeter obtained from Total station survey and Tape measurement is shown in Table 3:

Table 3: Comparison of Image Parcel Perimeter w.r.t Total Station and Tape Measurement.

Parcel Number	Perimeter (m.)			Difference of Image w.r.t (m.)		% Error Total Station w.r.t	
	Tape	Total Station	Image	Total Station	Tape	Total Station	Tape
1	56.58	55.95785	56.330219	0.372369	-0.249781	0.66	-0.44
2	77.51	78.556195	78.608177	0.051982	1.098177	0.07	1.40
3	43.83	46.155182	45.555086	-0.600096	1.725086	-1.32	3.79
4	44.35	45.223758	44.582872	-0.640886	0.232872	-1.44	0.52
5	50.4	50.449565	50.626621	0.177056	0.226621	0.35	0.45
6	43.4	43.847701	42.626155	-1.221546	-0.773845	-2.87	-1.82
7	21.28	21.469792	21.027082	-0.44271	-0.252918	-2.11	-1.20
8	39.7	39.638738	40.852109	1.213371	1.152109	2.97	2.82
9	54.95	55.283115	55.618224	0.335109	0.668224	0.60	1.20
10	45.5	45.009422	45.755819	0.746397	0.255819	1.63	0.56
11	41.8	42.398092	42.276811	-0.121281	0.476811	-0.29	1.13

Parcel Number	Perimeter (m.)			Difference of Image w.r.t (m.)		% Error Total Station w.r.t	
	Tape	Total Station	Image	Total Station	Tape	Total Station	Tape
12	39.55	39.935189	40.539609	0.60442	0.989609	1.49	2.44
13	41.07	39.018481	39.298142	0.279661	-1.771858	0.71	-4.51
14	128.7	129.621175	129.571766	-0.049409	0.871766	-0.04	0.67
15	41.3	41.802048	43.087454	1.285406	1.787454	2.98	4.15
16	163.27	163.295849	163.259666	-0.036183	-0.010334	-0.02	-0.01
17	41.15	41.483034	41.864823	0.381789	0.714823	0.91	1.71
18	57.7	58.023511	58.305439	0.281928	0.605439	0.48	1.04
19	37.92	37.612146	38.153945	0.541799	0.233945	1.42	0.61
20	43.7	43.764769	43.951566	0.186797	0.251566	0.43	0.57
21	38.47	38.598185	38.992482	0.394297	0.522482	1.01	1.34
22	45.2	47.455332	47.919713	0.464381	2.719713	0.97	5.68
23	50.4	50.125799	49.844987	-0.280812	-0.555013	-0.56	-1.11

The parcels derived from georeferenced ortho image of UAV were used for analysis and compared with the parcel obtained from total station survey as well as the perimeter of parcel from tape measurement. The above statistics shows that the perimeter of parcels obtained from georeferenced orthorectified UAV image is closer with the perimeter obtained from Total station survey than perimeter obtained from tape measurement.

Figure 3 shows the plot of difference (in meters) in perimeter of each parcel measured in Orthomosaic image with respect to Total Station and Tape measurement. The x-axis shows the number of parcels, and the y-axis shows the positive and negative differences in meters. As seen in the graphs, the minimum deviation seen with respect to Total Station measurement is in parcel number 16 and with respect to Tape measurement is also seen in parcel number 16. The maximum deviation seen with respect to Total Station measurement is in parcel number 15 and with respect to tape measurement is also seen in parcel number 22.

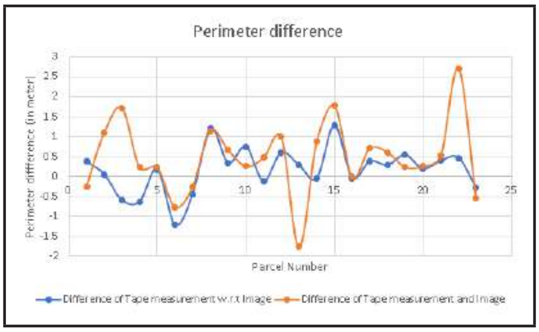

Figure 3: Plot of deviation of perimeter of parcel of image with total station and tape measurement

3.3 Positional Comparison

Positional Accuracy of the parcel boundary derived from Orthophoto, and Total Station Survey were assessed by identifying the shift in position of the parcels centroid coordinates calculated in terms of distance between them. Centroid Coordinates of each parcel derived from TS Survey as well as parcel derived from Orthomosaic image were calculated and the distance between them of the corresponding parcel boundary was measured using the Euclidean's Distance Formula:

$$\text{Distance}(\Delta d) = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (1)$$

Where, Δd is the deviation in meter

Table 4 Comparison of Image Parcel Centroid Position w.r.t Total Station Measurement.

Parcel Number	Centroid (Image)		Centroid (Total Station)		Deviation of Centroid (Image and TS)
	Easting	Northing	Easting	Northing	
1	352855.264	3058429.171	352855.277	3058429.067	0.105
2	352851.936	3058452.518	352851.952	3058452.485	0.036
3	352896.719	3058422.719	352896.841	3058422.743	0.124
4	352938.172	3058359.195	352938.210	3058359.115	0.088
5	352957.613	3058426.970	352957.398	3058427.113	0.258
6	352969.730	3058408.574	352969.867	3058408.411	0.213
7	352995.945	3058410.424	352995.907	3058410.448	0.045
8	352972.625	3058342.613	352972.522	3058342.738	0.162
9	352983.387	3058346.014	352983.416	3058345.950	0.070
10	352995.504	3058348.891	352995.471	3058348.857	0.048
11	353004.265	3058351.667	353004.224	3058351.532	0.141
12	353011.883	3058353.808	353011.853	3058353.751	0.065
13	353018.973	3058356.027	353018.883	3058355.913	0.146
14	353036.341	3058581.801	353036.484	3058581.757	0.150
15	353563.675	3058377.940	353563.547	3058377.975	0.133
16	353672.526	3058352.233	353672.610	3058352.202	0.089
17	353635.437	3058434.715	353635.437	3058434.638	0.077
18	353646.073	3058430.404	353646.009	3058430.357	0.079
19	353694.705	3058432.625	353694.660	3058432.799	0.180
20	353718.304	3058437.636	353718.222	3058437.571	0.105
21	353792.657	3058416.945	353792.683	3058416.987	0.050
22	352935.057	3058366.513	352935.189	3058366.250	0.294
23	352920.557	3058363.647	352920.417	3058363.589	0.151
			Average		0.122
			Standard Deviation		0.068
			RMSE Error		0.139

The standard deviation for the deviation of centroids from land parcels of image digitized and land parcels from total station survey is obtained by the following formula:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \mu)^2}{N}} \qquad (2)$$

Where σ is the standard deviation, μ is the mean value of observation and N is the number of parcels measured. The standard deviation calculated for the deviation of centroid of land parcels obtained from total station and UAV image digitization is 0.068m. Similarly, the value of average deviation of centroid for land parcels is 0.122m.

Similarly, the Root Mean Square Error (RMSE) for the deviation of centroid of land parcels obtained from total station and UAV image digitization obtained by the following formula:

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(\hat{y}_i - y_i)^2}{n}} \qquad (3)$$

Where RMSE is the Root Mean Square Error, y is the value of centroid deviation and n is the number of parcels measured. The RMSE calculated for the deviation of centroid of land parcels obtained from total station and UAV image digitization is 0.139m.

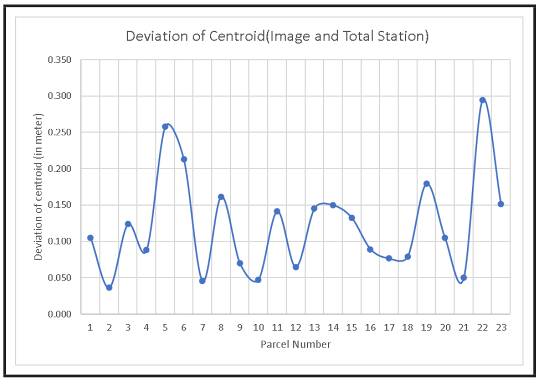

Figure 4: Plot of deviation of parcel centroid of image and total station with parcel number

4. CONCLUSION

Cadastral survey using Total station, UAV and Tape measurement were confirmed to be comparable in terms of accuracy, completeness, and expenditure of time. From the result of above study, the area as well perimeter of parcels obtained from georeferenced orthorectified UAV image seems to be closer with the area as well perimeter from total station survey than obtained from tape measurement. Difference in area and perimeter could be seen varying mostly due to the shape of the parcels. So, in some parcels difference in area could be seen higher whereas difference in perimeter is comparatively low.

The advantage of UAV systems is the ability to quickly observe the surface of areas at low flying altitude while still meeting the accuracy requirements of cadastral surveying. As our above results suggests, the limiting factors for image orientation accuracy are the camera calibration, the image quality, and the definition of the ground control points in the image space. The application of UAV systems for cadastral surveying is appropriate for the capturing of land cover or single objects. If the area is already demarcated, information can efficiently be gained. Therefore, UAV systems proved suitable to be used in addition to the standard surveying methods to gain further data through the acquired images such as overview images or orthoimages. Moreover, another added value of using UAVs in cadastral applications is the effortless generation of elevation models and 3D objects. UAV method with appropriate photogrammetric evaluation methods offers a great potential to gain information from the captured data that are useful for cadastral applications. These derivates from UAV measurements can present a great additional benefit to users of cadastral data, such as real estate agencies and insurance companies. In areas where access can be difficult, e.g., after natural calamities or in third world countries, UAVs offer a valuable alternative to traditional field survey method for cadastral survey. With further developments of specific system technology, the usability of UAV systems will increase in cadastral surveying. In future, UAVs will be used where a need of high accuracy is required, and fast data capturing is demanded. Therefore, the use of UAVs is an opportunity for cadastral surveying. UAV also can play vital role for data collection to solve the problem of informal settlement, re-cadastral survey, and other engineering surveys esp. in flat terrain.

This study recommends the use of UAV in cadastral survey as followings:

i. UAV survey is suitable for cadastral survey for clearly demarcated land parcels visible in UAV images.

ii. It can be performed for project with low budget and low time with comparison to other surveying techniques.

iii. The use of RTK receivers UAV can help for the betterment of output result.

iv. UAV survey is appropriate for the open areas, and it is difficult to extract features in shadow area.

v. Application of cadastral survey with field verification is useful for cadastral map updating and keeping the record of land parcel.

4.1 Benefits of Cadastral survey using UAV images:

From this study, the benefits of UAV applications in cadastral survey are as followings:

a) Reduce field time and survey costs Capturing cadastral data with a drone is up to faster than with land-based methods and requires less manpower and is also less expensive.

b) Provide accurate and exhaustive data Total stations only measure individual points. One drone flight produces thousands of measurements, which can be represented in different formats (Orthomosaic, point cloud, DTM, DSM, contour lines, etc.). Each pixel of the produced map or point of the 3D model contains 3D geo-data. Due to low flying height, more clear and accurate information can be obtained with comparison to conventional photogrammetry.

c) Mapping an inaccessible area An aerial mapping drone can take off and fly almost anywhere. There is no longer limitation by unreachable areas, unsafe steep slopes, or harsh terrain unsuitable for traditional measuring tools. The data collection by UAV is not interrupted by highway traffics, railway tracks, river etc.

d) With less effort 3D model of earth surface With comparison to other methods, the UAV method allows for the derivation of much more information. Based on the image orientation, a digital elevation model of different grid and area sizes can be calculated. d. In addition, 3D models of objects such as buildings can be generated based on the captured UAV data which can be useful for 3D cadaster.

4.2 Limitations of study

The limitations of the study are illustrated below:

- Demarcation of Parcel were not visible in orthorectified image acquired using UAV. So, some differences could be seen in the parcel digitized from the images and the parcels plotted using the co-ordinates acquired from Total Station.
- The point cloud has been generated from the ortho pairs of images acquired from UAV. The resulting point cloud may contain errors, such as image shadows, mismatches, and lens distortion.
- The timeframe for the study was limited. So, only limited number of control points could be surveyed. The limited number of DGPS also took longer time for observation of control points.
- The processing of UAV images requires high-capacity computers and well-equipped workstations. Otherwise, it requires longer time for image processing.

REFERENCE

Chio, S.-H. & Chiang, C.-C. (2020). Feasibility Study Using UAV Aerial Photogrammetry for a Boundary Verification Survey of a Digitalized Cadastral Area in an Urban City of Taiwan. *Remote Sensing*, 12, 1682.

Dangol, S. & Kwak, B. Y. (2013). Improvement of Cadastral System: Scope in Nepal. *Nepalese Journal of Geoinformatics*, 12, 19-24.

Karna, B. K., Mandal, U. K., & Bhardwaj, A. (2013). Urban Sprawl Modeling using RS and GIS Technique in Kirtipur Municipality. *Journal on Geoinformatics, Nepal*, 12, 50–56. https://doi.org/10.3126/njg.v12i0.9073

Manyoky, M., Theiler, P., Steudler, D. & Eisenbeiss, H. (2011). Unmanned Aerial Vehicle in Cadastral Applications. *Proceedings of the International Conference on Unmanned Aerial Vehicle in Geomatics* (UAV-G), 2011. Copernicus, 57-62.

Rijsdijk, M. & Van Heinsberg, W. (2013). Unmanned Aerial Systems in the Process of Juridical Verification of Cadastral Border. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 1, W2.

Tamrakar, R. M. (2012). A Prospect of Digital Airborne Photogrammetry Approach for Cadastral Mapping in Nepal. *Nepalese Journal of Geoinformatics*, 11, 1-6.

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Analyzing Water Poverty Components Using Geospatial Tools: Resource and Environmental Constraint in Kathmandu District

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KEYWORDS

Water poverty, Groundwater, Topographic Wetness Index, RUSLE, Resource and Environmental constraint

ABSTRACT

This current paper examines water poverty situation in Kathmandu district in terms of water resource and environment constraints. Integrated methodology was adopted for the study. Water source sample survey was carried out using GPS tool. Study area comprised total of 13 water sample sites. Household questionnaire survey was carried out for water poverty mapping and analysis. Resource component of water poverty comprised indicators, namely seasonal variation in water availability, water supply frequency and groundwater recharge potential. The environment constraint component comprised water quality rate of soil erosion and topographic wetness index. The result show that the average calculated value of water resource limitation component is 6.31 and out of 13 studied communities, 7 communities fall below average. It is found that environmental constraint is less associated with urban housing density. It is found that environmental constraint is less associated with urban housing density. The average calculated value of environmental component is 3.43 and out of 13 studied communities, 8 communities fall below average. Spatial variability in water poverty is prominent and highest water poverty is found in urban cores. Communities with lower water poverty are found in peri-urban location near the foothills. The average calculated value of water poverty is 9.74 and out of 13 studied communities, 9 communities fall below the average. The study concluded that water poverty index and resultant map is a very effective tool to visualize the distribution of water poverty at local spatial scale and to present the complex nature of water poverty.

1. INTRODUCTION

Bio-physical and socio-cultural assessment of resource and environmental constraints in water access and use in urban context is important research agenda in the wake of increasing domestic water demand. Studies show that water extraction for domestic and other use has increased with rapid urbanization in Kathmandu valley (Udmale et. al., 2016; Shrestha & Shrestha, 2013). The annual rate of change in basic water supply between 2000-2015 is -0.23, i.e. decreasing water supply, in urban area of Nepal (WHO/UNICEF, 2017).

Kathmandu valley, the capital region of Nepal is most populated and rapidly urbanizing region. The rapid urbanization and subsequent expansion of the built-up area has increased the spatial extent and demand of household water use. The implication of rapid population increase and degree of urbanization is water shortage and degraded water quality. Projected water demand for Kathmandu Municipality was 147mld for 2011 and 195mld for 2016 (Udmale et. al., 2016). The household water demand of Kathmandu valley in 2020 is 420 mld whereas average production is only 129 mld and supply through the water supply authority is only 103 mld excluding 20% real loss during supply (KUKL, 2020). The differential spatial distribution of water sources, differential capacity to access in one hand and improper utilization and management on the other, results conflict/rivalry and overuse of natural resource leading to water poverty. In this context, understanding and confronting the water resource availability and environmental constraints at urban household level becomes imperative.

A variety of methods, tools and techniques has been applied to examine and address the problem of water availability and access, equitable allocation and resource management. Spatial analysis and mapping of water poverty has become appealing research area in geographical research with the advancement of geospatial tools and spatial data availability. GIS-based spatial overlay and multi-criteria analysis devising analytic hierarchy process, AHP is becoming widespread in evaluating water poverty analysis involving multiple and diverse criteria (Estoque, 2012). Water poverty concept integrates water scarcity (bio-physical resource condition) with social and economic dimension of water resource management (Pan et. al., 2017). It is referred to as a condition where a nation or region cannot afford the cost of sustainable clean water to its people (Feitelson & Chenoweth, 2002). The most common tool used to analyze water poverty is Water Poverty Index, WPI (Tahmineh et. al., 2021). The concept of the WPI was originally developed by Sullivan (Sullivan, 2002; Sullivan et. al., 2002) as a tool, with total of 17 indicators, integrating both physical and social aspect of water allocation and management. WPI comprises five components, namely resource, access, capacity, use and environment.

Growing demand and extraction of groundwater in has intensified the resource condition which has lessened physical access to resource in some parts and has escalated vulnerability in other areas. Examining variations in water resource availability, access and constraints in terms of place vulnerability is very limited and most them are confined to climate change and environment rather than on resources access and use (Aksha et. al., 2019; Falkenmark, Lundqvist, & Widstrand, 1989). Besides, the earlier studies on water poverty of the country indicates that Bagmati basin is among one of the water poor area (Pandey et. al., 2012). In this context, this paper examines water poverty situation in Kathmandu district in terms of water resource and environment constraints.

2. STUDY AREA

Kathmandu district is the capital region of Nepal comprising 11 local administrative units with 1 metropolitan and 10 municipalities. The total area of the district is 413.6 km^2. It is located in the central hill region of the country and elevation ranges from 1023 to 2571 meters. The location map of Kathmandu district, the study area is presented in Figure 1. The average rainfall is 1400 mm, most of which occurs during months of June to August (DWIDP, 2009). The district comprises two primary landforms namely, river floodplains and elevated river terraces and are regarded as one of the most productive agricultural regions of the country. Major geomorphological divisions of the district include hill slopes, rocky outcrops, terraces, flood plains mostly with the lacustrine surface and riverbed (JICA, 2018). Bagmati River is the main river of the district flowing from north to south with tributaries like Bishnumati, Dhobi khola, Balkhu Khola and Manohara.

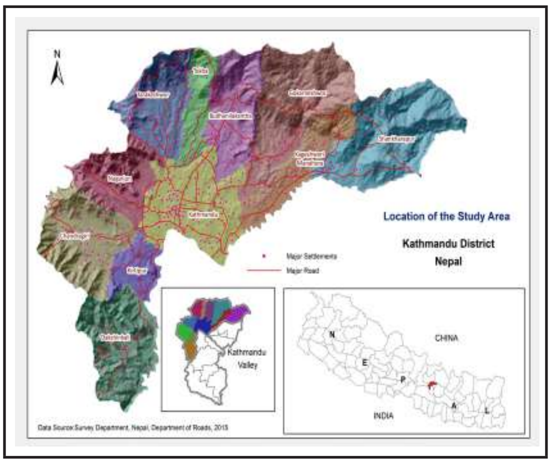

Figure 1: Study Area

According to preliminary result of national census 2021, Kathmandu is the most populated district among 77 districts of the country comprising 6.91% with total population of 20,17,532. It has highest population density of 4885 person/km^2 and holds the largest number of urban population of the country.

3. DATA AND METHODS

The study is based on primary and secondary data sources. Field data collection tools were developed for sample water sources, community and household survey, KII and FGD. Reconnaissance survey and field observation was carried out prior to water sample and household (HH) questionnaire survey and sample checklist was tested randomly. HH survey, KII and FGD were carried out to collect data and information on water availability and use, water demand, consumption and household water issues and problems.

Sample water source location was recorded using GPS and related information is recorded in GPS inventory sheet. Field survey checklist was prepared for Key informant interviews and Focus Group Discussion. Field survey questionnaire was used for household information collection. Informal discussion and community survey was carried out using Water Poverty Indicator checklist. Most of the spatial data required for resource and environmental components of water poverty analysis were collected from secondary sources and others were derived from Spatial data and their sources are presented in Table 1.

Table 1: Spatial Data source.

SN	Spatial data layer	Source
1	Groundwater sources: Shallow/ Deep wells	KUKL, KVWSMB and DoMG, 2019
2	Geology, Lithology, Lineaments	Department of Mines and Geology, 1998
3	Geomorphology	JICA, 2018
4	Soil	SOTER, Nepal. 2009
5	Rainfall	DHM, 2019
6	Administrative Boundary, settlements,	Topographical Sheets, Survey Department, 1998, 2021
7	Land cover / use	Derived from Google Earth, 2019
8	Drainage Density, Slope, Topographic Wetness Index (TWI)	Derived from SRTM DEM 30m USGS/ NASA, Topographical Sheets, Survey Department, 1998

The stratified spatial sampling method was adopted for selecting sample water source locations, the community water users (for public well) and household users (for private well). The stratified sampling method is used because study sample was of mutually exclusive and exhaustive subgroups. Sample selection reference was based on monitoring well of KUKL located in 13 different locations (Figure 2).

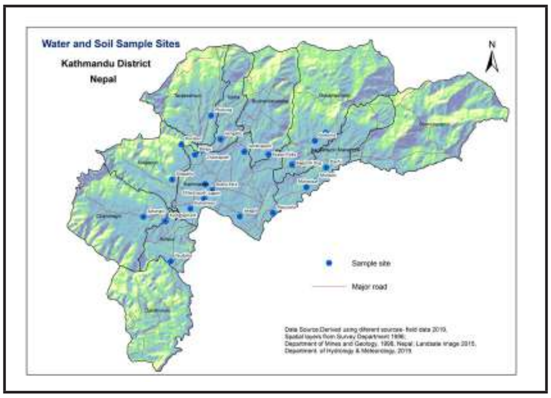

Figure 2: Water and soil sample sites in Study area

Water poverty mapping and analysis comprises five components, namely resource, access, capacity, use and environment. Resource and environment component focus on bio-physical aspects whereas access, capacity and use incorporates socio-cultural economic and institutional aspects. These five components incorporate number of indicators depending upon geographic scale and data availability (Koirala et. al., 2020; Shadeed et. al., 2019; Merz, 2004; Sullivan et. al. 2002). relevance of water poverty analysis using Water poverty index, WPI over traditional water assessment technique is that it overcomes the weakness of spatio-temporal dimension and incorporates temporal and spatial variability and their weightage in local context priority (Sullivan et. al. 2002). The overall methodological framework of this study is based upon bio-physical aspects of water poverty. The two components of water poverty namely, Resource availability/ constraints and environmental constraint situation was examined through the methodological framework presented in Figure 3. Multi-criteria weighted summative function, modified after weighted average of Sullivan et.al. (2003) was adopted for both resource and environmental component of water poverty analysis. The calculated index value is interpreted as higher the calculated index value better is the water resource condition (Sullivan et. al., 2003). The calculated value for each component was classified into five classes: very high, High, Moderate, Low and very Low. The classification into five class value was based on the Jenks natural break method.

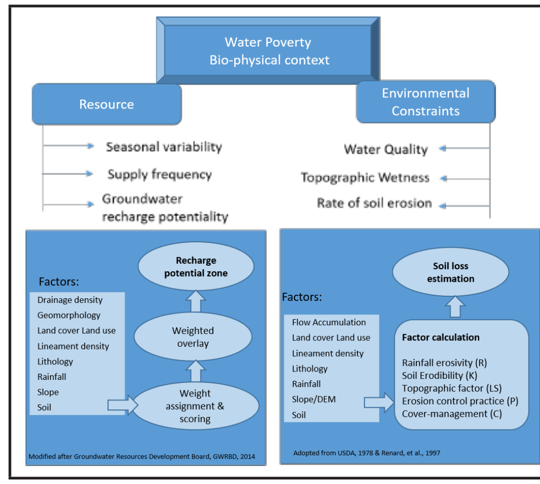

Figure 3: Methodological Framework

Analysis method for resource component of water poverty: Three indicators for resource component namely, seasonal variability, water supply frequency and groundwater recharge potentiality were selected for water poverty analysis. Seasonal variability and water supply frequency data were collected through HH survey and FGD. Groundwater recharge potential mapping was carried out using weighted overlay analysis with 8 spatial controlling/influencing factors listed in methodological framework. Resource component was calculated as:

$$R = \Sigma(R_g + R_v \; + \; R_f\,) * \Sigma(X_i + X_j \; ......+X_n) \,/\, N \qquad (1)$$

Where,

Rg - is groundwater recharge potential (GWRP) which is mapped and calculated as presented in Figure 2 using equation 2.

Rv - is Seasonal variability of water availability (wet and dry season) which is based on difference in number of water supply in piped water sources and water level in shallow/deep dug wells.

Rf - is supply frequency of water ranging from 24 hours to less than 1 hour and supply duration ranging from daily to weekly.

Xi…Xn is value of component indicators and N is total number of locations (Study site/Community).

Technique identified by GWRDB (2014) was modified and adopted as following for calculating groundwater recharge potential zones.

$$GWRP = \sum(LTw * LTf + GMw * GMf + LDw * LDf + DDw * DDf + SGw * SGf + SLw * SLf + RFw * RFf + LUw * LUf \quad (2)$$

Where;

GWRP = Groundwater recharge Potential, w = weight and f = factor rate assigned to each class category of individual factor; and (LT: Lithology, GM: Geomorphology, LD: Lineament Density, DD: Drainage density, SG: Slope gradient, SL: Soil Type, RF: Rainfall, and LU: Land cover)

Analysis method for environmental component of water poverty: Three indicators for environmental component namely, water quality (turbidity, acidity (pH) and iron content (Fe)), topographic wetness and rate of soil erosion were selected for water poverty analysis. Water samples were collected from 13 sites and physio-chemical properties of water was laboratory tested using digital technology.

The Environment (E) component is calculated as:

$$E = S(E_q + E_s + E_v) * \Sigma(X_i + X_j \ \ldots\ldots + X_n) / N \quad (3)$$

Where,

E_q - is water quality which includes water sample testing of turbidity, iron(Fe) and acidity (pH) methodology for water quality test is provided in section 2.2.7.

E_{ss}- is rate of soil erosion, Methodology for rate of soil erosion is presented under section 2.2.8.

E_v – is vegetation (forest) cover in the community, forest cover in or within 2.5km of the community

Topographic wetness is calculated using Topographic wetness, TWI as described by Beven and Kirkby (1979), i.e., TWI = ln(α/ tan θ), Where, a = upslope contributing area (m2), b = slope in radians.

Smaller values of the TWI indicate less potential for water accumulation and soil moisture.

Similarly, rate of soil erosion is calculate using modified USLE, i.e., RUSLE model as recognized by Wischmeier & Smith, (1978) using equation 4 as following. Erosion factors were calculated as adopted by different scholars namely: R and LS factor as per Morgan & Davidson, 1991), K factor as per Sharpley & Williams (1990), C factor as per Renard, et al. (1997), and P factor as per Wischmeier & Smith (1978).

$$E = R * K * L S * C * P \quad (4)$$

Where,

E = Annual average soil erosion rate

R = Rainfall erosivity

K = Soil erodibility

LS = Topographic factors

C = Land cover management factor

P = Protection factor

The potential soil loss estimation map is produced based on individual factor calculation of R, K, LS, P and C factor and integrated in RUSLE equation.

4. RESULT AND DISCUSSION

Study show that groundwater level in Kathmandu has decreased by 1 meter per year (GWRDB, 2014) and many parts of the valley are becoming critical in groundwater resource availability (KVWSMB, 2015). Three different zones for water extraction has been identified based on groundwater availability, water level, recharge potential and population/housing density in Kathmandu valley so that alarming rate of water extraction could be regulated. Safe area is the first zone for groundwater extraction and use comprises 23% of the total valley area and is confined to northern part, semi-critical area, the second zone, comprises 18.5% area and mostly include densely settled urban core of Kathmandu, Lalitpur and Bhaktapur municipalities. Southern part of the valley is identified as critical area (he third zone) in terms of groundwater extraction and use which comprises 33% of the valley area.

Resource component of water poverty included three indicators namely seasonal variation in water availability, water supply frequency and groundwater recharge potential. The seasonal and spatial variation of the static groundwater level (SGL) is found very high in the study area. The static groundwater level (Shallow wells) during wet season varied from 1.5 meters in Taudaha to 13 meters in Chhetrapati, both located in semi-critical groundwater extraction zone whereas seasonal variability of 12 meters was found in Kapan located in safe zone. Water supply frequency at household level from sources, varied in both duration and frequency. Field survey data show that, supply duration varied from 1 hour to 3 hours and frequency ranged from 1-3 daily, hours, 1-2 hours twice a week to 3 hours-once a week.

Resource potential mapping of groundwater was explored through 4 controlling factors: rainfall, geology, lineaments and slope and 4 influencing factors: drainage density, land cover land use, geomorphology and soil. The upper hill slope is mostly area of limited infiltration/recharge and covered by vegetation. Water usually accumulates in lower slopes, so only lower slope and valley floor is considered in the current study. Groundwater recharge potential in Kathmandu varies considerably. Most of the district area is moderate to low recharge potential. Fifty-one percent area is low to very low recharge potential (Figure 4). Of the total potential recharge area, only 2% area has very high recharge potential an 15% area has high recharge potential.

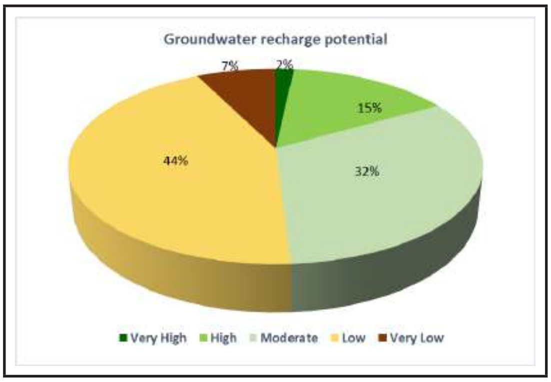

Figure 4: percent share of groundwater recharge potential area

Geology and soil are dominant controlling factors on spatial distribution of recharge potential. Patches of high recharge potential area are found in Sundarijal and Chunikhel in the north, Machhegaun, Chundevi and Chandragiri in the south (Figure 5).

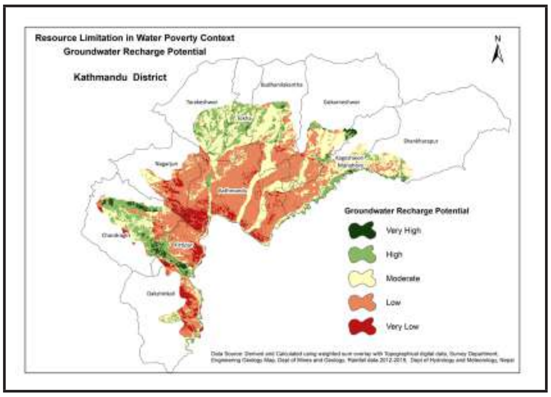

Figure 5: Spatial distribution of groundwater recharge potential

Resource limitation component in the study area is calculated based on three resource component as presented in Figure 6. It is found that the dense core urban area has very limited resource. At community level resource limitation is very high in Chhetrapati, and high in Jaisidewal, Kapan and Nayabazar- Kirtipur area. The average calculated value of water resource limitation component is 6.31 and out of 13 studied communities, 7 communities fall below average. Communities located in the north-western part are relatively high in resource availability as evident from Figure 6.

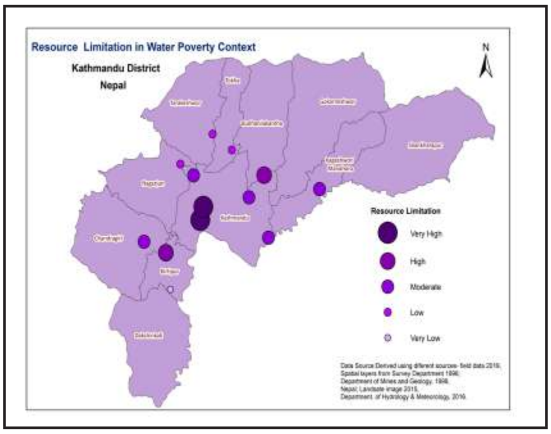

Figure 6: Water resource limitation in water poverty context in Kathmandu

The environment constraint component comprises water quality (turbidity, iron content and pH content) rate of soil erosion as proxy to environmental degradation and topographic wetness index as proxy to natural state of ecosystem productivity.

Water quality parameters tested as per WHO standard (WHO, 1996) for environment component included 3 parameters: turbidity, iron content and pH content. The summary statistics of measured parameters for 13 water sample location is provided in Table 2. The acceptable turbidity level for drinking water is up to 1mg/liter. A highest turbidity value of 14.7 mg/liter is found in Dhapasi, which doesn't meet the acceptable WHO standard for drinking purpose whereas Taudaha and Kapan has 0.1 mg/liter turbidity. Likewise, only 4 locations among 13 samples meet the standard pH value (6.6-8.0) for drinking purpose and 9 locations has less than 6.5 pH content which may cause metal corrosion and toxic release. Iron content is also low ranging from 0.36 (in Thali) to-0.55 (Dhapasi) than drinking water standard (1-3mg/liter). The summary statistics of water sample parameters is presented in Table 2.

Table.2: Measured parameters of water samples

Statistics	Turbidity (mg/liter)	Iron content (mg/liter)	pH
Minimum	0.07	0.36	5.05
Maximum	14.67	0.55	6.7
Mean	1.86	0.44	5.98
Standard Deviation	3.74	0.06	0.47

Spatial pattern of soil erosion susceptibility plotted against 13 sample study sites show that very high soil erosion susceptible area is largely confined to northern and south-western hill slopes. Foot hills and valley floor has low to very low erosion susceptibility (Figure 7). However, in 13 study sites, moderate to low erosion susceptibility was found. Raniban, Phutung and Kirtipur are moderately susceptible whereas soil erosion susceptibility is low in all other study sites. Major controlling factor of lower susceptibility is lower slope.

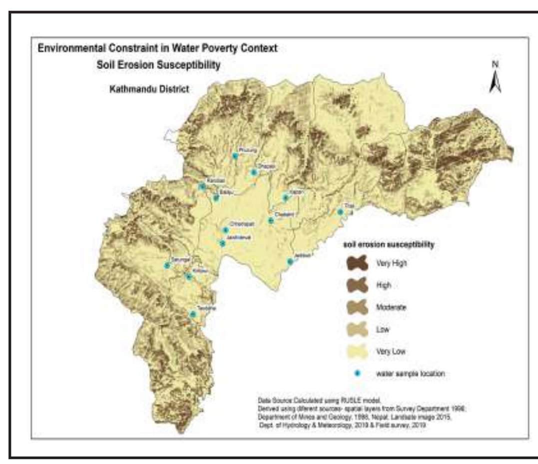

Figure 7: Soil Erosion susceptibility in Kathmandu

TWI is the indicator of topographic control on water distribution, runoff, direction of flow and accumulation. The calculated TWI values differs considerably depending on the topography of the landscape. Topographic wetness in Kathmandu is depicted in Figure 8. Area under very high and high wetness in combination covers nearly 13% of the total area while 63% area is under low topographic wetness and 24% area has moderate wetness.

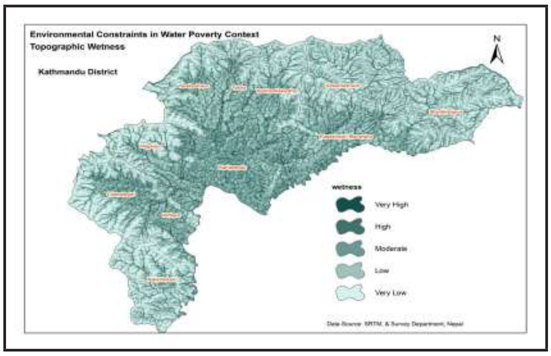

Figure 8: Topographic Wetness in Kathmandu

In contrast to resource component, environmental constraint was found more serious in water poverty context. It is found that environmental constraint is less associated with urban housing density. At community level, environmental constraint is very high in Dhapasi followed by Chhetrapati, and high in Jaisidewal, and Jadibuti area. The average calculated value of environmental component is 3.43 and out of 13 studied communities, 8 communities fall below average. Thimi, Phutung, and Satungal though, are peri- urban in characteristics, still has high environment constraint because of increasing urban sprawl. Kirtipur conversely, has low environment constraint largely due to open space and vegetation cover of Tribhuvan university complex as depicted in Figure 9. Taudaha and Raniban has lowest environmental constraint due to lower housing density and higher vegetation cover.

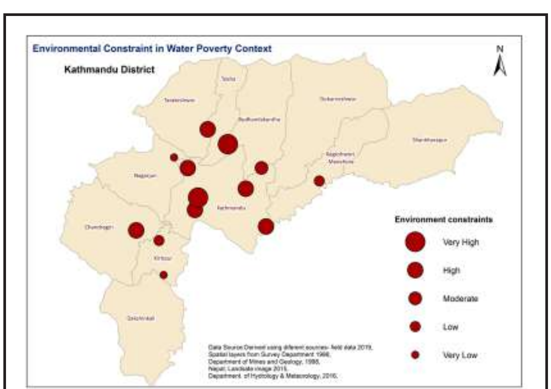

Figure 9: Environmental constraint in water poverty context in Kathmandu

Resource limitation, environmental constraint and overall integrated water poverty at community level is presented in Table 3 and summary statistics is presented in Table 4. Chhetrapati has the highest water poverty level followed by Jaisidewal, both located in traditional urban core. It is followed by Jadibuti, Kapan and Satungal with similar WPI value.

Table.3: Water poverty at community level

Community	Resource Limitation	Environment constraint	Integrated WPI	Water poverty rank
Chhetrapati	3.28	2.56	5.84	1
Jaisidewal	4.1	2.75	6.85	2
Jadibuti	5.74	2.75	8.49	3
Kapan	4.92	3.74	8.66	4
Satungal	5.74	2.95	8.69	5
Nayabazar	4.92	4.13	9.05	6
Chabahil	6.56	2.95	9.51	7
Dhapasi	7.38	2.16	9.54	8
Balaju	6.56	3.15	9.71	9
Thali	5.74	4.33	10.07	10
Phutung	8.2	2.95	11.15	11
Raniban	8.2	5.31	13.51	12
Taudaha	10.66	4.92	15.58	13

So far as overall water poverty is concerned, the variation is higher in maximum value regarding environment component whereas there is only slight variation in resource component (Table 4). The average calculated value of water poverty is 9.74 and out of 13 studied communities, WPI value of 9 communities fall below the average. Water poverty level of Taudaha, Phutung, Raniban, Thali and Balaju are relatively low. Standard deviation is also high as compared to individual resource and environment components.

Table.4: Summary Statistics of WPI Components

Component	**Min**	**Max**	**Mean**	**Standard Deviation**
Resource	3.28	10.66	6.31	1.96
Environment	2.16	5.31	3.43	0.97
WPI	**5.84**	**15.58**	**9.74**	**2.56**

Spatial variability in water poverty level is depicted in Figure 10. The communities with the highest water poverty tend to be the more urban cores located in central valley floor such as Chhetrapati and Jaisidewal. Recently urbanized locations like Jadibuti, Kapan, Satungal are also facing relatively high water poverty. Communities with lower water poverty tend to be the predominantly peri-urban located in or near the foothills such as Taudaha, Raniban, Phutung and Thali.

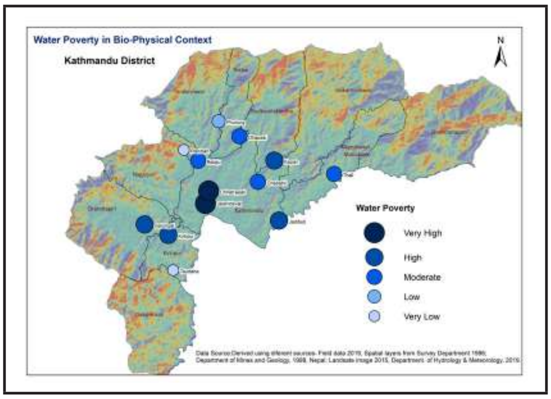

Figure 10: Water poverty in Bio-physical context

Studies show that water poverty in Kathmandu is more of an issue of mismanagement in water collection and distribution as compared to bio-physical constraint of resource availability (Shrestha, 2021; Gyawali et. al., 2019). Major distinction on water poverty is found among core urban and peri-urban area. Vulnerability of place and people has increased without effective management of resource This is exemplified by increased water poverty in communities like Kapan, Thali, and Satungal.

5. CONCLUSION

The current study exhibits that water poverty index helps to identify location specific and sector specific problems related to water resource allocation. Water poverty index and resultant map is a very effective tool to visualize the distribution of water poverty at local spatial scale and to present the complex nature of water poverty.

It is concluded that, in Kathmandu district, area with very high population concentration and high housing density has low to very low resource potential. It implies that the functioning and effective management of water authority, plays a significant role in combating water poverty issue and in depth examination of access, use and capacity components is required.

REFERENCES

Aksha, SK., Juran, L., Resler, LM., & Zhang, Y. (2019). An Analysis of Social Vulnerability to Natural Hazards in Nepal Using a Modified Social Vulnerability Index. *International Journal of Disaster Risk Science, 10*:103–116. DOI: 10.1007/s13753-018-0192-7.

Beven, K. J. and Kirkby, M. J.(1979). A physically based, variable contributing area model of basin hydrology, Hydrological Sciences Bulletin, 24, 43–69.

DWIDP. (2009). *The preparation of flood risk map of Kathmandu Valley.* Department of Water Induced Disaster Prevention, DWIDP Final Report, Kathmandu.

Estoque, RC. (2012). Analytic Hierarchy Process in Geospatial Analysis. In Y. Murayama (ed.), Progress in Geospatial Analysis, 157-181. DOI 10.1007/978-4-431-54000-7_11.

Falkenmark, M., Lundqvist, J. & Widstrand, C. (1989). Macro-scale water scarcity requires micro-scale approaches: Aspects of vulnerability in semi-arid development. *Natural Resource Forum,* December, 1989. pp. 258-267.

Feitelson, E., & Chenoweth, J. (2002). Water poverty: towards a meaningful indicator. *Water Policy*, 4, 263–281.

GWRDB, (2014). *Study of Hard Rock Aquifers in Hill and Mountainous Area of Central Nepal: Final Report.* Groundwater

Resource Development Board, Nepal.

Gyawali, D., Sharma, B. & Pokharel, G.S. (2019). *Water Scarcity: Nepal country snapshot.* Report prepared for the International Water Association and the Food and Agriculture Organization of the United Nations during August-December 2018. Kathmandu: Nepal Water Conservation Foundation. NWCF Working Paper 1/2019.

JICA, (2018). *The project for assessment of earthquake disaster risk for the Kathmandu valley in Nepal: Final Report Vol III-Map Book.* Japan International Cooperation Agency, JICA, Oriental Consultants Global Co., Ltd. and Oyo International Corporation. Kathmandu, Nepal.

Koirala, S., Fang, Y., Dahal, NM., Zhang, C., Pandey, B., & Shrestha, S. (2020). Application of water Poverty Index (WPI) in Spatial Analysis of Water Stress in Koshi River Basin, Nepal. Sustainability. 12 (2): 727; doi:10.3390/su12020727

KUKL. (2020). *Kathmandu Upatyaka Khanepani Limited (KUKL): Annual Report 2076 Falgun.* Kathmandu, Nepal.

KVWSMB (2015). *Guideline for licensing groundwater abstraction and use (in Nepali).* Kathmandu Valley Water Supply Management Board, Ministry of Urban Development, Government of Nepal, Kathmandu.

Merz, J. (2004). *Water balances, Floods and sediment Transport in the Hindu Kush-Himalayas.* University of Berne, Switzerland and ICIMOD, Kathmandu.

Morgan, R. P. and Davidson, D. A. (1991). Soil erosion and conservation. UK: Longman Group.

Pan, Z. W., Jin, J. L., Li, C. H., Ning, S. W. & Zhou, R. X. (2017). A connection entropy approach to water resources vulnerability analysis in a changing environment. *Entropy* 19, 591. doi:10.3390/e19110591.

Pandey, V.P., Manandhar, S., Kazama, F (2012). Water poverty situation of medium-sized river basins in Nepal. *Water Resources Management* 26 (1):2475-2489.

Renard KG, Foster GR, Weesies GA, McCool DK, Yoder DC (1997). *Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE*). Agriculture Handbook No. 703, USDA-ARS

Shadeed, SM, Judeh1, TG & Almasri. MN. (2019). Developing GIS-based water poverty and rainwater harvesting suitability maps for domestic use in the Dead Sea region. *Hydrol. Earth Syst. Sci.*, 23: 1581–1592, https://doi.org/10.5194/hess-23-1581-2019

Sharpley, AN. & Williams, JR.(1990). *EPIC – Erosion /Productivity Impact Calculator: 1. Model Documentation*. U.S. Department of Agriculture Technical Bulletin, v. 1768, p. 235 pp., 1990.

Shrestha, S. (2021). *Socio-Physical Vulnerability and Resistance in Bagmati Watershed of Kathmandu Valley: Mapping Water Poverty and Groundwater Potential.* Unpublished Faculty Research: Final Report. Submitted to University Grant Commission, UGC, Nepal.

Shrestha, B. K. & Shrestha, S. (2013). Water management in rapidly urbanizing Kathmandu valley: balancing structural linkages among water, society, and settlement. Narain, V., Goodrich, C. G., Chourey, J. & Prakash, A. (eds). *Globalization of Water Governance in South Asia*. Routledge, New Delhi, India.

Sullivan, CA., Meigh, J.R., Giacomello, A.M., Fediw, T., Lawrence, P., Samad, M., Mlote, S., Callan, J.A., Schulze, R.E., Dlamini, D.J.M., Cosgrove, W., Delli Priscoli, J., Gleick, P., Smout, I., Cobbing, J., Calow, R., Hunt, C., Hussain, A., Acreman, M.C., King, J., Malomo, S., Tate, E.L., O'Regan, D., Milner S. & Steyl, I. (2003). The Water Poverty Index: Development and application at a community scale. *Natural Resource Forum.* 27(2003):189-199.

Sullivan, CA. (2002). Calculating a water poverty index. *World Development.* 30(7):1195–1210.

Sullivan, C.A.; Meigh, J.R.; & Fediw, T.S. (2002). *Derivation and testing of the Water Poverty Index Phase 1. Final Report May 2002*. Wallingford, Centre for Ecology and Hydrology, 603pp. (Unpublished).

Tahmineh, L., Mahmoudpour, A., & Sharifi, A.(2021). Assessing impacts of the water poverty index components on the human development index in Iran. *Habitat International*. 113:102375.

Udmale, P., Ishidaira, H., Thapa, BR. & Shakya, NM. (2016). The Status of Domestic Water Demand: Supply Deficit in the Kathmandu Valley, Nepal. *Water* 8 (5). DOI: 10.3390/w8050196.

WHO/UNICEF (2017). *Progress on drinking water, sanitation and hygiene: 2017 update and SDG baseline.* World Health Organization (WHO) and the United Nations Children 's Fund (UNICEF). Geneva, Switzerland.

WHO (1996). *Iron in Drinking-Water: Background Document for Development of WHO Guidelines for Drinking-Water Quality.* Geneva: World Health Organization (WHO).

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

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CALENDAR OF INTERNATIONAL EVENTS

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

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

12^th Workshop on Pattern Recognition in Remote Sensing
Date: 21 August 2022
Country: Canada
Website: http://iapr-tc7.ipb.uni-bonn.de/prrs-2022/

FOSS4G 2022 Academic Track
Date: 22-28 August 2022
Country: Italy
Website: https://2022.foss4g.org/

SUNRISE (Seashore and UNderwater documentation of aRchaeological herItage palimpSests and Environment) SUMMER SCHOOL
Date: 3-9 September 2022
Country: Italy
Website: https://www.sunrisesummerschool.com/

XXVII FIG Congress
Date: 11-15 September 2022
Country: Poland
Website: https://www.fig.net/fig2022/

41^st EARSel Symposium
Date: 13-16 September 2022
Country: Cyprus
Website: https://cyprus2022.earsel.org/index.php

58^th Photogrammetric Week
Date: 13-16 September 2022
Country: Germany
Website: https://phowo.ifp.uni-stuttgart.de/

43^rd Asian Conference on Remote Sensing
Date: 3-7 October 2022
Country: Mongolia
Website: http://www.acrs2022.mn/

The 7^th International Conference on Smart City Applications
Date: 18-20 October 2022
Country: Portugal
Website: http://www.medi-ast.org/SCA22/

InterGEO Conference
Date: 18-20 October 2022
Country: Germany
Website: https://www.intergeo.de/

Smart Data, Smart Cities, 2022
Date: 19-21 October 2022
Country: Australia
Website: https://conference.unsw.edu.au

9th International Symposium on the History of Cartography
Date: 24-26 October 2022
Country: Germany
Website: https://history.icaci.org/berlin-2022/

ISPRS WG IV/7: Geoinformation week 2022
Date: 14-17 November 2022
Country: Malaysia
Website: https://www.geoinfo.utm.my/geoweek/

Pacific Islands GIS and Remote Sensing User Conference
Date: 28 November – 1 December 2022
Country: Suva Fiji
Website: http://www.pgrsc.org/

Geo Week
Date: 13-15 February 2023
Country: USA
Website: https://www.geo-week.com/

20^th International Course on Engineering Surveying
Date: 11-15 April 2023
Country: Switzerland
Website: https://ingenieurvermessungskurs.com/

FIG Working Week 2023
Date: 28 May – 1 June 2023
Country: USA
Website: www.fig.net/fig2023

The 12^th International Conference on Mobile Mapping Technology
Date: 24-26 May 2023
Country: Italy
Website: https://www.cirgeo.unipd.it/mmt/

Detecting Surface Displacement in Kathmandu Valley with Persistent Scatterer Interferometry

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KEYWORDS

Interferometry, PSI, Subsidence, Persistent Scatterer Interferometry

ABSTRACT

Kathmandu Valley has been susceptible to surface displacement due to natural as well as anthropogenic causes since a long time. Previous studies till 2017 suggest that displacement (specially subsidence) with rates of several centimeters per year have occurred in the Kathmandu Valley indicating uncontrolled groundwater withdrawal as the major cause. Owing to the history of surface displacement, this study aims at detecting the nature of land subsidencein Kathmandu for years: 2017 (18th January to 26th December) and 2019 (2nd January to 28th December) based on Persistent Scatterer Interferometry (PSI) technique using Synthetic Aperture Radar (SAR) datasets from Sentinel 1. PSI is able to detect persistently backscattering targets and evaluate respective displacements from the backscattered signal. The results of 2017 and 2019 revealed significant displacement of -100.54mm and -129.19mm along Line Of Sight (LOS) of radar during the study period at Baluwatar and Lazimpat area of Kathmandu district respectively. Similarly, New Baneshwor, Bode and Imadol exhibited a substantial displacement of -88.81mm,-103.55mm, -127.35mm respectively for year 2019.

1. INTRODUCTION

Surface Displacement here generally refers to change in position of the surface of earth or any feature like building, bridges etc. thereon due to natural as well as anthropogenic activities. Apart from uplifts that occurred during earthquake of 25th April 2015, Kathmandu Valley (KV) has been exhibiting significant land subsidence. Land Subsidence (LS) can be defined as the gentle settling or rapid sinking of the discrete segments of the ground surface due to the consolidation of sediments, causing the subsurface movement of earth materials as a result of increasing effective stress (Galloway and Burbey, 2011; Ma et al., 2018) Due to removal of the extractable materials from underneath the surface of earth, the pressure exerted by the material in the pores and cracks of the storage system is reduced. In case of water and petroleum extraction, the fluid pressure on aquifer system and petroleum reservoirs respectively reduce. Because of the granular structure, the skeleton of the fluid-bearing and storing rocks is not rigid and the shift in balance of support for the overlying material causes the skeleton to deform slightly (Galloway et al., 2008).

The previous studies by Bhattarai *et al.*, 2017; Palanisamy Vadivel and Kim, 2018; Palanisamy Vadivel, Kim and Jung, 2018 have already verified the occurrence of LS in Kathmandu Valley (KV) till 2017 A.D. This study is also aimed at detecting surface displacement, especially subsidence of year 2017 and comparing with LS of 2019 in KV.

1.1 Cause of Displacement in KV

Previous studies ((Bhattarai *et al.*, 2017; Palanisamy Vadivel and Kim, 2018; Palanisamy Vadivel, Kim and Jung, 2018) have already shown that the driving factor for LS in Kathmandu valley are its geology and the persisting overexploitation of groundwater.

1.1.1 Geology of KV

The valley constitutes alluvial plains of Bagmati, Bishnumati and Manohara rivers flowing towards south of the valley. The valley is mainly composed of quaternary sediments overlying bedrock and consists of thick (more than 650m deep), semi-consolidated fluvio-lacustrine sediments from Pliocene to Pleistocene age (Piya, Westen and Woldai, 2006).

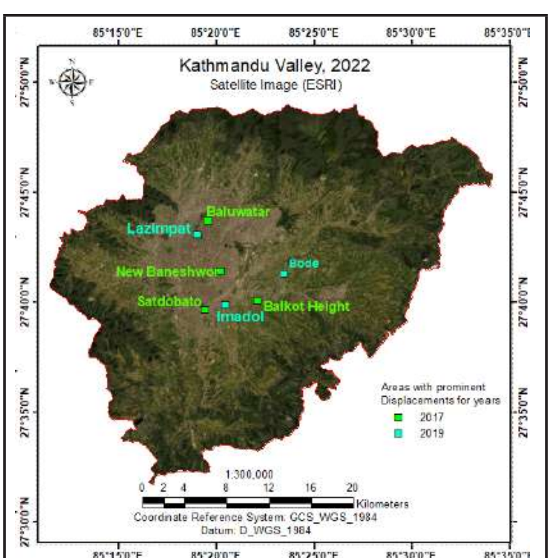

Figure 1: Study Area (Note: Only municipalities of Lalitpur Districts have been selected for study)

1.1.2 Water exploitation in KV

Owing to groundwater exploitation, the valley has been suffering from GW level declination from the very beginning of 1980s when the inception of GW development and extraction occurred with low but noticeable impacts on GW level (Pandey, Shrestha and Kazama, 2012). The water demand in the valley, using Bureau of Indian Standards (BIS) guidelines, was estimated to be 183.9 Million Liters per Day (MLD) in 2001, 224.9 MLD in 2006, 282.5 MLD in 2011, 366 in 2016 and expected to reach about 482 MLD by 2021 (Udmale *et al.*, 2016). Further, ground water extraction rate of 21.56 Million Cubic Meters (MCM)/ year in the decade of year 2000, exceeded the aquifer's recharge rate of 9.6 MCM/year and the groundwater level decreased from 13 m to 33 m and 1.38 m to 7.5 m during 1980-2000 and 2000-2008 respectively (Pandey, Shrestha and Kazama, 2012). The data on recent water usage could not be retrieved for this study so inferences on current water exploitation were made from aforementioned studies.

1.2 Methods for Displacement Monitoring and Measurement

The magnitude of subsidence can be measured with several ground-based: spirit leveling, borehole extensometer, GPS, tripod LIDAR and aerial/space-based techniques: satellite SAR interferometry (InSAR and PSI, airborne LIDAR etc. The space-based geodetic technique like: GPS is able to automatically determine three- dimensional coordinates of ground and track a long-term time series with millimeter-level resolution of horizontal position and sub-centimeter level resolution of vertical position and InSAR technique is able to measure sub-centimeter ground displacements at a high spatial detail (10-100m) over regions spanning over hundreds of kilometers (Galloway *et al.*, 2008). Moreover, the remotely sensed approaches have proven to be a highly efficient and accurate means for monitoring deformation processes from millimeters to centimeters level accuracy with large ground coverage (Zhu *et al.*, 2019).

This study also focuses on use of space-based technique viz. PSI, a multi-temporal InSAR technique, for detecting the subsidence occurred in the years 2017 and 2019.

1.3 ABOUT PSI

A Synthetic Aperture Radar (SAR) dataset consists of phase and amplitude information of the reflected signal. The phase differences of same location in two images can provide range with help of interferometry. When a Digital elevation Model is used to subtract the topographic signal components from an interferometric product i.e. interferogram, it generates differential interferogram and the process is termed as Differential Interferometric SAR (DINSAR) (Ferretti *et al.*, 2007). A PSI technique is such a DINSAR technique applied to multi-temporal images that estimates corrections due to temporal and spatial decorrelations along with other noises to calculate remaining deformation signals (Crosetto *et al.*, 2016). These deformation signals can be subsidence, uplifts or any other horizontal movement of an object that strongly reflects the transmitted signals consistently over a required period, termed as Persistent Scatterer (PS) (Höser, 2018) . Thus, this study applies PSI technique to detect subsidence occurring in the valley.

2. DATA AND METHODOLOGY

2.1 Data

SAR datasets of 2017 (25 images) and 2019 (37 images) were used for PSI. The datasets were taken for descending orbits in VV polarization along with SRTM DEM and GACOS correction.

2.2 Methodology

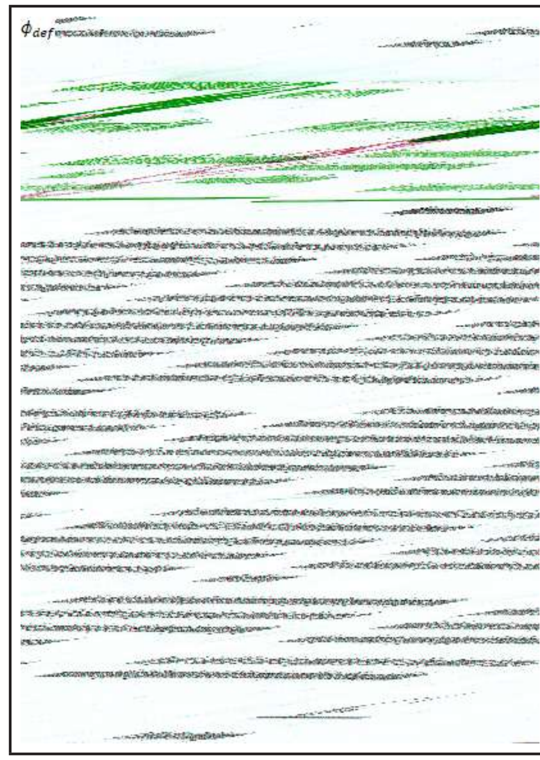

Figure 2:PSI workflow

2.2.1 Jobs in Sentinel Application (SNAP)

First of all precise orbits were applied to the SAR datasets and the required portion of the SAR scenes were extracted from each original swath. Then master image was identified for preparing stacks of the relevant master-slave images and co-registration of slave images with master images was done. The output was then processed to generate interferograms as an input for PSI implemented in StaMPS/MTI package developed by Hooper *et al.*, 2018 .

2.2.2 Jobs in Stanford Methods for PSI/ Muti-temporal InSAR(Stamps/MTI)

PSI technique estimated noise in interferograms and eliminated noisy pixels from each interferogram in the stack. The remaining phase signals in the interferogram contained several components (Equation 1) (Hooper, Segall and Zebker, 2007). These components were estimated and eliminated from the original phase to acquire deformation phase (ϕ_{def}). Then phase unwrapping of each interferogram was performed to calculate actual deformation signals in each pixel. The phase signals (in radians) were then converted to linear units (mm) with equation 2 (Hooper *et al.*, 2004). The velocitiy of each pixel or Persistent Scatterer (PS) were then estimated from these phase signals and atmospheric correction was done. Finally, the output of PSI were collected in csv format with latitude, longitude and history of deformation signals of the PSs. The CSV file was then imported in arcmap and excel for mapping and plotting cumulative displacements, mean velocities and time-series of deformations.

All the deformations were calculated in reference to Kakani CORS station i.e. KKN4 as this station was found to be much stable based on the GNSS datasets at KKN4 (~0.0006m along LOS in 2017).

$\phi_p = \phi_{flat} + \phi_{topo} + \phi_{orb} + \phi_{atm} + \phi_{def} + \phi_{(n}$	(1)
$\phi_{def} = \frac{4\pi}{\lambda} d$	(2)

Where: ϕ_{flat}= phase due to the reference ellipsoid, ϕ_{topo}= phase due to topography of the surface, ϕ_{orb}=phase due to inaccuracy in orbital information. ϕ_{atm}=phase due to atmospheric delay, ϕ_{def}= Phase due to deformation between the acquisitions, ϕ_n = phase due to other noise sources like: temporal changes of scatterers, defocusing, miscoregistration etc. and d=displacement in linear units.

3. RESULTS AND DISCUSSION

Table 1: Cumulative displacements (in mm) and mean velocities (mm/year) for year **2017**

Location	Cumulative displacement	Mean Velocity
Baluwatar	-100.54	-121.80
New Baneshwor	-49.74	-68.51
Satdobato	-67.51	-87.44
Balkot Height	-74.49	-98.57

Table 2:Cumulative displacements (in mm) and mean velocities (mm/year) for year **2019**

Location	Cumulative subsidence	Mean Velocity
Lazimpat	-129.19	-136.34
New Baneshwor	-88.81	-92.59
Imadol	-127.35	-125.62
Bode	-103.55	-101.09

The study area showed variations in the nature of subsidence in KV. Among them, the area with prominent subsidence are depicted in Map 1The Baluwatar and New Baneshwor areas are situated in Kathmandu Metropolitan City (KMC) of Kathmandu district, Imadol and Satdobato areas fall under Mahalaxmisthan municiplality and Lalitpur municipality of Lalitpur district respectively. Similarly, Bode and Balkot Heights are located in Madhyapur Thimi and Suryabinayak municipalities respectively in Bhaktapur district. Table 1 and Table 2 illustrate the prominent displacement values for several locations for years 2017 and 2019. All these displacements were calculated along LOS of radar signal. The maximum subsidence of -100.54mm for 2017 occurred at Baluwatar with mean velocity of -121.8mm/year. Similarly, Lazimpat area seem to exhibit highest displacement of -129.19mm for year 2019 with mean velocity of -136.34mm/year. These areas lie within a same neighborhood and seem to share a similar geology and population. The velocities and subsidence are seemed to have increased significantly from year 2017 to 2019 and almost doubled for some areas. The time series of subsidence have been illustrated in Figure 3. The time series clearly shows the movement away from satellite along LOS direction. The movement can be the consequence of subsidence as well as tectonic movement. The tectonic movement indicates the movement of Indian plate in northeast direction towards Eurasian plate at a rate of 47mm/year(Benedick *et al.*, 2002).The movement away from satellite thus can have

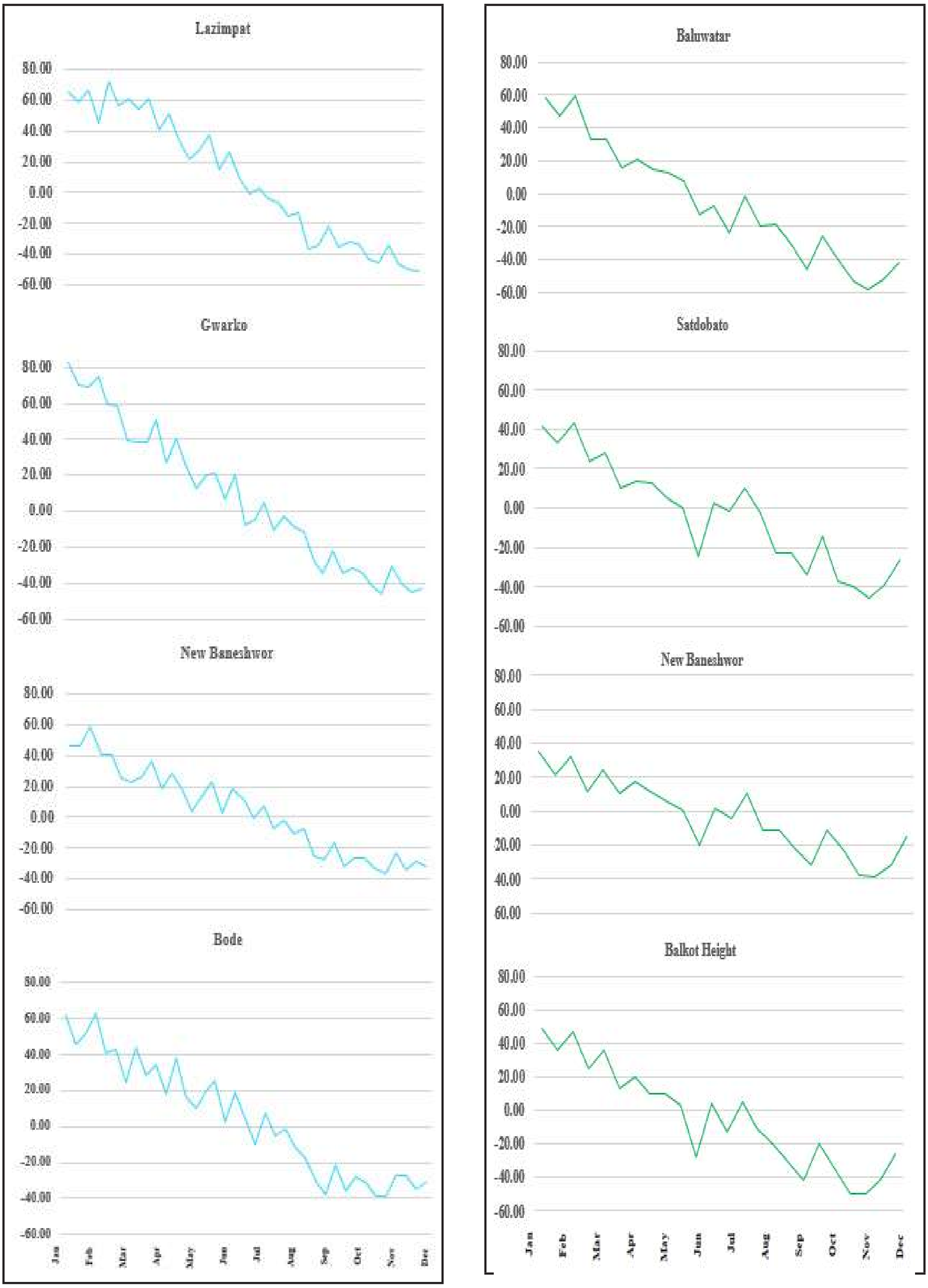

Figure 3: Time-series of subsience along LOS for prominent areas for year 2017 (left green) and 2019 (right cyan)

contribution of both subsidence as well as horizontal movement. The displacement could not be decomposed into its component due to lack of adequate SAR datasets in ascending orbit. However, based on subsiding nature suggested by previous studies and known tectonic movement rate, it can be inferred that the movement away from satellite also suggests a significant amount of subsidence.

Based on fact from the previous studies related to ground water exploitation in KV, it can be suggested that the increased demand of groundwater might be a crucial factor for cause of displacement. Owing to lack of adequate information on ground water usage in the study area, a concrete justification could not be provided for cause of LS, rather only logical inferences could be presented.

4. CONCLUSION AND RECOMMENDATION

The surface displacement occurring in KV was detected using PSI technique for years 2017 and 2019. The results show significant displacement away from the satellite along LOS direction in areas around Lazimpat, Baluwatar, New Baneshwor, Satdobato, Imadol, Bode and Balkot heights. The major cause of displacement can be suggested as the overexploitation of groundwater, supported by tectonic movement occurring towards northeast. Further improvements can be done to this study by incorporating data on both orbits, water exploitation in the valley, peizometric levels of monitoring wells etc.

REFERENCES

Benedick, R. *et al.* (2002) *NOAA Science Review, 2002*, *Cooperative Institute for Research in Environmental Sciences*. Available at: http://cires1.colorado.edu/science/reviews/noaa/2002/abstracts/18bendick. html (Accessed: 23 February 2021).

Bhattarai, R. *et al.* (2017) 'Detection of Land Subsidence in Kathmandu Valley, Nepal, Using DInSAR Technique', *Land*, 6(2), p. 39. doi: 10.3390/land6020039.

Crosetto, M. *et al.* (2016) 'Persistent Scatterer Interferometry: A review', *ISPRS Journal of Photogrammetry and Remote Sensing*, 115, pp. 78–89. Available at: https://linkinghub.elsevier.com/retrieve/pii/S0924271615002415 (Accessed: 26 February 2021).

Ferretti, A. *et al.* (2007) *InSAR Principles: Guidelines for SAR Interferometry Processing and Interpretation*. Edited by K. Fletcher. ESA Publications. Available at: https://www.esa.int/About_Us/ESA_Publications/InSAR_Principles_Guidelines_for_SAR_Interferometry_Processing_and_Interpretation_br_ESA_TM-19 (Accessed: 15 March 2021).

Galloway, D. *et al.* (2008) 'Land subsidence hazards', *Landslide and land subsidence hazards to pipelines. US Geol Surv Open-File Rep*, 1164. Available at: https://www.researchgate.net/publication/260002901_Land_subsidence_hazards (Accessed: 4 May 2021).

Hooper, A. *et al.* (2004) 'A new method for measuring deformation on volcanoes and other natural terrains using InSAR persistent scatterers', *Geophysical Research Letters*, 31(23), pp. 1–5. Available at: http://doi.wiley.com/10.1029/2004GL021737 (Accessed: 11 May 2021).

Hooper, A. *et al.* (2018) 'StaMPS/MTI'. Available at: https://homepages.see.leeds.ac.uk/~earahoo/stamps/ (Accessed: 3 September 2021).

Hooper, A., Segall, P. and Zebker, H. (2007) 'Persistent scatterer interferometric synthetic aperture radar for crustal deformation analysis, with application to Volcán Alcedo, Galápagos', *Journal* *of Geophysical Research*, 112(B7), p. B07407. Available at: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2006JB004763 (Accessed: 15 March 2021).

Höser, T. (2018) *Analysing the Capabilities and Limitations of {InSAR} using {Sentinel-1} Data for Landslide Detection and Monitoring*. Department of Geography, Bonn University. doi: 10.13140/RG.2.2.35085.59362.

Palanisamy Vadivel, S. K. and Kim, D. (2018) 'Subsidence Due to Groundwater Withdrawal in Kathmandu Basin Detected by Time-series PS-InSAR Analysis'. Available at: https://www.koreascience.or.kr/article/JAKO201827750146694.page (Accessed: 26 February 2021).

Palanisamy Vadivel, S. K., Kim, D. and Jung, J. (2018) 'Subsidence in the Kathmandu Basin, before and after the 2015 Mw 7.8 Gorkha Earthquake, Nepal Revealed from Small Baseline Subset-DInSAR Analysis', *GIScience & Remote Sensing*, 55(4), pp. 604–621. Available at: https://www.tandfonline.com/doi/full/10.1080/15481603.2017.1422312 (Accessed: 26 February 2021).

Pandey, V., Shrestha, S. and Kazama, F. (2012) 'Groundwater in the Kathmandu Valley: Development dynamics, consequences and prospects for sustainable management', *Europ. Water*, 37, pp. 3–14. Available at: https://www.researchgate.net/publication/292026833_Groundwater_in_the_Kathmandu_Valley_Development_dynamics_consequences_and_prospects_for_sustainable_management (Accessed: 26 February 2021).

Udmale, P. *et al.* (2016) 'The Status of Domestic Water Demand: Supply Deficit in the Kathmandu Valley, Nepal', *Water*, 8(5), p. 196. Available at: http://www.mdpi.com/2073-4441/8/5/196 (Accessed: 7 May 2021).

Zhu, B. *et al.* (2019) 'Land subsidence (2004--2013) in Changzhou in Central Yangtze River delta revealed by MT-InSAR', *Natural Hazards*, 97(1), pp. 379–394. Available at: https://link.springer.com/article/10.1007/s11069-019-03650-z (Accessed: 4 May 2021).

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Price of Maps

S.No.	Description	Scale	Coverage	No. of sheets	Price per sheet (NRs)
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11.	Nepal Map (Nepali)	1:1000 000	Nepal	1	50
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14.	Nepal Map (English)	1:2000 000	Nepal	1	15
15.	Physiographic Map	1:2000 000	Nepal	1	15
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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
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Landslide Susceptibility Mapping Using Machine Learning Approach: A Case Study of Baglung District, Nepal

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KEYWORDS

Landslide Susceptibility, Random Forest, Frequency Ratio, Classification and Regression Tree, Area Under Curve

ABSTRACT

Assessment of Landslide Susceptibility Map (LSM) is crucial to the reduction of risk of the landslides. This paper focusses on modelling LSM using two different machine learning algorithms namely Random Forest (RF), and Classification and Regression Tree (CART). Ten landslide causative factors along with an inventory of landslides containing 89 recent and historic landslide points, and 90 randomly generated non-landslide points were used to prepare a susceptibility map. The study area; Baglung district is located in the Gandaki province of Nepal, a highly landslide susceptible zone. Frequency ratio (FR) of each class of conditioning factors were calculated. FR values of landslide and non-landslide points were extracted from normalized FR classified raster. The extracted FR values of each point (landslide and non-landslide) was randomly split into training (70%) and testing (30%) samples which were used for training and testing the model. The performance of each algorithm was evaluated using receiver operating characteristics (ROC) curves in combination with area under the curve (AUC) and error matrix. The AUC results introduced success rate of 1 and 0.88 for RF and CART respectively. Also, the rates of prediction were 0.86 and 0.96 for RF and CART respectively. Similarly, RF and CART showed accuracy of 0.88 and 0.83 from confusion matrix. Therefore, the RF algorithm was superior to CART in identifying the regions at risk for future landslides in the study area. The outcomes of this study is useful and essential for the government, planners, researchers, decision makers and general land-use planners.

1. INTRODUCTION

The movement of rocks, soil, earth or debris of the sloped area due to the unstable slope of the land is known as landslide. Landslides can cause, or occur due to various factors i.e., earthquakes, rainfall, soil type, climate change, geological, hydrological, geomorphological conditions, and other geographic. Landslide is caused by variety of natural process that triggers the movement of earth materials from slow to rapid downslope (Health, 2020). Every country in the world is facing landslide as a major natural disaster. The top five countries with the highest risk of landslides are Italy, Austria, China, The Philippines, and Ethiopia with more than 7500, 6000, 5600, 4800,4800 square miles respectively (Watch, 2021).

Likewise, dozens of natural hazards and human induced disasters have been exposed in Nepal. Every year thousands of people have lost their lives and millions of properties have been damaged due to landslides occurring around the Nepal (Portal, 2021). Thus, major incidents for death are flood, landslide, thunderbolt, fire, cold wave, high altitude and heavy rainfall (Affairs, 2019). Nepal Disaster Risk Reduction Portal data 2021 shows, 2386 landslides incidents has occurred in Nepal in a decade time period (2010-2020) thus leading to third highest natural disaster incidents in the country (Portal, 2021). Landslides is one of the very common natural hazards in the hilly region of Nepal. In Nepal, where two third of the total area falls in hilly and mountainous region, landslides represent a major constraint on development, causing high levels of economic loss and substantial numbers of fatalities. Each year rugged and stepped topography, unstable geological structures, soft and fragile rocks, along with concentrated and prolonged heavy rainfalls during monsoon periods collectively cause severe land sliding and related phenomena in the mountainous part of Nepal (Acharya, 2018). To overcome these problems, landslide susceptibility model can play a crucial role in determining the most vulnerable landslide areas (Mersha & Meten, 2020). Susceptibility models are very useful to represent the likelihood of a landslide occurring in any specific location in terms of relative probability (Pradhan, 2010). Landslide inventories containing data on the factors that causes landslide, can be used to model landslide susceptibility which can be used to predict future landslide occurrences and their characteristics.

There are many approaches for predicting landslide prone areas. Some of them include frequency ratio, Shannon entropy, analytical hierarchal approach etc. However, machine learning approaches are effectual and more accurate approaches to develop landslide susceptibility model (Pham & Prakash, 2018).

Machine learning (ML) is a method of data analysis that automates and gives computers the capability to learn without being explicitly programmed (Li, 2021). It has been used in many applications such as urban growth monitoring (Shrestha S. , 2019), image classification (David N., 2021) , agriculture land classification and yield estimation (Fernandez-Beltran, 2021), building extraction (Shrestha S. V., 2018) etc. The main advantages of using ML methods in landslide mapping is for its analysis for the contributing factors for landslide development and their potential for continuous updating (Youssef & Pourghasemi, 2021). Two machine learning algorithms were used for this research namely CART and RF.

CART is a machine learning with classification and prediction tree model. The model would be appropriate to use for decision tree making with the classification and prediction model. Further explanation, the CART term is used to describe decision tree algorithms that are used for classification and regression learning tasks (Ninja, 2021). Thus, to explain the CART we have to understand the classification and regression decision tree individually; (i) Classification tree: Basically, classification decision tree is used to classify the datasets into multiple groups. Alternatively, the process of splitting the datasets into classes according to its response variable (homogeneity). i.e.; training and test dataset. (ii) Regression tree: It process of predicting the problems with response to the continuous variable (Prakash, 2018) . Its main task is to split the datasets for each independent variable by fitting the target variable by using the independent variables.

RF classification, which was originally developed by Breiman, is a machine learning algorithm for nonparametric multivariate classification (Catani, 2013). RF is a popular machine learning method that is widely used for classification and regression. Generally, a single decision tree individually exhibits weak prediction performance because of a high variance or bias (Taalab, 2018). RF creates numerous decision trees for classification which can also be perceived as a group of random decision trees. Therefore, RF is a combination of individually created decision trees to form a decision forest. Each tree in the forest has independent and identical distribution and thus, they are relatively uncorrelated with each other. The property that makes the RF, far from the overtaking risk. The results obtained from all decision trees are combined to obtain the result of the RF.

Nepal being prone to landslides during monsoon, he Nepal Disaster Risk Reduction Portal, 2021 shows that, Baglung district has recorded the highest number of landslides incidents in the past decade (Portal, 2021). So in this context, the paper tries to compare different machine learning algorithm for the preparation of land susceptibility map.

1.1 Objectives

The primary objective of this study area is to prepare landslide susceptibility map using ML algorithms and compare the accuracy results how it would vary accordingly.

The secondary objectives of this study are as follows:

- To prepare a landslide inventory map of Baglung district.
- To determine which landslide conditioning factor plays major and minor role in the occurrence of landslides within the study area.

1.2 Rationale of the Work

There have been many studies of landslide susceptibility mapping based on analytical and statistical methods but there are less studies in which machine learning algorithms are used. This study combines statistical method with machine learning algorithms to analyze its effectiveness for landslide susceptibility mapping and comparing the accuracy of both RF and CART models would also allow us to know the performance of each model.

This research can be very effective as landslide susceptibility map could help to minimize property loss, human lives and management of landslides. This study also helps in knowing what are the major and minor factors causing landslide within the study area.

2. STUDY AREA

Baglung district lies in the Gandaki province of western Nepal covering 1837 sq. km. Geologically, it lies on the Himalayan range of Nepal. The Nepal Disaster Risk Reduction Portal, 2021 shows that, Baglung district has recorded the highest number of landslides incidents in the past decade (Portal, 2021). Figure 1 represents the study area at a scale of 1:400000

Figure 1: Study Area

3. MATERIALS AND METHODS

The research examines probable areas within the study area using landslide inventory and landslide conditioning factors. To obtain the LSM, the methodology (Figure 2) followed these major processing steps: data collection, reclassification of landslide factors, and calculation of relative frequency ratio of each factor variable, model development, model verification and preparation of the LSM.

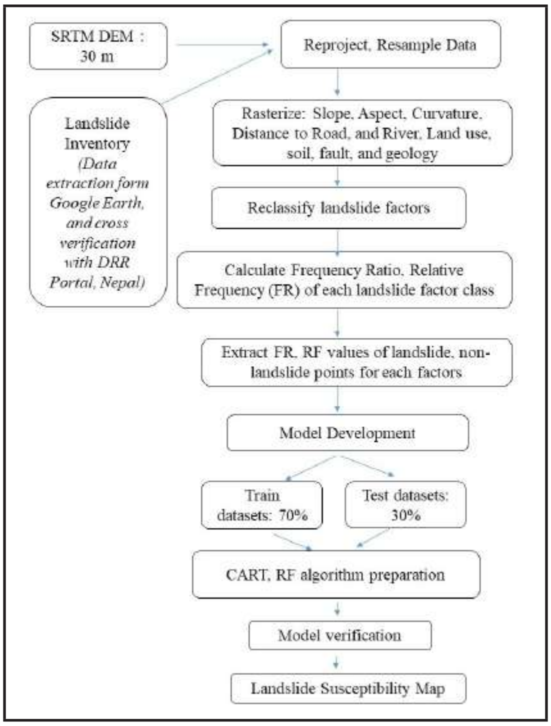

Figure 2: Methodology for the Preparation of Landslide Susceptibility Map.

3.1 Data and Software

Table 1 and Table 2 present the landslide causing factors considered and the software used for our research respectively.

Table 1: Landslide conditioning factor used in the study

S. N	Landslide Factors	Data Source
1	Distance to River	ICIMOD Portal
2	Distance to Road	ICIMOD Portal
3	Distance to Fault	ICIMOD Portal
4	Land use	ICIMOD portal
5	Geology	ICIMOD portal
6	Soil	ICIMOD portal
7	DEM (slope, curvature, elevation, aspect)	USGS (Earth Explorer)

Table 2: Software Used

S.N	Software	Usage
1	Google Earth	Sample Collection
2	R Studio	Analysis and modelling
3	GIS software	Visualization

Landslide Inventory: A total of 89 landslide points and 90 randomly generated non-landslide points were taken to create a landslide inventory, for the purpose of preparing binary class for landslide susceptibility mapping. For the training the classifier/algorithm, the generated points were furthered classified into training (70%) and testing (30%) data for our study.

3.2 Landslide Causative Factors

There are no fixed guidelines for selecting the parameters that influence landslides in susceptibility mapping (Carrara & Cardinali, 1991). The causative factors were selected based on previous landslide studies (Pradhan & Lee, 2010), (Youssef & Pourghasemi, 2021), (Catani, 2013), (Wang, Fang, & Hong, 2019), (Yilmaz, 2009), (Mersha & Meten, 2020), (Hawas, 2019), the scale of analysis, data availability and fieldwork in Baglung district. The most significant landslide-related data namely slope, elevation, aspect, curvature, geology, soil, land use, distance to river, distance to road, distance to fault were selected for this study area.

3.2.1 Preparation of Landslide Causative Factors.

The slope angle, aspect, curvature derived from 30 m DEM were extracted using package raster in R studio. Similarly, rivers, road, fault, geology, soil and land use data were obtained from the Database of ICIMOD. The layers of distance to streams, fault line, road was calculated by buffering R studio. Since remaining factors geology, soil, land use were continuous data so the data were kept raw. All data were converted to raster format with the same pixel resolution as DEM and each raster map was divided into several classes.

The following are the landslide causative factor used in this study:

a. **Slope**

The slope map does play crucial role to

develop landslide susceptibility because it is directly related to slope angle. The steeper the slope, the greater the landslide probability (Lee & Min, 2001). In this study, Slope Map was classified into 6 classes and number of landslide pixel in each pixel was calculated where highest number of landslides point with 43 in the class of slope angle 40-55 degree.

b. Aspect

Aspect is another important factor in the preparation of LSM. It is also connected with various factors like exposure to sunlight, drying winds, rainfall, and discontinuities that may affect the occurrence of landslides (Carrara & Cardinali, 1991). Aspect map was classified into eight classes where southern part was given the highest number of landslides point 30.

c. Curvature

Curvature is another commonly used parameter in landslide hazard analysis. Curvature can be subdivided into regions of concave outward plan curvature called hollows, convex outward plan curvature called noses, and straight contours called planar regions. Also, hollows have a slightly higher probability for landslides than noses (Gregory & Ohlmacher, 2006). Curvature map was classified into 3 classes namely concave, flat and convex where concave had the highest number of landslides with 52.

d. Elevation

Elevation map helps to determine the minimum and maximum heights of landslide occurrence within the ROI. Elevation map ranged between 580m to 4682m and was classified into 8 classes where maximum number of landslides 35 was assigned for class 1600-2100m.

e. Land use/Land cover

It is important to know which area of land cover has higher number of landslide and low or no landslide (Sivakami, 2014). Land use map with 8 classes was prepared where agriculture area had the highest number of landslide frequency with 44 followed by forest area with 22.

f. Geology

Geology plays an important role in landslide susceptibility studies because geological units have different susceptibilities to active geomorphological processes of the area (Pradhan, 2010). The study area was covered by 10 geological formations with highest number of landslide points 22 within lakharpata formation.

g. Soil

Land cover with different soil characteristics has diverse effects in the occurrence of landslides. It does not only affect the development degree of landslides in the areas, but also determines the type and scale of landslide (XIanyu Yu, 2021). The soil of study area was classified into 4 types in which 46 landslide point were within soil type of Dystrochrepts, Halpumbrepts, Haplustalfs-calcarious soil Materials.

h. Distance to River

The distance to river map showed the buffer zones with seven different classes. It does not affect in the occurrence of landslides directly. Despite that, the proximity of the slope to the drainage structures is important factor in terms of stability because it may affect stability of slopes or by saturating the lower part of material until the water level increase (Sivakami, 2014). More than 60 landslides occurred in buffer distance of 400 m.

i. Distance to Road

Landslides are very common along road cuts. This is mainly due to the damage in the natural condition of the slope during road construction. Also, the road cut exposes the joints and fractures that make the slope unstable. Road cuts are usually sites of anthropological instability (Pradhan, 2010). The distance to road map was prepared with 7 classes where

58 landslide points occurred in buffer zone of more than 450 m from highways.

j. Distance to Fault

The study area contained only one fault line where almost all landslides point were found on buffer zone of more than 450 m from the fault line.

3.3 Determination of Frequency Ratio

Frequency ratio is a quantitative technique for landslide susceptibility assessment using spatial data (Lee & Min, 2001). It is frequently and effectively used for landslide susceptibility mapping. As it is quantitative method so it quantifies between the landslide inventory and causative factors. (Hawas, 2019). The frequency ratio was calculated for each class of causative factors type or range were calculated from their relationship with landslide occurrence. Likewise, the ratio was calculated for sub criteria of parameter. The Frequency Ratio of each class were calculated with the following formula.

$$FR = (Mi/M)/(Ni/N), \quad (1)$$

where,

Mi= The number of pixels with landslides for each subclass conditioning factor,

M= The total number of landslides in the study area,

Ni= The number of pixels in the subclass area of each factor,

N= The number of total pixels in the study area.

Relative Frequency: FR of class / sum total of all FR value in that factor.

The relative frequency is calculated to normalize FR value within 0 to 1.

Relative frequency of each factor class was calculated. The classified raster was again reclassified with RF values. The rf value of each landslide and non-landslide point for each landslide conditioning factor was extracted later which was used as training and testing data set for model preparation using machine learning algorithms.

3.4 Model Development

The following ML algorithms were used to develop landslide susceptibility model which were further used to prepare landslide susceptibility map.

3.4.1 Classification and Regression Tree (CART)

The pre-processed and modelled data were carried out for the final stage of the landslide susceptibility. CART decision tree was used to classify and run the regression among the data.

Thus, in the classification, the data was split into training and test datasets within 70% -30% ratio respectively. The assigned percentage of the datasets were used to fit in model. Now, making a decision tree using R where, landslide/non-landslide point was used as dependent variable in the training datasets, and other variable as independent variables. Then, class method was used to classify the datasets. CART Package available in R was used to use CART algorithm to prepare a susceptibility model from the training dataset. Thus, the importance value of each factor variable from model was taken and multiplied with respective factor variable raster to create landslide susceptibility map. Not only that prediction of outcome on the test dataset, was done and predicted those classes into either 0 or 1, 0 as non-landslide and 1 as landslide.

3.4.2 Random Forest

Similar to CART random forest algorithm was also used to prepare a model from training dataset. The package in R was used to use random forest algorithm to prepare a landslide susceptibility model from the training dataset available. Thus, the importance value of each factor variable from model was taken and multiplied with respective factor variable raster to create landslide susceptibility map.

Also, the model was used on test data set to check the accuracy of the model.

3.5 Accuracy Assessment

Accuracy assessment of model from CART and random forest algorithm was performed using test data set. Two accuracy assessment methods namely confusion matrix and Area Under Curve (AUC) was used to check the accuracy of the both models.

To check the performance of the model Receiver Operator Characteristics (ROC) curve was used as accuracy assessment method. Area Under Curve AUC is calculated for multiple logistic regression models because it allows us to see which model is best at making predictions. The interpretation of the ROC curves moves to the top left corner of the plot, thus in this category it does better accuracy or it does better classification of the data. Likewise, the AUC is calculated to quantify and tells us how much of the plot is located under the curve. Thus, we can say, closer of AUC to 1, the better the model. Moving toward the graph representation, the ROC curve places the True Positive Rate (Sensitivity) in the Y-axis, and on the X-axis, it will be the False Positive Rate (1- specificity). The prediction and success rate curve were also developed from the test and train datasets respectively.

Confusion matrix is another way to evaluate the performance of the model. Confusion matrix from the test data set was obtained and overall accuracy was derived. Overall accuracy is the probability that an individual will be correctly classified by a test, i.e., the sum of the true positives plus true negatives divided by the total number of individual tested.

4. RESULT AND DISCUSSION

The final landslide susceptibility map was prepared by multiplying landslide causative factor with the importance value of each factor given by both the model. The final map is classified into four groups (i.e., Low, Medium, High, Very High) to see the susceptibility level from both the model.

The final Landslide susceptibility map by using random forest algorithm was generated using equation 2 where each factor is multiplied by its respective weight. The weight of each factor is calculated by running training dataset on random forest algorithm.

$$Model = river*0.22364691 + road*0.41075731 + fault*0.08207446 + geology*0.38538238 + soil*0.41437370 + elevation*0.55454643 + landuse*0.84776509 + slope*1.42814362 + aspect*1.40435311 + curvature*0.30321441 \quad (2)$$

The final map from Random Forest method is shown in figure 3 as below:

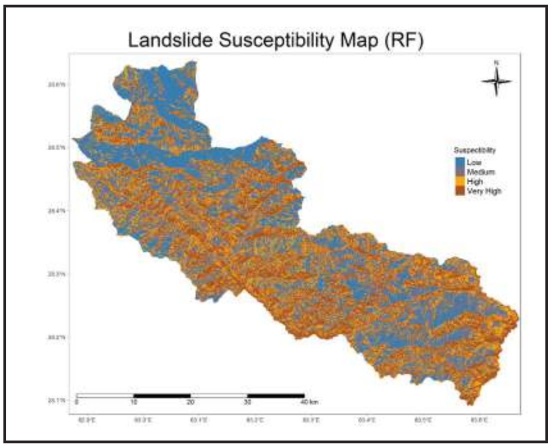

Figure 3: Landslide Susceptibility Map using Random Forest Model

The final Landslide susceptibility map by using CART algorithm was generated using equation 3 similar to method RF as mentioned earlier.

$$Model = river*0.3157572 + road*0.7556933 + fault*0.1294887 + geology*0.0381617 + soil*0.4016218 + elevation*0.1241790 + landuse*0.3923891 + slope*1.6985024 + aspect*1.2517241 + curvature*0.1908085 \quad (3)$$

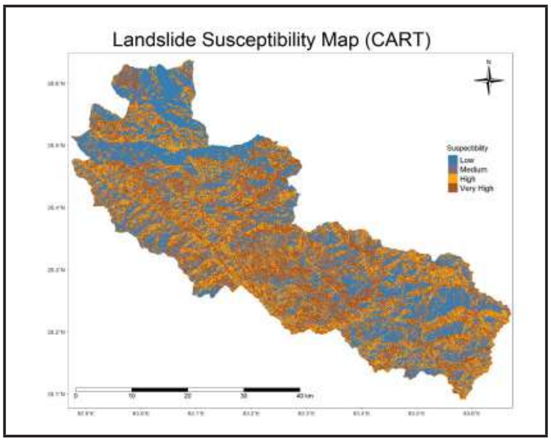

Figure 4: Landslide Susceptibility Map using CART Algorithm

The landslide susceptibility map from CART shows that almost 24.44 % and 17.83% of the total Baglung is susceptible to high and very high-risk zones. Similarly, the landslide susceptibility map from RF shows that almost 30.41% and 17.64% of the total area is susceptible to high and very high-risk zones. From both the model it can be seen that more that 40% of the total area is susceptible to landslide risk.

In RF model using test dataset to check the accuracy of the model the confusion matrix showed an overall accuracy of 88%. Similarly, two ROC curves namely prediction rate curve (figure 5) using test dataset and success rate curve (figure 6) using training dataset was generated and AUC was calculated which showed an AUC of 0.96 and 1 on PRC and SRC respectively.

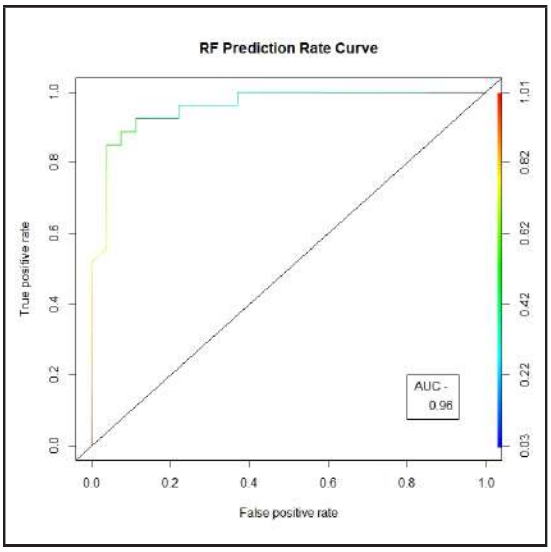

Figure 5: Prediction Rate Curve (RF)

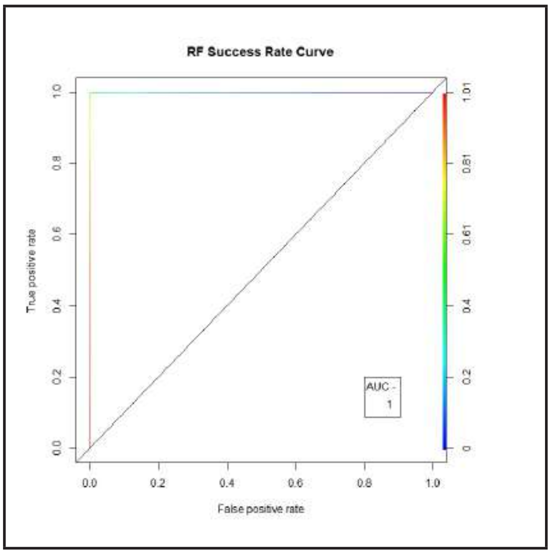

Figure 6: Success Rate Curve (RF)

In CART model using test dataset to check the accuracy of the model the confusion matrix showed an overall accuracy of 83%. Similarly, two ROC curves namely prediction rate curve (figure 7) using test dataset and success rate curve (figure 8) using training dataset was generated and AUC was calculated which showed an AUC of 0.86 and 0.87 on PRC and SRC respectively.

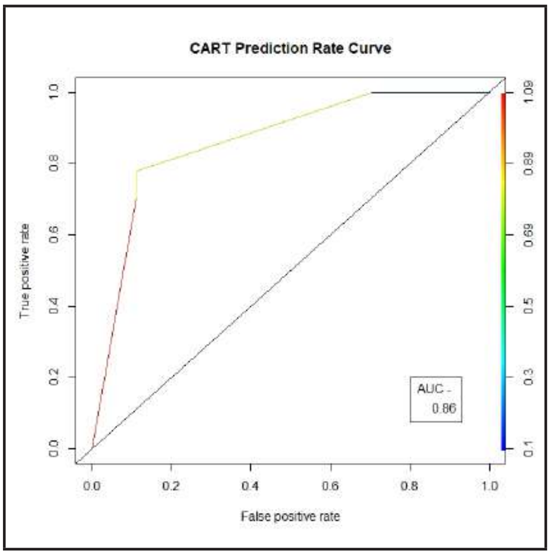

Figure 7: Prediction Rate Curve (CART)

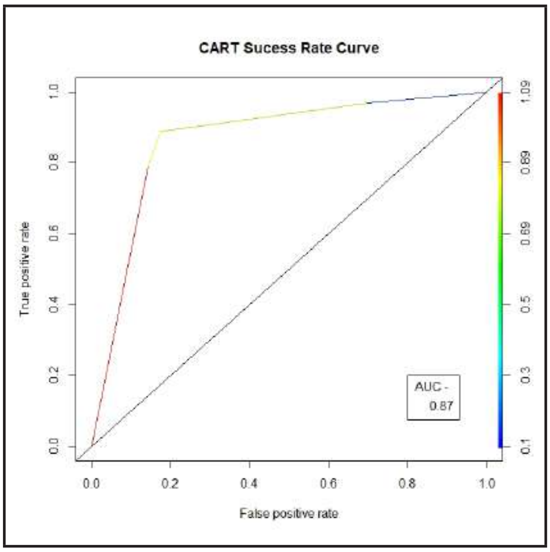

Figure 8: Success Rate Curve (CART)

The accuracy assessment obtained from test data set (30%) using AUC method shows Random Forest model in comparison to CART algorithm performs better as the accuracy assessment shows 88 % and 96% accuracy from CART and RF respectively. The main reason behind the more accuracy from random forest model can be that its randomized feature selection method. Unlike CART algorithm which depends specially on a feature and then creates child trees, the RF algorithm randomly selects a feature which makes this method more accurate than the other.

5. CONCLUSION

This paper focuses on predicting landslide susceptible zones with in Baglung district using two algorithms RF, CART and assess the accuracy of both models.

The accuracy obtained from RF algorithm is better than the accuracy obtained from CART algorithm. For a better landslide susceptibility results high accurate data is preferred. Since more than 40% of the total area is susceptible to landslide risk it can be concluded that Baglung district is one of the most risk prone area for landslide. Also, machine learning algorithms can be effective methods for landslide susceptibility analysis with RF being more accurate than the CART.

REFERENCES

Acharya, T. D. (2018). Regional Scale Landslide Hazard Assessment using Machine Learning Methods in Nepal.

GoN (2019). Nepal Disater Report. Kathmandu, Nepal: Ministry of Home Affairs, Government of Nepal.

Carrara, A., & Cardinali, M. D. (1991). *GIS Techniques and Statistical Models in Evaluating Landslide Hazard.* Earth Surface Processes and Landforms.

Catani, F. L. (2013). Landslide Susceptibility Estimation by Random Forests. *Natural Hazards Earth System*, 2815–2831.

Nhemaphuki, D., Chhetry, K. T. & Shrestha, S. (2021). Fusion of Radar and Optical Data for Land Cover Classification Using Machine Learning Approach. *Journal of Geoinformatics, Nepal*, 39-45.

Fernandez-Beltran, R. B. (2021). Rice-yield Prediction with Multi-temporal Sentinel-2 Data and 3D CNN: A case Study in Nepal. *Remote Sensing*, 1391.

Gregory, C., & Ohlmacher. (2006). *Plan Curvature and Landslide Probability in Regions Dominated by Earth Flows and*

Earth Slides. USA: Elsevier.

Hawas, K. M. (2019). *Landslide Susceptibility Assessment Using Frequency Ratio, a Case Study of Northern Pakistan.* Pakistan: ScienceDirect.

Health, E. R. (2020). Landslide Susceptibility Mapping Using Machine Learning.

Lee, S., & Min, K. (2001). *Statistical Analysis of Landslide Susceptibility at Yongin.* Korea.

Li, H. (2021). *Machine Learning: What it is and Why it Matters.* Retrieved from https://www.sas.com/en_us/insights/analytics/machine-learning.html

Mersha, T., & Meten, M. (2020). GIS-based Landslide Susceptibility Mapping and Assessment Using Bivariate Statistical Methods in Simada area, Northwestern Ethiopia. *Geoenvironmental Disasters 7*, 20.

Ninja. (2021). *Classification & Regression Trees*. Retrieved from https://www.codingninjas.com/blog/2020/12/02/what-is-classification-regression-trees/

Pham, B., & Prakash, I. (2018). Spatial Prediction of Landslides Using a Hybrid Machine Learning Approach Based on Random Subspace and Classification and Regression Trees. *Geomorphology*, 303.

Portal, N. D. (2021). *Reported Number of Incidents.* Kathamandu, Nepal: Nepal Diaster Risk Reduction Portal.

Pradhan, B. (2010). Landslide Susceptibility Mapping of a Catchment Area Using Frequency Ratio, Fuzzy Logic and Multivariate Logistic Regression Approaches. *Journal of the Indian Society of Remote Sensing*, 301-320.

Pradhan, B., & Lee, S. (2010). Landslide Susceptibility Assessment and Factor Effect Analysis: Back Propagation Artificial. *Environ. Model. Softw.*, 747-759.

Pradhan, B., & Lee, S. (2010). Landslide Susceptibility Assessment and Factor Effect Analysis: Backpropagation Artificial Neural Networks and Their Comparision With Frequency Ratio and Bivariate Logistic Regression Modelling. *Environmental Modelling Software*, 747-759.

Prakash, I. (2018). Machine Learning Methods of Kernel Logistic Regression and Classification and Regression Trees for Landslide Susceptibility Assessment at Part of Himalayan Area, India. *Indian Journal of Science and Technology*, 1-10.

Shrestha, S. (2019). Spatio-Temporal Analysis and Modeling of Urban Growth of Biratnagar City, Nepal. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 97-102.

Shrestha, S. V. (2018). Improved Fully Convolutional Network With Conditional Random Field For Building Extraction. *Remote Sensing*, 1135.

Sivakami, C. S. (2014). *Landslide Susceptibility Zone Using FR Model.* IISTE.

Taalab, K. T. (2018). Mapping Landslide Susceptibility and Types Using Random Forest. *Big Earth Data*, 159-178.

Wang, Y., Fang, Z., & Hong, H. (2019). Comparison of Convolutional Neural Networks for Landslide Susceptibility Mapping in Yanshan County, China. *Sci. Total Environ*, 975-993.

Watch, R. (2021). The List of Countries at High Risk of Landslides. . In *Retrieved from watch: https://blog.resourcewatch.org/2018/08/27/italy-austria-and-china-top-the-list-of-countries-at-high-risk-of-landslides-right-now/.*

XIanyu Yu, K. Z. (2021). *Study On Landslide Susceptibility Mapping Bases On Rock-Soil Characteristics Factors.* Scientific Reports.

Yilmaz, I. (2009). Landslide Susceptibility Mapping Using Frequency Ratio, Logistic Regression, Artificial Neural Networks And Their Comparison: A Case Study From Kat Landslides(Tokat- Turkey). *Comput. Geosci.*, 1125-1138.

Youssef, A. M., & Pourghasemi, H. R. (2021). Landslide Susceptibility Mapping Using Machine Learning Algorithms and Comparison of their Performance at Abha Basin, Asir Region, Saudi Arabia. *Geoscience Frontiers*, 639-655.

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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.

Bekha Lal Shrestha
Then Director General
2078/10/13

Bhalchandra Singh Chaudhary
Surveyor
2078/9/13

Kedar Prasad Dev
Then Survey Officer
2078/6/8

Hari Nandan Mandal
Survey Officer
2078/3/28

Prem Raj Sharma
Then Survey Officer
2078/1/16

Online Service Delivery in Survey Offices of Nepal

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KEYWORDS

Online service, NeLIS, LRIMS, MeroKitta, e-land administration

ABSTRACT

The Survey Department of Nepal has started transformation of cadastral management from offline to centralized online system. This has enabled the department to provide the online services to the clients beyond the physical boundaries of Survey Offices. This paper elaborates the present status of online service delivery in different survey offices based on recent policy, institutions and their applications. Data analysis shows that Nepal Land Information System (NeLIS) supports basic norms and values of online service delivery effectively and has become a major milestone in the e-land administration. The provision of assigning different roles and sections inside a survey office has made the system more secure, reliable and responsive. Recently, directives of digital land surveying, mapping and administration for public service delivery have been formulated to address the legal aspect of service delivery. The provision of online application for map, field book and plot register print through https://www.merokitta.dos.gov.np has simplified the working procedure for general public and institutional users too. The expansion of this system in more survey offices along with additional and more advanced features are necessary. Similarly, legal provision of data sharing between Land Records Information Management System (LRIMS) and NeLIS in a meaningful way is also essential in the days to come.

1. INTRODUCTION

A Land Administration System (LAS) with its cadastral component is the infrastructure that facilitates the implementation of land policies to attain sustainable development. Therefore, the availability of a digital, up-to-date and easily accessible cadastral database has become a primary requirement for undertaking efficient land administration and/or spatial planning decisions for any country (Sengupta et. al., 2016). The Bhoomi (meaning land) project for online delivery of land records in Karnataka, shows that making government services available to citizens in a transparent and efficient manner can empower them to challenge corrupt and arbitrary bureaucratic action (Chawla & Bhatnagar, 2004). However, to achieve betterment in managing land, there is a need for accurate, reliable and up to date information about land. Such proper land management policies however remain a challenge to most governments in African nations (Kurwakumire, 2014).

In the recent development, Survey Department of Nepal has developed client-server system architecture where application and database servers are managed in a central server hosted in Government Integrated Data Center (GIDC) and clients access these servers to provide the service (Dangol et. al., 2020). In Nepal, at present, district level survey offices have their own server within the office premises and conduct daily office activities through desktop applications run on each computer. There are 126 district survey offices, 5 special survey offices and 1 digital cadastral survey office running in Nepal. The office applications were developed as extensions of ArcMap software which is proprietary. These local servers were maintained in the office. Databases were stored in it and the individual computers accessed these servers during the transaction. Most offices did not have skilled manpower to operate these servers and required assistance from the department. Further, the applications were not updated and it would encounter problems with newer Operating Systems. The business process and the transaction tracking mechanism of the application could be bypassed from the underlying system. This was a huge security issue. Hence the necessity of a system which could address these problems was felt.

2 ONLINE STATUS ANALYSIS

2.1 Policy Status

Recently, *"Directive on digital technology-based land surveying, mapping and land administration service delivery, 2078"* has been formulated. The major provisions of current directive are as following:

1) Varieties of service delivery:

   Cadastral map print, field book print, plot register print, boundary delineation and online revenue payment services shall be available.

2) Different types of service user:

   General users do not need to create user accounts. Loan Providing Institutions and local level governments need to make a user account through merokitta webapp. "Merokitta" translates to "my parcel" in english.

3) Online Service Delivery:

   Notification of process, service delivery progress and status, revenue payment, final delivery information shall all be performed using online means.

4) Data security:

   Digital data must only be stored in storage locations determined by the Nepal Government. Internal users shall get access to data according to their roles. External service users will be verified by internal users before service delivery.

2.2 Institutional status

2.2.1 Survey Department

The IT unit of the Cadastral Survey Division in the Survey Department is working as a major implementing and monitoring unit.

2.2.2 GIDC

The Government Integrated Data Center acts as a data bank of information and assists in computerization of records at governmental offices. GIDC provides physical server hosting for government institutions including the Survey Department. GIDC hosts the database server, application server, and network point for various ISPs providing intranet services.

2.2.3 Survey Offices

Survey Offices provide cadastral services through NeLIS and MeroKitta applications. MeroKitta is a public access module of NeLIS. It provides an online interface to general public and external users to get cadastral maps. It is currently a web-based application and works best on newer versions of all browsers. It can be accessed from https://merokitta.dos.gov.np.

NeLIS is a desktop application used to carry out daily activities of services like Map Print, Parcel division, Parcel Update and all other technical activities of land administration services by the survey office. It works only within the intranet network. Internal users are provided their own respective username and password. They can access the application according to their assigned roles and assigned sections which are assigned and managed by the respective office admin (Office Head).

2.2.4 Internet Service Providers

ISPs provide intranet connectivity between survey offices, GIDC and Survey Department. Dual ISPs are used to ensure network redundancy.

2.3 Application Status

2.3.1 NeLIS:

Unlike the predecessors SAEx, Parcel Editor (Dangol et. al., 2020), which were based on ArcGIS platform, NeLIS is a client-server based standalone application. It is locally developed, built using Free and Open Source Software (FOSS). Due to its custom and focused development, NeLIS follows the predefined survey office business process and it can easily and quickly implement future changes in business process.

New features of this application include the concept of sections which was not available in previous applications (SAEx, Parcel Editor). Data access is controlled by office ID , sections and roles, preventing unauthorized access and use of data. Data access and operations are tracked. Provision for adding owner/tenant information is available. Latest feature is provision for multi-parcel split i.e. applying spatial operations on two or more parcels as if they are single.

NeLIS identifies each transaction with a unique CaseId. CaseId is 15 digits long code in following format: xxxxyyyyzzzzzzz where

xxxx - 4 digit office code (2601)

yyyy - 4 digit fiscal year (7879)

zzzzzzz - auto increasing number.

This CaseId is unique over the whole system. This is used to transfer the transaction details between section, check unit, verification unit and vice versa. It is used to track work status and progress and can also be used to get an overview of whole transactions in the future. By default, the NeLIS work status window only shows cases from the last 15 days.

2.3.1.1 NeLIS Desktop Application

There are two clients in NeLIS client -server architecture. A thick client to carry out the processing of the heavier tasks of spatial management. These includes:

- Map View
- Map Print
- Georeference
- Map Update (Segments / Construction)
- Split Parcel
- Update Attribute
- Spatial Update
- Trace Map Print
- Merge Parcel
- Multi Parcel Split

NeLIS thick client works best on the Windows 10 platform. It is restricted to departmental intranet networks. To run the NeLIS client, the application has to authenticate with the server using Network code, office code and username/password. Without these the application does not start. Furthermore, each computer which runs a NeLIS client has to be specially configured to run inside the departmental intranet. Other computers (e.g. computers of account, admin section) do not access the departmental intranet and have no access to NeLIS data. Beyond these, the NeLIS client also includes a software auto update system. This helps to deploy new features, release bug fixes, and maintain consistency across the whole network automatically.

Besides this, NeLIS categorizes transactions in categories and progress states. Categories can have sub-categories too. Existing categories in NeLIS are as follows:

1. Parcel Unification
2. Parcel Split
3. Parcel Print (trace)
4. Land Registration
5. Map Update
6. Map Print
7. Map Amendment
8. Field Book/ Plot Register
9. Demarcation
10. *Halsabik*

The progress states are:

1. Registration Incomplete
All the transactions that have been started to register in the survey office but were not able to complete are in this state. Registration process can be performed by any internal user.

2. Registration Complete
The transactions that have been completely registered are in this state. It requires the date of registration, type of transaction and the task assignee name, section and parcels. After registration is completed a unique case id is generated for that transaction. Then the transaction state changes to Split/Merge/Update in Progress and only users with proper section and role can view and work on them.

3. Split/Merge/Update in Progress
Only users assigned to the section can access the transaction. In this stage surveyors will apply spatial operations and update the attributes accordingly. Spatial tools are the same as in previous applications (one point and area, move line and area, join points, offset distance, general editing). An added provision is multi-parcel split, in which the parcels are temporarily merged and spatial operations are performed in the merged parcel. At the end the operation on the merged parcel is transferred to the original parcels. This window tracks and displays which and how many parcels are formed from the original parcel. This provides an additional checking mechanism than previous systems. Finally, when the surveyor completes and submits the transaction for further processing the status is changed to Split/Merge/Update Completed.

4. Split/Merge/Update Completed
Authorized users (surveyors and officers) can view cases in this state. The users have to have the same section as the case for cases to be visible. Users will have to check and submit comments for each original parcel. They may also submit a rejection of the case with appropriate comments. Rejected cases will move to Split/Merge/Update in Progress state.

5. Checked
The transactions that have been checked are in the checked state and are waiting for approval. After approval they will appear on the main map. Hence, approval can only be done by authorized officials. The process is the same as checking. Rejected cases will move directly to Split/Merge/ Update in Progress state.

6. Approved
Approved state is the final state of transactions and makes the tasks permanent in the database. It is only for viewing and references.

7. Rejected
If the transaction is rejected from checking or approval staff, then the transaction appears in the rejected state. The rejected transaction needs to be corrected and

resubmitted for check. Rejected cases will show additional options to view the rejection comments.

2.3.1.2 NeLIS Web Application

Another is a thin client to manage computationally lighter tasks. It works with any modern browser which is connected to the departmental intranet. This app facilitates following tasks:

- User / Staff Management
- Roles and section management
- Reporting
- Transaction detailing
- Public modules handling
- Field Book Image Management
- Plot Register Image Management
- User Transfer

2.3.2 MeroKitta:

MeroKitta is a system that provides online map printing and field book and plot register print services. Thus, can be obtained by providing necessary details of landowner (i.e. land ownership certificate, citizenship certificate) and detail information of parcel (survey office, vdc, ward, sheetno and parcel no.) through https://merokitta.dos.gov.np/ webpage. After submitting the application, OTP will be received via SMS to the mobile number provided by the service recipient. The application provided by the service recipient will be verified by the concerned survey office. If the application of the service recipient is official, the office will request for the payment of revenue and if it is not seen as official, the recipient will receive an SMS saying "No service flow" along with reason. The client must pay the revenue through online or by generating revenue voucher and then visiting bank, upon which the link of the document (map print) related to the service requested by the client will be made available for download through the same webpage https://merokitta.dos.gov.np/ for 15 days.

This service can be divided into two categories according to the user.

- Single Client (Landowner)
- Loan Providing Institutions and local level governments

In case of a landowner, he/she can get only his/her map print related to his/her land. The institutions and local levels of government can get the map print of bulk land parcels but must provide necessary documents of each land parcel. Also, such users need to have their own user account created for the services.

2.3.3 Network Monitoring

As discussed before, a functional intranet network is crucial for NeLIS operation. Although every office has two intranet networks for redundancy, it is important to monitor the network situation. For this, network monitoring tools have been deployed. This is a vital tool in identification, communication and coordination for resolution of network issues that arise from time to time.

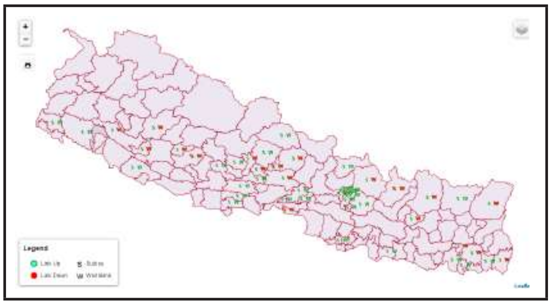


Figure 1: Network status in survey offices

3. CURRENT STATUS

Till the end of Asar 15, 2079 B.S., NeLIS and *merokitta* had been implemented in 50 survey offices. The number of transactions for each transaction type that has performed through NeLIS has been tabulated below.

Table 1: Status of transactions in NeLIS

Transaction types	Count
Copy of Field Book and Plot Register	15
Field Visit	26
Hal Sabik	7660
Map Amendment	830

Map Update	44435
Merge	23093
Parcel Split	142998
Print Map	400283
Print Parcel	88
Grand Total	619441

The pie chart in Figure 2 shows the percent of transactions for each survey office that has been performed through NeLIS. It shows that survey office Kalanki has the highest (25.11%) and survey office Lalitpur has second highest (16.36%) transactions performed through NeLIS.

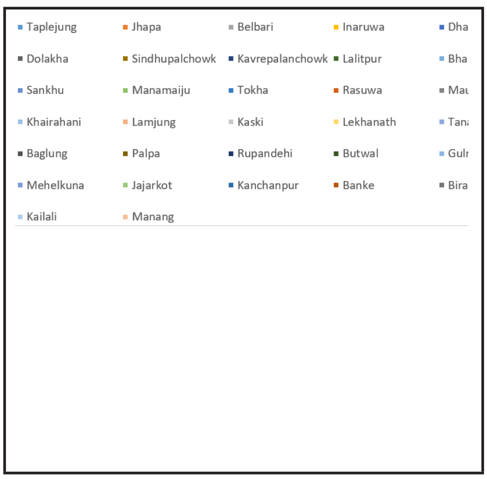


Figure 2: Pie chart showing transactions in 50 survey offices

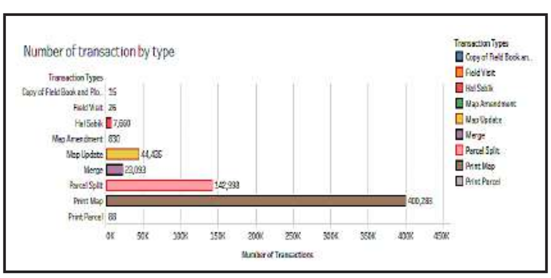


Figure 3: Number of transactions by type

Map Print, Parcel Split and Map update are the transactions with highest frequency. Further investigation of the transaction by month and by the survey office is done. Figure 4 shows the number of transactions have increased after July 2021. Survey Office Kalanki, being the first office to implement NeLIS, is leading in number of transactions. SO Lalitpur is in runner up position, while SO Bhaktapur and SO Chitwan are competing closely.

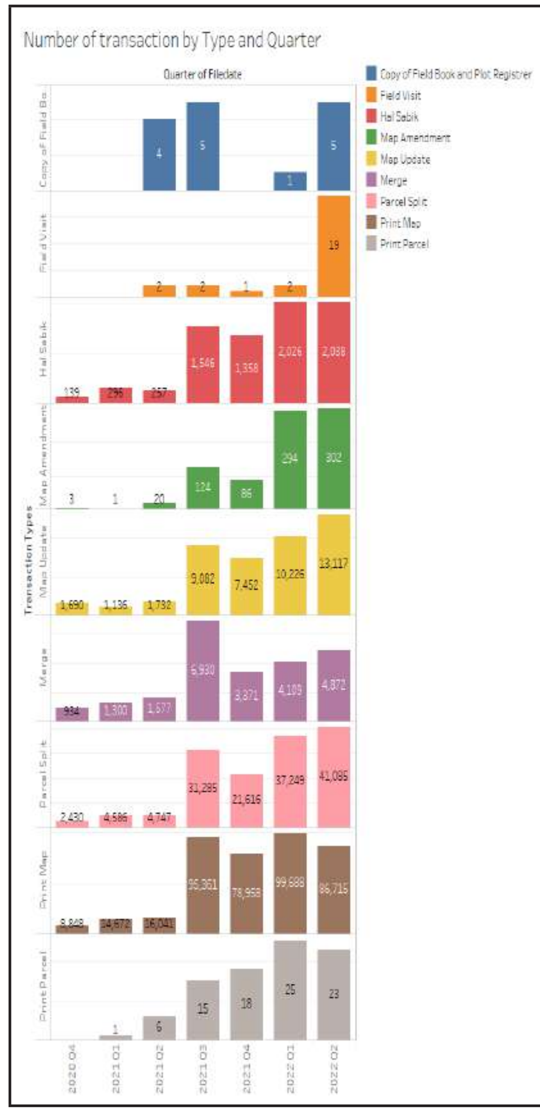


Figure 4: Number of Transaction by Transaction Type and Quarter

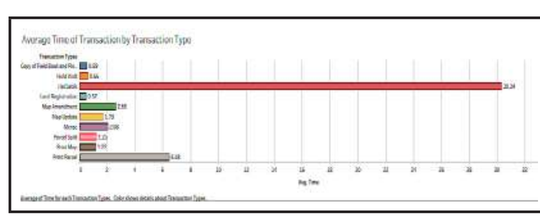


Figure 5: Average Time Taken to complete transaction by type

Figure 5 shows that *Halsabik* is the most time-consuming process. Map print is also a fast process but some transactions include parcels which are not updated or run into other errors. These issues take longer times to resolve hence these transactions skew the average to higher value. With more time and bug fixes, it is expected to have less of these and the statistics should reflect the real situation. Figure 6 shows the comparative extent of time taken by *Halsabik* to other transactions. *Halsabik* takes more time than all others combined.

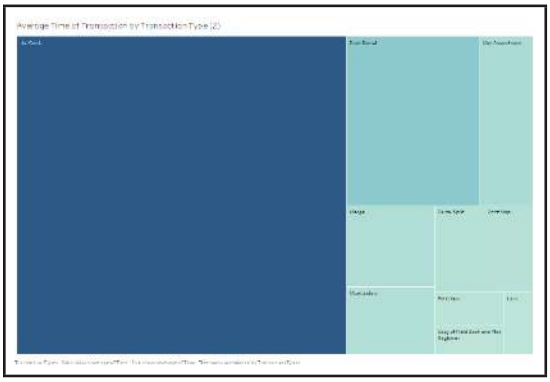
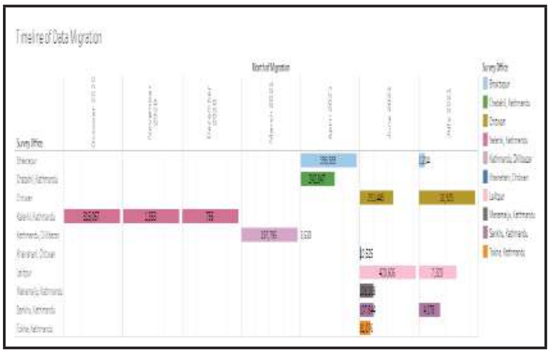


Figure 6: Tree map of Average Time Taken to complete transaction by type



(A)

(B)

Figure 7: TimeLine of Data Migration (A) Fiscal Year 77-78, (B) Fiscal Year 78-79.

Kalanki, being the pilot implementation office, started migration in October 2020. It went through lots of testing and iterations of migrations and software. After 3 months, it was successful. The results, improvements and learning from Kalanki were then carried over to Dillibazar and tested in March and then to Bhaktapur and Chabahil in April. Then in geometric progression Chitwan, Lalitpur, Manamaiju and sankhu followed next. Some data are updated and migrated in later time in Lalitpur and Kalanki.

3.1 Gap Analysis

As this system is currently in the development phase there are many needed improvements. Some of the gaps on this system are:

- **Infrastructure**: This system is dependent on the intranet service, needing to create a new network on every survey office and replacing the old network.
- **Data**: With passing time and different situational complexity in survey offices, survey offices have amended the data structure to address the office's requirements. Due to this, database in survey offices may be inconsistent than the original structure (like having ward number: numeric and textual like 1,1ka, parcel numbering done based on sheet in some place and ward on some places)
- **Interoperability**: NeLIS is based on the open source and these are best on the windows 10 as the library used are the latest packages. But this system can also be operated on other versions of windows like windows 7 or 8, even on ubuntu but there needs to be some updates or additional software needed to operate smoothly.
- **Integration of NeLIS and LRIMS:** Both LRIMS and NeLIS are the land administration-based applications, the major differences between these applications being the mode of the operation. For a single service, customers

need to visit two different offices operating two different systems. In order to provide the efficient land administration services, these systems need to be integrated so that customers do not need to carry the paper documents from one office to another.

4. CONCLUSION

NeLIS is the web-based application developed by the Survey Department for the management of the cadastral data. This application replaces the existing system and performs all the cadastral data related operations from a single application. This makes current cadastral data seamless with a centralized database system. It also provides better security of cadastral data along with fast, reliable and effective service delivery. The provision of recording of all user activities through the system enhances transparency, responsibility and accountability.

5. RECOMMENDATION

Expansion of the system all over the country is recommended in coming years. The improvement of the network is essential for stable, reliable connection with the central server. The establishment of a backup server and disaster recovery server in each province will help in case of system failure. As both NeLIS and LRIMS use parcel as the base entity, integration of their system is convenient in near future. Integration with the spatial data of other public institutions like department of road, forest, Nepal electricity authority, national planning commission is also recommended. NeLIS can also be the backbone of NSDI.

REFERENCE

Sengupta, A., Lemmen, C., Devos, W., Bandyopadhyay, D., & Veen A. (2016). *Constructing a seamless digital cadastral database using colonial cadastral maps and VHR imagery – an Indian perspective,* Survey Review, United Kingdom 48(349), 258-268

Chawla, R., & Bhatnagar, S. (2004). *Online Delivery of Land Titles to Rural Farmers in Karnataka, India,* Scaling Up Poverty Reduction: A Global Learning Process and Conference Shanghai.

Kurwakumire, E. (2014). *Digital Cadastres Facilitating Land Information Management.* South African Journal of Geomatics, 3(1), 64-77.

Dangol, S., Joshi, P., & Dahal, T. P. (2020). *Online Service Delivery in Survey Offices: Step towards e-Land Administration*. Journal on Geoinformatics, Nepal, 20(1), 67–74.

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Status of Parcel Fragmentation in Nepal

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KEYWORDS

Parcel, Parcel Fragmentation, Cadastral Map, Parcel Boundaries

ABSTRACT

Prevailing laws of Nepal provide legal rights to the private land owners to register, transfer, mortgage their own land. Parcel fragmentation is the division of a parcel into two or more parcels. This research was carried out to analyse the current status of parcel fragmentation in Nepal. According to the findings of this research, parcel fragmentation in Nepal is haphazard mainly focussing on urban and peri urban arears consequently parcel being irregular in shape & smaller in size and ultimately incrementing huge number of land owners with in fixed area. In the context of Nepal, factors that drive parcel fragmentation are cultural, social, legal, economical, frequent disasters, geographic variations, unmanaged migrations, haphazard land use planning amongst others.

The uncontrolled and unmanaged parcel fragmentation in Nepal is the major challenge for land use planning and its implementation. Dense parcel fragmentation has created land related disputes. it is recommended that the government should reformulate and implement the proper land use policy as well as its supporting acts that encourage land consolidation in agricultural zone and reducing haphazard parcel fragmentation in urban and peri urban areas.

1. INTRODUCTION

Parcel is a portion of land surrounded by its boundaries and surveyed by a specified tools and technique under the land related act of the country. Parcel has fixed location on land with its covered area and the additional attributes. Parcel is enclosed at least three parcel boundaries. A parcel cannot be a complete parcel, without enclosed by its boundaries and collecting other related attributes. Fragmentation, in literal meaning, indicates 'fragment' referring to a small or incomplete part or piece broken off to which it originally belongs. Parcel fragmentation is the scattering or division of parcel in which a single farm consists of numerous spatially separated parcels (Demetriou D. , 2013). In the same way, according to the King and Burton (2014), land fragmentation is the sub-division or scattering of the existing parcel into individual ownership and fragmentation is the spatial division of the parcel. According to Shrestha (2005), in the cadastral surveying, boundary is the main object visibly seen in somewhere. In the cadastral map, rather than parcel boundaries, there are roads, water courses, buildings, temples and other additional features. The primary purpose of parcel boundary is to define or demarcate the parcel on the ground according to its shape, size and dimensions. Ojalammi (2006) described that due to the lack of permanent structure or demarcation on the ground according to the parcel dimensions, it is more chance to be a land dispute. So, boundary is a part of the discursive landscape of social power, governance and to control the land disputes. Likewise, according to Tuladhar (1996), parcel is constructed from three or more parcel boundaries lines and boundary line is formed by two boundary corners which location is known in local or national geodetic coordinate reference system. He further explained about fixed and general two types of boundaries. In the general boundary, a boundary line between adjoining two parcels is defined through physical boundary features, it may be natural such as rivers, roads, streams etc. or manmade such as; hedge or fences etc. Generally, farm fragmentation consists of three activities first one is ownership fragmentation, second one land use fragmentation and third one internal fragmentation.

According to Platonova and Jankava (2012), in the ownership fragmentation, the ownership of agricultural land is divided into more than two land owners and land use of farm land may varied according to interest of according to the land owners. Similarly, Dijk & Van (2003) have described four types of land fragmentations including fragmentation of land ownership, land use, internal fragmentation and separation of ownership and use. Land ownership fragmentation refers to separation of ownership that increases number of land owners in the given piece of land. Likewise, land use fragmentation refers to the use of land by users or by tenants of the parcel. Parcel size, shape and distance from the node played the main role in the fragmentation of a parcel. When there is discrepancy between ownership and use in a parcel, then there occur separation of ownership and its use. In Nepal, fourth type of land ownership and use of fragmentation is prevalent. But You (2010) claimed that there are mainly two kinds of land fragmentations: one is land ownership fragmentation and the next is land use fragmentation. He further described that in the land ownership fragmentation, there are number of separated land parcels which are registered in the cadastral system. But in the land use fragmentation, there are distinct numbers of separated land parcels which are being used in the fragmented land use situation. Likewise, Massikamae (2006) has claimed that parcel area information on the related documents can play vital role for planners, politicians, and decision makers. He further added the average size of the parcel could be used to compare the land use condition among different countries and also used for the assessment of land fragmentation.

2. LITERATURE REVIEW

This literature review deals with the present status of parcel fragmentation in Nepal. The purpose of literature review was to explore the existing knowledge & idea or information about the parcel fragmentation and parcel related information. This section has three distinct sub-sections for the need of study. In the first section, there is presentation of various on factor of parcel fragmentation. This is followed by second sub-section which explores parcel fragmentation on Nepalese context. Similarly in the third section factors of parcel fragmentation in Nepal have been reviewed.

Based on the literature review, the exiting gaps and lapses on the subject matter were identified and different types of factors or reasons were identified in the nation and beyond nations. The review of literature has been based on the national and international research reports, books, thesis, dissertation, research journals, proceedings and other research related published and unpublished documents about the parcel fragmentation.

2.1. Factors of Parcel Fragmentation

Various studies from the researchers around the globe have pointed out different reasons or factors that induce parcel fragmentation. These major factors causing parcel fragmentation across few countries are also examined in this study. Parcel or Land fragmentation may vary country to country and from region to region (Demetriou D. , 2013). According to him there were main four factors which play the catalytic role in parcel fragmentation. These four factors were inheritance, population growth, land markets and historical/ cultural factors. He claimed inheritance was the primary cause of land fragmentation, in which land fragmentation happen by the equal sub-division of parcel among all heirs or descendants. Due to this region, land fragmentation has become a continuous process and hence parcels getting smaller and irregular. Population growth was directly related to the inheritance. People wish to acquire a parcel not only for agricultural activities but for investment, enhancing personal prestige and status and also for future of family.

Another factor of parcel fragmentation is urbanization. Urbanization is the process of increasing people living in towns and cities due to the movement from rural to urban areas. Urban population growth is directly related to the natural growth, migration and boundary changes (Djurfeldt & Jirstrom, 2013). Natural growth means growth of population within the urban region and migration is coming from outside. Zhang (2013) also claimed that parcel fragmentation is especially more in the periphery of the rapidly urbanization area. The new urban areas were being built on the agricultural land which is located across the developed or developing cities (Labbe, 2011). The main reasons of migration from rural to urban area are opportunities for proper employment, education, knowledge & technology transfer, better housing and suitable markets for agricultural products in urban areas (Maina Thuo, 2013). As the urban area provides the above- mentioned opportunities, in the meantime the urbanization process changes the parcel shape and size (Djurfeldt & Jirstrom, 2013). Such type of urbanization affects agricultural productivity (Rembold, 2002). Likewise, according to the King and Burton (2014) the main causes of land fragmentation were social, cultural, economic and physical process. After the land fragmentation, the fragmented piece of land is mostly used for new buildings, charities, religious organizations or used as dowries. Lusho & Papa (1998) were also agreed landowners land was divided due to the practice of parental land division among all their heirs, it was divided on the basis of quality of soil (fertility, irrigation, capacity, cropland), distance between house and parcels and physical conditions (hilly, flat and mountainous land) due to these causes each land parcel was fragmented.

The large amount of parcel fragmentation was caused by the residential development in various countries (Neal, Doye, & Brorson, 2012). According to You (2010), well understanding of land fragmentation helps policy makers to make policies that can solve the problems and also decide which measures are appropriate for reducing land fragmentation. He further explained that the causes of land fragmentation distinguished with regard to the persistence and emergence that was demand side and supply side. Natural and social facts such as inheritance, land scarcity, low land/labour ratio, population pressure and traditional agriculture are the supply side causes of land fragmentation. Similarly, equality principle, farm capability (low producing efficiency level and production method), living safeguard, topography, reducing the risk of production and difference of land quality including slope, altitude, water retention capability, agro-climate conditions and soil type are the demand side causes of land fragmentation. Similarly, Bullard (2007) also agreed that the major factors of land fragmentation were population growth, laws of inheritance and poverty. He further explained that fragmentation results smaller parcels and could be attributed to a many owners or parcels, where single parcel was owned by many owners in separate shares or one land owner owned many parcels.

The laws of inheritance of parcel fragmentation vary in different cultures. In some countries, like in Germany due to the causes of inheritance, the land was undivided but inheritance law had played vital role in the parcel fragmentation in many other countries (Bullard, 2007). In the same matter, he added inheritance law was one of the main factors of parcel fragmentation in Italy and in France. The additional factors of parcel fragmentation in Italy were pointed out as; population growth, economic depression, and social function of land, construction of houses and desire of land in different locations. Bullard (2007) further noticed that, in France, the main reasons of parcel fragmentation were compulsory crop rotation, and the nature of the land market. Likewise, institutional, political, historical and social factors also played vital role in the parcel fragmentation (King & Burton, 2014). They further described that parcel fragmentation might be influenced by the four types of processes which were physical, economic, operational and socio-cultural. They again claimed that in socio-cultural process inheritance laws played vital role in the parcel fragmentation which facilitate the equal division of parcel among their heirs. In the economic process when the land price was high, it was obstacles in changing new technology. In the same way due to fence or ridge between parcels, construction of roads, canals, industries, railways and others in the parcels also played the vital role in parcel fragmentation which was considered as operational process. According as the others, Van Hung, MacAulay & Marsh (2007) had also given different factors of parcel fragmentation such as historical & geographical issues, population pressure and patterns of inheritances. The fragmentation occurred due to the geographical condition such as hilly & upland area. High population growth also accelerates the parcel fragmentation in that area and farmers have more fragmented parcels. They further mentioned that farmers in different Countries like India, China, Nepal, Vietnam, Ghana, and others they want to divide the similar quality of land among their children that results land fragmentation.

Likewise, according to the Chapagain (2004) the root of parcel fragmentation is traditional Hindu law where parental property as well as land is divided into their sons. In addition to the legal rights to do parcel fragmentation, there are some other reasons which drag the parcel to be more fragmented parcels that are; inheritance rights, population growth, land markets & cultural perspective (Demetriou D., 2013). Bizimana (2009) also agreed on those parcels were further fragmented with the increasing of population. The one more reason was also described by the Maina Thou (2013), as some landowner sales their high prized parcel of land to buy cheaper and bigger parcels in the ruler area and some land owners' sales portions of their parcels and construct houses in the remaining portions of the land which causes parcel fragmentation. The other factors which affect the land fragmentation was found to be land reforms, inheritance, transaction, environmental & ecological factors, social and cultural factors, operational and physical factors such as parcel distance from road, soil quality, land steepness, water availability, climate, topography, height & morphology (Rejael, Jamshidi, Mostafa, & Roosta, 2012). Similarly, they gave additional causes of parcel fragmentation such as, parental land division among their heirs make parcel smaller, irregular and insufficient to do farming as well as due to the lack of basic developmental infrastructure in the rural area, people are moving from rural to urban area to get these things such as, good education, proper employment, transport facility, health save & security and also to live in the newly developed technology of environment. When people move from rural to urban area, they buy portion of land from a whole parcel to make home hence there occurs parcel fragmentation, so migration is another important factor of parcel fragmentation.

2.2. Parcel Fragmentation: Nepalese Context

In Nepalese context, parcel fragmentation is prevalent in private land, customary lands and in some cases in public and government lands too. Nepal is a land locked country and located between the India & China. A Cadastral map is a map which shows the boundaries and ownership of land parcel and in addition unique identifying numbers of each parcel. According to the Land (Survey and Measurement) Act, 2019 BS, parcel is the piece of land surrounded in all directions by its boundaries and having similarity in ownership, use & enjoyment and kind of land within these parcel boundaries. The area of agricultural, residential and residential concern is covered in the Cadastral map. In the context of Nepal, the land record system is very old and the transformation towards modern cadastral system is very slow. In the starting period or in the 1951 BS, the Cadastral maps required for land administration were prepared by Chain Survey having lesser accuracy. Since 1980 BS, Plane Table, Plane Alidade and Chains had been used to make Cadastral maps for the improvement of map accuracy. Such prepared cadastral maps were not sufficiently accurate and up to date, so systematic Cadastral Surveying was started to prepare maps with full coverage where Plane Alidade & Chain were replaced by the Telescopic Alidade & Measuring Tapes.

In the initial time there was no national network of control points so island or free sheet Cadastral map were prepared on the basis of local control points in the 38 districts (Shrestha B. , 2005). After the establishment of national geodetic networks Cadastral mapping was performed based on those control points on the grid sheet in the 37 districts where free sheets cadastral mapping was not done. Currently, the government of Nepal has initiated using digital technology in the few parts of the country for the cadastral re- surveying purposes. In the digital technology of cadastral mapping, Total Station named instrument and its related software were used to make maps and to prepare cadastral related information. However, Nepal is just crawling towards the digital activities but Ali (2013) claimed different countries are using high resolution satellite imageries in the maintaining of parcel boundaries and the use of Cadastral map in Land Information System (LIS) which is also necessary in the Nepalese land administration system.

Parcels formed from the above-described technologies are located in Hill, Terai and Mountain regions. However, the parcels are located in different ecological zones but it is varied in total amount of parcels. out of the total number of parcels 46 percent were located in Hill ecological belt, 43 percent were located in Terai region and remaining 11 percent of parcels were situated in mountain area (Agriculture Census Monograph Nepal 2001/02, 2006). From the data it was pointed out that large numbers of parcels were found in the Hill belt compared to the Terai and Mountain region. Such types of parcels are holdings by the female land holders were reported only 6.8 percent but male holders were 93.2 percent out of the total land holders. Figure has shown the male dominant in the land ownership or land holding. Likewise, in the cooperation of female holders in different ecological zones were as, 9.9 percent out of the total parcels in the Hilly area, only 3.6 percent of the total parcels in the Terai and 6.1 percent in the mountain belt.

After describing the mapping history of parcels and its holdings, there is shown average parcels per farm and number of parcels per hectare in different ecological zones is shown in the following Table 1 which indicate situation of parcel fragmentation.

Table 1: Parcel Fragmentation based on Ecological Region.

Regions	Average parcels per farm	Number of parcels per hectare
Nepal	3.96	4.2
Mountains	4.63	6.8
Hills	3.92	5.1
Terai	3.85	3.1

Source: CBS, 1994

Centre Bureau of Statistics (CBS), Nepal (1994) has, mentioned that the parcel fragmentation information in the ecological regions of Nepal has been illustrated in above table. This table describes average parcel per farm and number of parcels per hectare in the different ecological belt. While comparing these data the height average parcels per farm was in mountain ecological region i.e., 4.63 number of parcels per farm. Similarly, 3.92 average parcels per farm in hills and lowest i.e., 3.85 in terai ecological region. Similarly, number of parcels per hectare was also seen greater i.e., 6.8 in mountain ecological belt. Further 5.1 parcels numbers per hectare in hills and 3.1 in terai ecological belt. As it observed that the highest number of average parcels per farm and number of parcels per hectare was in mountain region comparing than hill and terai, it is due to the topographical nature of land. In the undulation land, the available parcels were smaller and irregular in shape so there created more parcels in smaller area. Similarly, the average parcel per farm is 3.96 and number of parcels per hectare was 4.2 in Nepal.

2.3. Factors of parcel fragmentation in Nepal

In the above section 2.1, there is described various factors which played vital role to be a parcel fragmentation in different countries. In the context of Nepal, to pull out the main reasons or factors of parcel fragmentation a field survey was done by making a questionary. The main respondents of this present study was included land administration export, land owners, land brokers, housing & real estate company holders, land planners, lawyers & Lekhapadhi kanun Byajasaui, In the questionary, there is given six alternatives such as; Distribution of Patriarchal Property, Unmanaged or unplanned Urbanization, lack of Legal Provision for Minimizing Parcel Fragmentation, Migration, Lack of Money and All the Specified Reasons as a reason of parcel fragmentation. These five types of reasons are chosen because such reasons had played directly or indirectly main roles in the parcel fragmentation in different countries. Respondents had given to choose one option among these six options that is helping in parcel fragmentation. After the collection of views from all respondents, the out is summarized on the following Table 2.

Table 2: Factors of Parcel Fragmentation.

SN	Reasons/Factors	No. of Respondents	Percent
1	Distribution of Patriarchal Property	13	3.5
2	Unmanaged Urbanization	40	10.8
3	Lack of legal provision for minimizing parcel fragmentation	26	7.0
4	Migration	2	.5
5	Lack of Money	5	1.3
6	All the specified reasons	286	76.9
	Total	**372**	**100.0**

Source: Field Survey, 2016

In the above table 2, it has been illustrated the main factors of parcel fragmentation. The main reasons have been given to the participants as in the alternatives such as Distribution of patriarchal property, Unmanaged urbanization, Lack of legal provision for minimizing parcel fragmentation, Migration, Lack of Money and all the specified reasons. On these alternatives, out of the 372 participants 13 respondents i.e., 3.5 % agreed on the reason of parcel fragmentation is due to distribution of patriarchal property. Similarly, 40 respondents i.e., 10.8 % agreed on the reason of parcel fragmentation is due to unmanaged urbanization. Likewise, 26 responders i.e., 7 % agreed on the reason of parcel fragmentation is due to lack of provision for minimizing parcel fragmentation. In addition, 2 or only 0.5 % respondents agreed on that migration is the main reason of parcel fragmentation and most of respondents i.e., 286 or 76.9 % agreed on the all above-described reasons played main roles in the parcel fragmentation. Therefore, from the study, it is indicated that distribution of patriarchal property, unmanaged urbanization, lack of legal provision, migration and lack of money all played the vital role in the parcel fragmentation. Likewise in Nepalese context, one main factor of parcel fragmentation is to solve the money crisis. Mostly the poor land owner sells their piece of land to cover the expenditure of child education, treatment, dowry and marriage and other cultural activities that causes parcel fragmentation.

In addition, respondents had to choose the option on; Are you agree or disagree on the statement " Migration increase parcel fragmentation"? The summarized output is shown in figure 1 below which is illustrating about the relationship between the parcel fragmentation and the migration. Out of 372 respondents 240 i.e., 64.5% totally agreed on that migration increases the parcel fragmentation. It means when people migrate from one place to another place, they buy piece of land in the migrated zone to make their own home as well as other purposes hence it increases parcel fragmentation. Likewise, 91 i.e., 24.5% respondents partially agree on that statement. Similarly, 15 i.e., 4% respondents neither agreed or nor disagreed on those statements. But only 11 i.e., 3% respondents partially and 15 i.e., 4% respondents totally disagree on those statements. It means migration does not increase parcel fragmentation. So, a greater number of respondents or 64.5% of respondents are fully agreed on that statement hence it is declared migration increased parcel fragmentation.

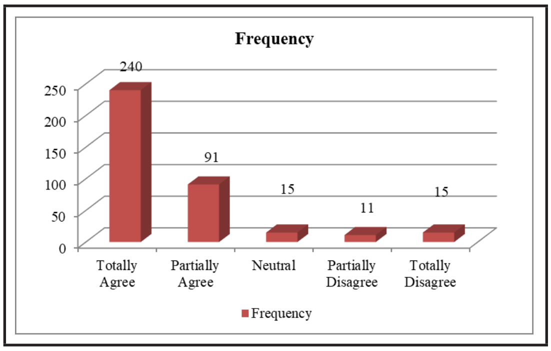

Figure 1: Migration Increases the Parcel Fragmentation

Source: Field Survey, 2016

3. STATUS OF PARCEL FRAGMENTATION IN NEPAL

Personal land is known as personal property. Every land owner has constitutional right to use, right to sell, right to buy land as their interest. Due to this constitutional rights parcel fragmentation is happening all over the nation. By these activities, the status of parcel fragmentation is different in different districts. The number of fragmented parcels of whole Nepal covering as mountain, hills & terai belts is shown in the table 2 as below. In this table, the number of parcels and number of land owners during the first survey of different districts is collected from the Survey Department. Likewise, number of parcels and number of land owners up to BS 2072 is collected from the annual report 2071/72 of Department of Land Revenue and Management. From these time periods data, the total change in parcel number and number of land owners is calculated and it has given the status of parcel fragmentation.

Table 3: Status of Parcel Fragmentation.

Districts	First Time Mapping		Till 2072 BS			
	Number of Parcels	Numbers of Land Owners	Number of Parcels	Numbers of Land Owners	Change in Parcel Numbers	Change in Land Owners
Jhapa	153137	25690	1457992	491351	1304855	465661
Ilam	148582	42749	195388	107847	46806	65098
Panchthar	170730	47596	234130	80417	63400	32821
Taplejunga	165595	44794	189283	61150	23718	16356
Morang	215693	42496	1410309	458053	1194616	415557
Sunsari	137795	22765	805933	491836	668138	469071
Dhankuta	137126	31312	167344	122538	30218	91226
Sankhuwasbha	261363	45835	402140	60220	140777	14385
Aokhaldhunga	291729	55538	293900	70546	2171	15008
Bhojpur	270860	64706	324782	104397	53922	39691
Udayapur	103385	4455	192933	108296	89548	103841
Mohattari	293827	70460	510640	212766	216813	142306
Sarlahi	271129	54507	515096	592237	243967	537730
Rautahat	358002	70016	596177	276684	238175	206668
Chitwan	80198	23696	424953	290680	344755	266984
Makwanpur	121414	33884	366959	118044	245545	84160
Sinduli	122744	14217	219479	105752	96735	91535
Ramechhap	270131	49400	318966	116373	48835	66973
Kavre	392294	52000	484261	252417	91967	200417
Dolakha	438770	59402	517797	102265	79027	42863
Sindhupalchok	463895	69060	535613	145072	71718	76012
Kathmandu	279344	91708	881115	652613	601771	560905
Lalitpur	169459	77237	368329	367220	198870	289983
Bhaktapur	159370	52283	219754	162033	60384	109750
Nuwakot	253906	40424	338100	148552	84194	108128
Dhading	311913	48810	384440	129253	72527	80443
Rasuwa	47437	5753	128830	12224	81393	6471
Nawalparasi	163302	19987	281935	124547	118633	104560
Rupandehi	473121	40029	1098220	330829	625099	290800

Kapilwastu	615604	36536	829460	169944	213856	133408
Gulmi	389221	66755	455567	105703	66346	38948
Tanahu	289109	47166	641269	249597	352160	202431
Gorkha	381606	58597	461270	124345	79664	65748
Lamjunga	296760	48617	326631	95593	29871	46976
Kaski	354374	50150	604520	297013	250146	246863
Parwat	331061	42713	374410	79903	43349	37190
Baglunga	367181	54415	660035	71050	292854	16635
Myagdi	136570	25985	147013	34112	10443	8127
Manang	21122	3833	57334	5375	36212	1542
Mustang	36470	3939	75884	5717	39414	1778
Dang	256636	21913	384425	152610	127789	130697
Banke	156227	15673	441495	52310	285268	36637
Bardiya	60755	7347	340573	161549	279818	154202
Surkhet	8889	21385	142682	89203	133793	67818
Salyan	242173	36845	301002	70787	58829	33942
Ropla	354977	42970	389107	61494	34130	18524
Pyuthan	251040	41597	315358	59458	64318	17861
Dailekha	266613	42475	299549	58943	32936	16468
Kalikot	199365	15679	206916	21510	7551	5831
Jumla	397234	15414	426802	25176	29568	9762
Dolpa	124219	6470	173325	8096	49106	1626
Humla	119690	12098	139702	20103	20012	8005
Kailali	73897	12768	327656	203826	253759	191058
Kanchanpur	34028	2600	179631	86246	145603	83646
Dadeldhura	156977	14410	278205	43051	121228	28641
Doti	295772	30947	390414	41855	94642	10908
Bajura	224616	16553	229336	19243	4720	2690
Bajhang	329344	25304	394122	26380	64778	1076
Darchula	144167	17146	146820	25838	2653	8692
Baitadi	477335	39027	515507	51751	38172	12724

Source: Survey Department & Annual Report of Department of Land Revenue Management 2071/72

From the above Table 3, it is observed that total numbers of parcels in the mountain regions are lower than the Terai and Hilly regions so it is concluded that parcel fragmentation is highest in Terai than Hilly and Mountain belt. The percentage of parcel fragmentation is calculated from the above data as follows;

Total number of parcels during the surveying time = *14119283*

Total number of parcels up to the data collection time (2072 BS) = *24520848*

$$\text{Percentage of parcel fragmentation} = \frac{24520848}{14119283} \times 100$$

$$= 1.736 \times 100$$

$$= 173.6\ \%$$

It means that 100 numbers of parcels became 173.6 parcels. In addition, the total numbers of parcels 14119283 were increased up to *24520848* parcels all over the Nepal due to parcel fragmentation during the 35 years. The initial cadastral surveying was started in 2021 BS and it was completed in 2054 BS. So, the parcel fragmentation was started from 2021 BS to 2072 BS in some districts and it was started from 2054 BS to 2072 BS in other remaining districts. Now the average was taken 51 years (2072 – 2021) and 18 years (2072 – 2021) and hence total time period of parcel fragmentation up to 2072 BS was calculated as 35 years.

As the percentage of parcel fragmentation, the rate of parcel fragmentation per day all over the Nepal is also calculated as below;

In 35 years, total number of parcels increased = 10401565

In 1year, total number of parcels increased = 10401565/35 = 297188

In 12 months, total numbers of parcels increased = 297188

In 1month, total numbers of parcels = 297188/12 = 24766

In 30 days, total numbers of parcels increased = 24766

In 1day total numbers of parcels increased = 24766/30 = 826

It means that 826 numbers of new parcels are adding per day due to the parcel fragmentation within the nation.

Different researchers have defined different types of methods to calculate Parcel fragmentation index such as Simpson Index, Average farm size index, Igbozurike's Index, Schmook Index and Januszewski's Index. To calculate the parcel fragmentation index different types of parameters are required but Januszewski index is simple, gives accurate result and only area is required to calculate the parcel fragmentation index. In this study parcel index was calculated by using the Januszewski index (JI) formula by using one parent parcel and its subdivision portions as a symbolic as below,

Figure 2:Fragmented Parcel

Source: Survey Office, Lalitpur

In the above figure 2 there were shown different parcels having their parcel numbers. These parcels were created by parcel fragmentation from one parcel. In the following Table there are shown object id, shape, parcel key, parcel number, district, vdc, ward number, shape length and shape area of the shown parcels.

Table 4: Attributes of Fragmented Parcels.

Object ID	Shape	Parcel Key	Parcel No.	District	VDC	Ward NO.	Shape Length	Shape Area
1	Polygon	<null>	608	25	32	1_1	34.16413	72.658804
2	Polygon	<null>	609	25	32	1_1	48.703359	145.823376
3	Polygon	<null>	610	25	32	1_1	24.199321	24.776049
4	Polygon	<null>	611	25	32	1_1	39.956092	47.865476
5	Polygon	<null>	612	25	32	1_1	50.8365	127.001209
6	Polygon	<null>	613	25	32	1_1	63.114836	152.377055
7	Polygon	<null>	614	25	32	1_1	72.893585	322.234531
8	Polygon	<null>	615	25	32	1_1	38.114341	86.017681
9	Polygon	<null>	616	25	32	1_1	46.468854	65.047733
10	Polygon	<null>	617	25	32	1_1	55.825242	158.081202
11	Polygon	<null>	618	25	32	1_1	61.337401	165.428125
12	Polygon	<null>	619	25	32	1_1	63.859656	182.941146
13	Polygon	<null>	620	25	32	1_1	84.52197	365.428714
14	Polygon	<null>	621	25	32	1_1	55.498528	141.326754

Source: Survey Office, Lalitpur

Januszewski Index *(JI)* = $\sqrt{\sum a} / \sum \sqrt{a}$, *where a represent the parcel size.*

$$= \frac{\sqrt{(72.66+145.82+24.78+47.86+127.00+152.34+322.23+86.00+65.04+158.08+165.43+182.95+365.43+141.33)}}{\sqrt{72.66}+\sqrt{145.78}+\sqrt{24.78}+\sqrt{47.86}+\sqrt{127.00}+\sqrt{152.34}+\sqrt{322.23}+\sqrt{86.00}+\sqrt{65.04}+\sqrt{158.08}+\sqrt{165.43}+\sqrt{182.95}+\sqrt{365.43}+\sqrt{141.33}}$$

$$= \frac{45.35}{161.35}$$

$$= 0.281$$

According to the Jha, Nagarajan, & Prasanna (2005), the JI value lies between within the range 0 to 1. When its value is smaller or nearer to 0 then the parcel fragmentation indicates higher degree and when JI value is higher or nearer to 1 then parcel fragmentation refers lesser ratio of parcel division. From the above calculation, the JI value is obtained as 0.281 which is near to 0 so the parcel fragmentation index or ratio of parcel division is seen higher of that parcel.

This study was analysed by the number of parcels and number of land owners within the time period of first survey and till 2072 BS of all districts of Nepal. The status of parcel fragmentation is seen different in individual ecological belt. It is seen highest in the Terai belt than in Hilly area and lowest in the Mountain region. The average percentage of parcel fragmentation was observed as 173.6%. It means 100 numbers of parcels became 173.6 parcels due to the fragmentation. The average time period was taken as 35 years. On the basis of this time period, 2 lakhs 97 thousand 1 hundred eighty-eight number of parcels were increased in one year. Likewise, 24 thousand 7 hundred sixty-six parcels in one months and 8 hundred fifty-nine number of parcels were increased in one day due to the fragmentation all over the Nepal. It means 7 hundred twenty-six numbers of new parcels were added in the land administration in one day within the nation. From the study, the status of parcel fragmentation was also depended on different reasons of parcel fragmentation. It was concluded that the main reasons of parcel fragmentation were the distribution of patriarchal property, unmanaged urbanization, and lack of legal provision, migration, plot adjustment, parcel exchanging, and court decision and to solve the financial crisis. This study also identified that urban area was more fragmented compared to the urban oriented as well as rural areas.

4. CONCLUSION/ RECOMMENDATION

The objective of this paper is to describe the meaning of parcel fragmentation, the main factors which plays vital role in the parcel fragmentation, the status of parcel fragmentation and the ways to reduce parcel fragmentation in Nepal. As the constitution has provided the rights to the private land owners to transfer, mortgage and to register land. Mostly poor land owners sell their piece of land to cover the expenditure of child education, treatment, dowry and marriage and also in other cultural activities that causes parcel fragmentation. From the study, the status of parcel fragmentation is observed highly dense and parcel fragmentation index is also obtained high from the calculated data. The high parcel fragmentation activities reduce agricultural land and also increases haphazard urbanization ultimately escalating land conflicts. Therefore, the government has to amend and implement the formulated land policy, land use policy, and land use act and recently formulated land use regulations to reduce the parcel fragmentation and encourages on the land consolidation process that help in the overall development of the nation.

REFERENCES

Bullard, R. (2007). Land Consolidation and Rural Development. *Papers in Land Management*. Anglia Ruskin University, Cambridge & Chelmsford.

Chapagain, D. (2004). *Land Tenure and Poverty: Status and Trends Land System in the Hills and Mountain of Nepal.* Kathmandu.

Demetriou, D. (2014). *The Development of an Integrated Planning and Decision Support System for Land Consolidation.* Springer.

Dijk, V., & T. (2003). *Dealing with Central Ureopean Land Fragmentation* . Eburon.

Djurfeldt, A., & Jirstrom, M. (2013). Urbanization and Changes in Farm Sizes in Sub- Saharan Africa and Asia from a Geographical Perspective, A Review of the Literature. *Independent Science and partnership Councial* , 1-40.

King, R., & Burton, S. (2014). Land Fragmentation : Notes on Fundamental Rural Spatial Problem. pp. 1-20.

Labbe, D. B. (2011). Understanding the Causes of Urban Fragmentation in Hanoi : The Case of New Urban Areas. *International Development Planning Review* , 273 - 292.

Lusho, S., & Papa, D. (1998). *Land Fragmentation and Consolidation in Albania.* Madison: University of Wisconsin Madison.

Maina Thuo, A. (2013). Impacts of Urbanization on Land Use Planning, Livelihood and Environment in the Nairobi Rural-UrbanFringe, Keney. *International Journal of Scientific and Technology Research* .

Maasikamae, S. (2006). *Land Fragmentation and the Need for the Land Consolidation in Estonia.* Estonia: Estonia University of Life Sciences.

Neal, K., Doye, D., & Brorson, B. (2012). Fragmentation of Agricultural Land Parcels. S*elected paper preparation at the southern Agricultural Economics Association Annual meeting,Birmingham*, (pp. 1-20).

Ojalammi, S. (2006). Contested Lands: Land Disputes in Semi-arid Parts of Nothern Tanzania. Helsinki, Tanzania: Department of Geography, Faculty of Science, University of Helsinki.

Platonova, D., & Jankava, A. (2012). *Description of Land Fragmentation in Latvia and its Prevention Opportunities.* Latvia: Department of Land Management Geodesy,LLU.

Shrestha, B. (1985). *Bhumi Lagat Registration and Kitta Napi.* Kathmandu: Sarada press, Kel tole.

Tuladhar, A. (1996). Spatial Cadastral Boundary Concepts and Uncertainty in Parcel Based Information System. *Internation Archive of Photogrammety and Remote Sensing*, (pp. 890-893). Vienna.

You, L. (2010, March). Analysis of Land Fragmentation in People's Republic of China. Enschede, The Netherlands: International institute for Geo-information of science and Earth observation, Enschede, The Netherlands.

Zhang, S. (2013). *Socio- ecological Drivers and Consequences of Land Fragmentation Under Condition of Rapid Urbanization.* Arizona State University.

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Price of Aerial Photograph

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

Price of District Level Land Use Digital Data

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

Price of Local Level Land Use Digital Data

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

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

Price of Digital Topographic Data Layers

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

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

Image Data:

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

Price of SOTER Data	Whole Nepal	NRs : 2000.00.

Prospection of Potential Iron Deposit in Gandaki and Lumbini Province of Nepal Using Remote Sensing Technology

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KEYWORDS

Analytic Hierarchy Process (AHP), Suitability Analysis, Iron Deposit, Multi-Criteria Decision Analysis, Landsat-8, Principal Component Analysis (PCA), Remote Sensing (RS)

ABSTRACT

Integrated remote sensing and Geographic Information System provides an aid to find presence of metallic and non-metallic minerals. This approach was used to explore Iron deposits in districts of Gandaki and Lumbini province of Nepal in which 8 districts were identified as the reserves of iron ores namely Nawalpur, Palpa, Baglung, Parbat, Syangja, Tanahu, Arghakhanchi and Gulmi. These districts fall under various geological formation such as Suntar formation, Melpani formation. These formations are found to be rich in metallic minerals. Remote Sensing (RS) and Geographic Information Systems (GIS) offers a cost effective and attractive strategy in mineral prospection, notably for a mineral exploration project. Landsat 8 satellite images, processed through band rationing method highlights the hydrothermal alterations and Iron Oxide containing region. False Color Composite and Principal Component Analysis method highlights sedimentary rocks. Each method exaggerates spectral signatures which highlights the surfaces by different colors indicating presence of iron ores. Lineaments are also extracted from Landsat images combining with Digital Elevation Model (DEM). Lineaments are those structures that provide information about fault and fractures on the surface and helps to identify mineral deposition zones. The result produced through different RS techniques were introduced in GIS environment. Potential iron content region were identified by using Suitability analysis i.e. multi criteria decision analysis (MCDA). Map showing the potential iron ore deposit map was generated by integrating the results together reclassified into a common scale and overlaid with suitable weightage. Final output/map indicates the best possible sites for detailed study of iron ores. The study demonstrates the usefulness and effectiveness of remote sensing and GIS in iron and other mineral mapping.

1.INTRODUCTION

Hematite (Fe2O3), is the most abundant and important ore of iron. Among economic potential for 63 mineral commodities, different preliminary studies have hinted towards the presence of Iron ores and old mining sites by Department of mines and Geology of Nepal (Sah & Paudyal, 2019). Iron ores have been reported from several parts of Nepal including Lalitpur, Ramechhap, Tanahun,

Chitwan, Nawalparasi, Parbat, Baglung, Bitadi, Dahabagar, Bajhang districts (Paudel, 2019). Iron mineralization in Pokhari area of Hupsekot Rural Municipality-5, Nawalpur district was preliminarily studied by Deparment of Mines and Geology Nepal and hematite mineralization zone was traced under. The genesis of iron ore deposit of Dhauwadi-Pokhari is of sedimentary metamorphosed hematite magnetite type as the other important iron deposits of Nepal.

Nepal lies in the center of the 2,500 km Himalayan belt, which has favorable geography for various minerals. It has a very diverse and unique geography divided into five major morphogenetic zones; the Indo-gangetic plain, Siwaliks, Lesser Himalaya, Higher Himalaya and the Tethys Himalaya from south to north. Chronology of the Mio-Pliocene fluvial sediments of the Siwalik Group from southern Asia are seen to be a reserve for magnetic minerals. The Lesser Himalaya is made up mostly of the unfossiliferous sedimentary and metasedimentary rocks like slate, phyllite, schist, quartzite, limestone and dolomite ranging in the age of the Precambrian to the Oligocene (Devkota & Paudel, 2012).

Remote sensing technology is used in various aspects like Earth sciences, geography, archeology and environmental sciences where high spectral resolution remote sensing have developed spatial emphasis for mineralogical mapping. Landsat data have been used by many authors and researcher to locate and map the areas of hydrous minerals including iron ores. GIS (Geographic Information System) is being used to integrate several digital data such as geographical, geochemical, geological, topographical as well as remote sensing data for different studies and research (Partington, 2010). There have been a number of studies on the suitability analysis carried out using the GIS-based multi-criteria evaluation (MCE) procedures (Akinci, YavuzÖzalp, & BülentTurgut, 2013), (Chandio & Matori, 2011). The MCDA allows for the assessment of the individual contribution in knowledge driven approach with respect to the criterion. Relative weightings are assigned to the different evidential themes during knowledge-driven approach of potential mineral mapping using subjective approach and expert's opinion (Takyi & Jnr, 2018).

Landsat imagery has been intensively used for identification and prospection of minerals over the world. The Landsat images records the reflected energy in different absorption bands from the earth surface. Minerals either absorbs or reflect energy depending on their physical and chemical properties throughout electro-magnetic spectrum. The iron oxides minerals absorbs energy in between 0.45µm to 0.85µm, whereas hydrous minerals are characterized to absorb in 2.2 µm and reflects near 1.6µm (Hunt, April 1977). Different rationing techniques enhance spectral signatures and represents with different color based on used spectral bands and color composites.

2.STUDY AREA

Nepal is located in South Asia sharing boundary with China in the north and India in the south, Nepal is located in South Asia sharing boundary with China in the north and India in the south, east and west. The study area of the project includes 6 districts from Lumbini province and 5 districts from Gandaki province making a total of 11 districts of Nepal as our study area (Figure 1). The study area lies in latitude from 27° 51' 10.46" to 28° 30' 41.14" and longitude from 83° 6' 17.16" to 83° 18' 50.01". Among five morphogenetic zones of the Nepal from south to north, the study area comprises the Indo-gangetic plain, Siwaliks and lesser Himalayas. Iron ores (mainly hematite) have been reported from several locations of Lumbini province and Gandaki province including Labdi Khola (Tanahun), Dhauwadi - Pokhari (Nawalparasi), Falamkhani/ Dhuwakot (Parbat), Bhedikhor and Lukarban (Baglung) all lies within our study area. Among the well-known iron ore deposits, Dhoubadi-Pokhari mineralization of Nawalpur district lies in the study area.

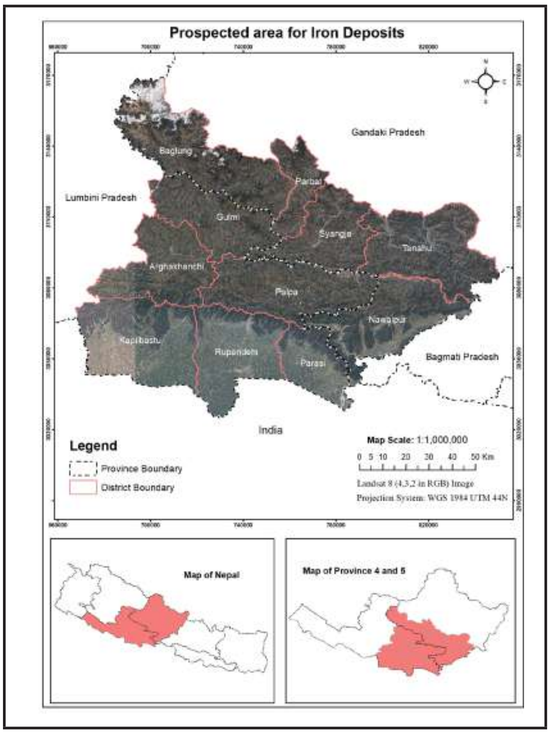

Figure 1: Study Area for prospection of potential iron ore deposits

3.MATERIALS AND METHOD

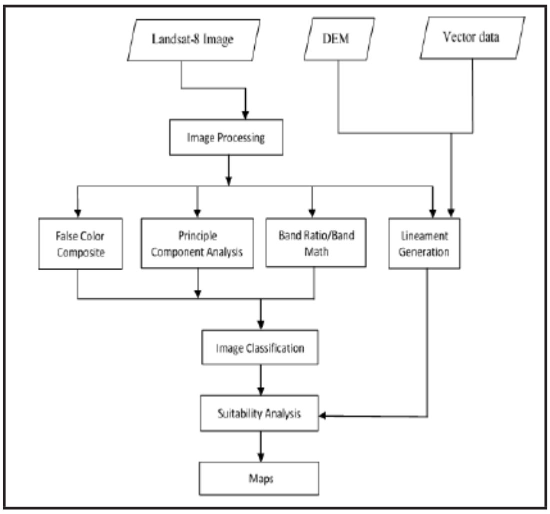

Figure 2: Methodological Flowchart of Prospection of Iron Ores

The Work flow can be divided into five steps; Data Analysis Data Processing, Classification of data, Suitability Analysis and Results and Map Generation. The Figure 2 shows the overall process workflow of this study.

3.1 Data Analysis

This study was performed using an integrated approach combining various raster and vector data sets. Table 1 below comprises the name of individual band name, wavelength and resolution contained by Landsat 8 TIRS/OLI image and were collected from USGS website (https://earthexplorer.usgs.gov/). Other relevant data such as topographic data, maps were collected from various data sources. The datasets were based on different datum and projection system in different data type format. These datasets from various sources were processed, cleaned, transformed to UTM projection system and adjusted according to the requirement of project.

Table 1: Landsat 8 Bands with corresponding wavelength and resolution.

Bands	Wavelength (µm)	Resolution (meters)
Band 1 - Coastal aerosol	0.43-0.45	30
Band 2 - Blue	0.45-0.51	30
Band 3 - Green	0.53-0.59	30
Band 4 - Red	0.64-0.67	30
Band 5 - Near Infrared (NIR)	0.85-0.88	30
Band 6 - SWIR 1	1.57-1.65	30
Band 7 - SWIR 2	2.11-2.29	30
Band 8 - Panchromatic	0.50-0.68	15
Band 9 - Cirrus	1.36-1.38	30
Band 10 - (TIRS) 1	10.6-11.19	100

3.1.1 Spectral Reflectance Curve

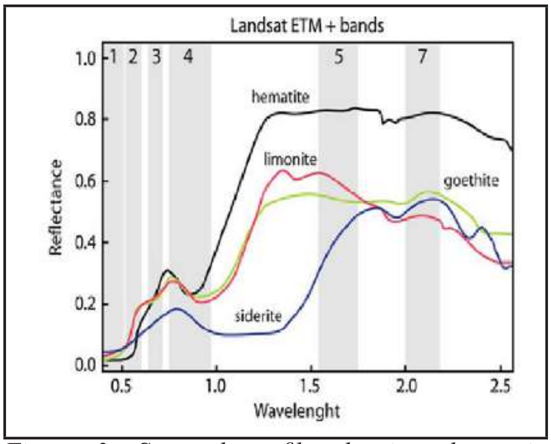

Figure 3: Spectral profile showing the main absorption features of some iron minerals (hematite, limonite, goethite, and siderite (spectra from USGS spectral library).

Different type of mineral shows different spectral anomalies with change in wavelength on spectral reflectance curve. Iron ores shows change in reflectance at different range of wavelength as represented in Figure 3. These changes are usually seen due to absorption or reflection of energy. Landsat-8 records these anomalies caused due to absorption that lies within the spectral range of 0.45µm to 0.85µm by Band 2, 3, 4, 5 and at wavelength 2.2µm by Band 7. Band 6 records the anomalies near wavelength of 1.6µm caused due to reflection of energy. Remote sensing techniques are used incorporating these bands to generate different color ratio composites which further enhance the spectral anomalies and represent potential iron ores by different colors.

3.2 Data Processing

The methodologies used in the study are based on using Landsat 8 images. False color Composite (FCC) is a method for clarifying the lithological discrimination, regional lineaments and structural pattern. Principal Component Analysis (PCAs) to produce uncorrelated output bands, segregate, noise components and to reduce the dimensionality of data sets in the way of showing iron ore concentrations. Band ratio methods have been used for exploring the iron ore rich localities separating them from the host rocks and creating an iron index map (Crosta & Filho, 2003), (Kargi, 2007), (Massironi, et al., 2008) (Amer & Kusky, 2010), (Hashim, Pournamdary, & Pour, 2011). Each method exaggerates spectral anomalies occurred due to presence of iron content on surface. These anomalies are represented by various colors such as dull pale yellow, greenish brown, red according to method applied to image.

3.2.1 False Color Composite (FCC)

The FCC on the Landsat 8 bands (7, 5, and 3) as red, green and blue color respectively of the study area highlighted the geological and lineament features and provided lithological discrimination between basement and sedimentary rocks. From FCC, sedimentary rocks containing iron composition appears as dull pale yellow and greenish brown color pixels (Salem & Gammal, 2015).

3.2.2 Principle Component Analysis (PCA)

Applying of PC2 and PC3 on Landsat 8 image shows a wide range of color reflecting the iron ore distribution and concentrations at the different sedimentary physiographic features. From PC3, the maximum iron concentrations of the study area appeared as yellow and the minimum iron concentrations are of deep brown color pixels (Salem & Gammal, 2015).

3.2.3 Band Ratio Image

The use of band ratios (4/2, 5/7, 5/4) and (4/2, 5/7, 4/5) of Landsat 8 OLI/TIRS as red, green, blue, respectively highlights the distribution and concentrations of the iron ore in the study area by red and pale red color pixels (Salem & Gammal, 2015).

FCC image of RGB= (5*6)/7, (4*6)/ (5*2), (5*6)/

(7*2) as red, green and blue color respectively shows hydrothermally altered rocks as black spots. FCC image of RGB=2, 6-7, 5-6 as red, green and blue respectively shows hydrothermally altered rocks as blue color pixels (Safaria, Pourb, & Hashim, 2017).

3.2.4 Lineaments

Lineaments can be generated automatically using proprietary application as well as can be created with semi-automatic approach. In the semi-automatic approach lineaments were created based on 4 Hill shades. These hill shades were created by using Digital Elevation Model (DEM) with varying the values in Sun angle 0°, 45°, 90°, 135° for different outputs. These generated outputs gets combined using spatial analysis tool to form one shaded image (B.S. Manjare, 2019). The fault and fractures gets digitized based on generated one shaded image..

3.3 Classification of data

The iron content region (region of interest) samples were collected for each technique used to identify iron content region based on color. The samples were collected from northern region of Hupsekot rural municipality of Nawalpur district. The Landsat 8 image was classified into two different class based on the samples collected. Supervised classification was applied on the image to classify image into two different class; one in Iron content region and other as Non Iron content region for each of processed dataset.

3.4 Geographic Information System

Application of Geographic Information System can manage a large quantity of spatially concerning information and facilitate integration of multiple data layers with spatial suitability models. Therefore, the integrated GIS-based MCDA process was used to evaluate land suitability for the possible iron ore deposit. Five components from processed results were used as the layers for MCDA process (Chandio & Matori, 2011). The AHP method is one of the multi-criteria decision-making approaches that is commonly used in land use suitability analysis (Akinci, YavuzÖzalp, & BülentTurgut, 2013).

3.4.1 Iron oxide containing region

Sabins (1997) introduced an ETM+ band-ratio “3/1” by dividing the digital number (DN) of the two bands to produce an image that enhances spectral differences and reduces the effect of topography. The induced procedure helps to locate the areas of iron oxides and hydrous minerals in given environments (Sabins, 1997).

3.4.2 Hydrothermal Alteration Zone

From the interaction of hot aqueous fluids with the rocks through which they circulate, hydrothermal alteration zone is formed by a complex mineralogical, chemical and textural change procedure under evolving physicochemical condition (Rahele Moradi, 2017), (Safaria, Pourb, & Hashim, 2017).

3.4.3 Sedimentary Rock Zone

Sedimentary rocks are rich in iron oxides including hematite and magnetite (King, 2020). The FCC, PC2 and PC3 combination exaggerates the sedimentary physiographic features (Salem & Gammal, 2015).

3.4.4 Lineament

Abundant amount of minerals has been recorded in fractures and steep terrain over the world. Lineaments helps to identify the faults and fractures where the abundance of minerals is usually found. A buffer zone of 250m around lineament feature is created for weighted overlay of lineament layer.

3.5 Weighting of Evidential Themes

The weights were determined after a thorough literature review on iron mineralization within the study area. Furthermore, consultations with geologists on minerals potential in Nepal was carried out during the weighting of the themes. Weightage of individual themes are illustrated in given Table 2. (Takyi & Jnr, 2018) (Chandio & Matori, 2011)

Table 2: Summary of weights attached to evidential themes

S.N.	Components	Weightage (%)
1	Iron Oxide Containing Zone	25
2	Hydrothermal Alteration Zone	10
3	Lineament	20
4	Sedimentary Rock Zone FCC	20
5	Sedimentary Rock Zone PCA	25

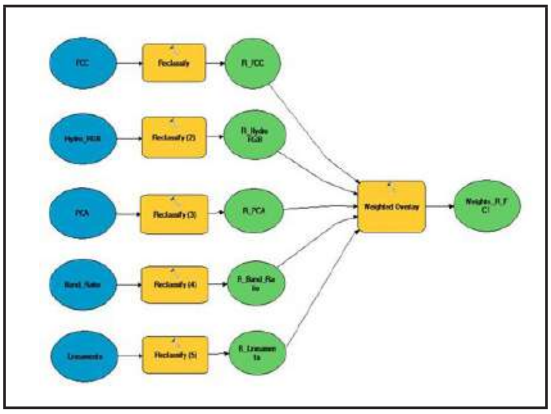

Figure 4: The Multi Criteria Decision Analysis (MCDA) model build in GIS

4. RESULT AND DISCUSSION

4.1 Interpretation of the processed Landsat 8 Imageries

4.1.1 False Color Composite (FCC)

The FCC on the Landsat 8 bands (7, 4, and 2) exaggerated the iron content region of Dhoubadi/Pokhari region that is appeared as dull pale yellow and greenish brown color can be seen as indicated by yellow circle in Figure 4. These region appears to have high iron concentration than other region represent by other spectral colours (Salem & Gammal, 2015).

Figure 5: False Color Composite of Landsat 8 image showing maximum iron concentration as dull pale yellow and Greenish brown with band combination of (7, 4, 2 as RGB) in Northern part of Hupsekot Rural Municipality.

4.1.2 Principal Component Analysis (PCA)

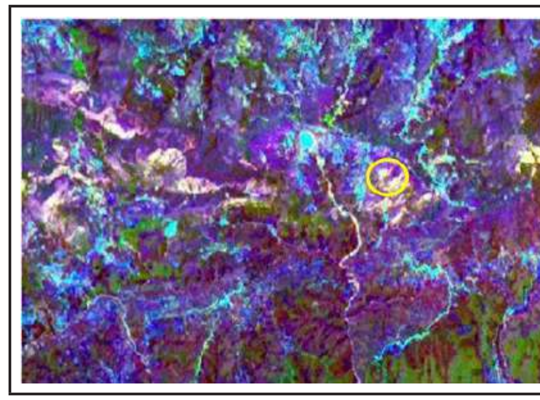

Figure 6: PCA applied on northern region of Hupsekot Rural Municipality

PCA reduces the correlation and improves the spectral signatures. PC2 and PC3 of Landsat 8 providing the iron distribution and concentration. The surface with high iron concentration is represented by yellow color as indicated by yellow circle and low concentration is represented by deep brown color in Figure 5 (Salem & Gammal, 2015).

4.1.3 Band ratio/Band math

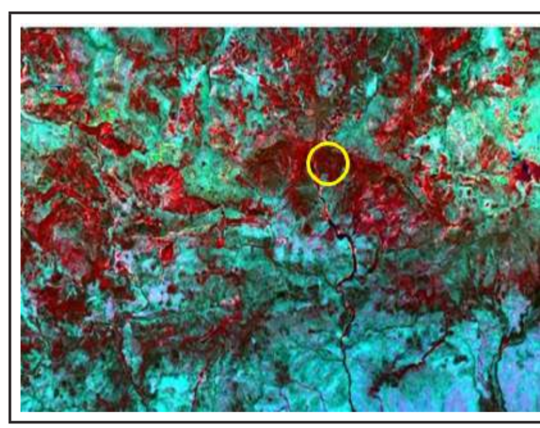

Figure 7: FeO containing region representd by red color in Northern part of Hupsekot Rural Municipality

The band ratios (4/2, 5/4, 5/7) in Landsat 8 image as red, green, blue, respectively enhanced the distribution and concentrations of the iron ore. Dhoubadi area appeared with maximum iron concentration (red color) as indicated by yellow circle and the surrounding areas with minimum iron concentration (yellow) in Figure 6 (Salem & Gammal, 2015).

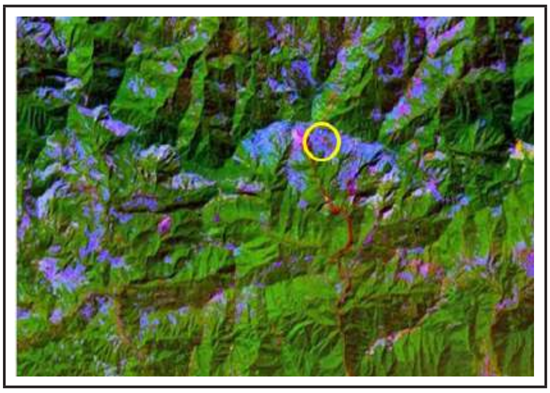

Figure 8: Hydrothermal Alteration Zone highlights the mineral deposits by blue color in northern part of Hupsekot Rural Municipality

Hydro thermal alteration zone represents mineral deposits. Using band math and using the bands (2, 6-7, 5-6) as red, green and blue combination intensifies the presence of mineral on the surface represented by blue color as indicated by yellow circle in Figure 7 (Salem & Gammal, 2015).

4.2 Iron deposits map

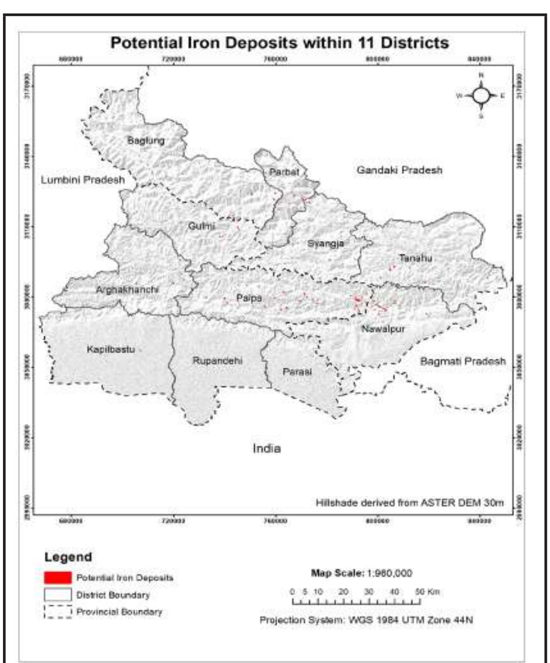

Figure 9: Map showing the distribution of potential iron ore deposit in 8 districts of former western development region of Nepal

The Figure 9 shows Siwalik and lesser Himalayan morphogenetic zone holds huge reserve for potential iron ore deposits. Among the 11 districts of the study area, 8 districts holds reserve for potential iron ore deposit as seen from the results, where maximum amount could be seen in lower Siwalik region and notable amount is distributed as we move north to lesser Himalayas.

4.3 Interpretation of the field geology

4.3.1 Existing Iron Ore Deposits

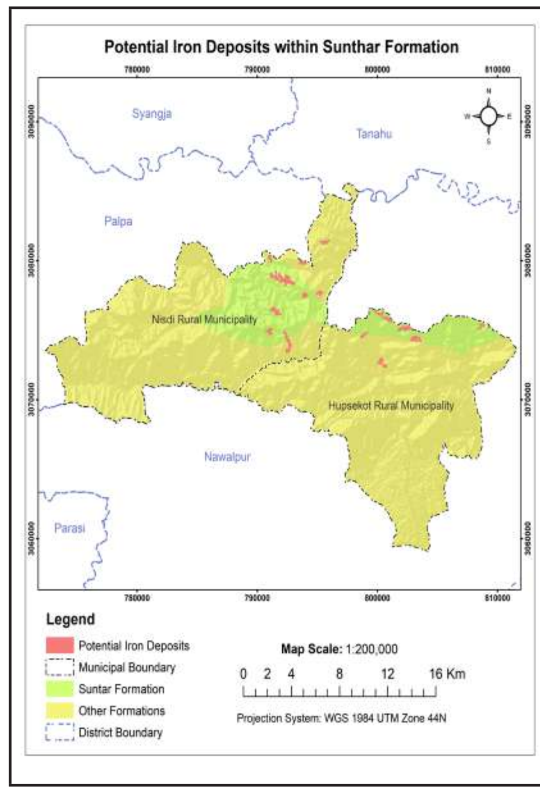

Figure 10: Potential Iron Deposits in Hupsekot and Nisdhi Rural Municipality are mostly observed in Suntar formation of Rocks

In course of time Geological investigations and mineral exploration activities carried out mainly by DMG since its establishment in 1961 till present day and partly by DMG/ UNDP, UNDP/ DMG/MEDP projects and Geological Survey of India. From the past studies it has been seen that that the chronology of the Mio-Pliocene fluvial sediments of the Siwalik Group from South Asia including Pakistan, India and

Nepal can be a source for magnetic polarity and magnetic mineral reserve (Gautam, Hosoi, Regmi, Khadka, & Fujiwara, 2000). Nepal is situated at the center of Himalayan belt, which has favorable geography for various minerals (metallic, non-metallic, and fuel) where local people had used different types of mineral resources in small-scale through ancient times (Kaphle, 2013). Extensively mining of metallic ores was practiced in different parts of Nepal for more than 100 years till 1951 (2007BS) but none of these mines are in operation since then. Iron ore has been excavated and used locally and traditionally since ancient times in different parts of Nepal. Traditionally iron ores were excavated in Baitadi, Bajhang, Jajarkot, Rolpa, Surkhet, Myagdi, Baglung, Parbat, Chitwan, Ramechhap, Okhaldhunga, Taplejung etc (DMG, 2011) (Amatya, 1996) (Poudyal, 2019)

4.3.2 Geological Settings of Results Obtained

Major portion of the study and the potential deposits lies within Surkhet Group and Tansen Group of geological settings of Nepal. The Tansen Group comprises rocks from the Permian to the Oligocene and is further divided into the Sisne Formaiton, Taltung Formation, Amile Formation, Bhainskati Formation and the Dumri Formation (Sakai, 1983). A geological formation or a formation is a body of rock having a consistent set of physical characteristics with respect to its adjoining set of rocks and which occupies a position in the layers of rock exposed in a geographical region. Surkhet group comprises rocks from Paleocene and lower Miocene and is further divided into Suntar, Swat and Melpani formations (Kayastha, 1992). Suntar Formation consists predominantly of dark gray to dark greenish gray metasandstone and purple to dark gray shale/slate mostly suitable for the occurance of metallic minerals and iron ores. Similarly, Suntar formation is composed up of bauxite paleosol occurs with kaolinite and hematite pisolites under the surface (Li, 2013). The Bhainskati Formation of Tansen Group comprises rocks from the Permian to the Oligocene age. Hematite bands are notably reported in the Bhainskati Formation also (Devkota & Paudel, 2012). Figure 9 shows that the potential iron ores are found within Surkhet group majorly within suntar formation.

4.4 Conclusion and Recommendation

Iron potential map of the study area has been produced through the application of Remote Sensing and GIS. This study helps to demonstrate the usefulness and effectiveness of the application of Remote Sensing and GIS in the exploration for Iron ores. The Landsat 8 imageries were used successfully for identifying Iron oxide containing region, hydrothermal alteration zone, Lineament and Sedimentary rock zones. Remote sensing and GIS can be used as powerful exploratory tools in the preliminary stages of mineral exploration because of its cost effectiveness, effective and efficient interpretation, environmental friendly and most of the data required are open source. This technique can be applied for the exploration of other metallic and non-metallic minerals too. As remote sensing and GIS can be useful for preliminary feasibility study of prospection of iron ore deposits, further detailed geological study/survey can be carried out to explore the amount and volume of possible iron ore.

REFERENCES

Akinci, H., YavuzÖzalp, A., & BülentTurgut. (2013). Agricultural Land Use Suitability Analysis Using GIS and AHP Technique. *Computers and Electronics in Agriculture*, 71-82.

Alasta, A. F. (2011). Using Remote Sensing Data to Identify Iron Deposits in Central Western Libya. *International Conference on Emerging Trends in Computer and Image Processing*, (pp. 56-61). Bangkok.

Amatya, K. M. (1996). *Geological and Mineral*

Resources of Nepal: An Overview. 30th International Geological Congress. Beijing.

Amer, R., & Kusky, T. (2010). Lithological Mapping in the Central Eastern Desert of Egypt Using ASTER Data. *Journal of African Earth Science*, 75-82.

Appel, E., & Fassbinder, W. R. (1989). Magnetostratigraphy of the Neogene Surai Khola Siwaliks. *In West Nepal: Preliminary Results.*

B.S. Manjare, A. P. (2019). Lineament Mapping Using Shaded Relief Images Derived from Digital Elevation Model. *Journal of Geoscience Research*, 155-161.

Chandio, I. A., & Matori, A. N. (2011). *Land Suitability Analysis Using Geographic Information System (GIS) for Hillside Development A case study of Penang Island.* International Conference on Environmental and Computer Science, 88-93.

Crosta, & Filho. (2003). *Searching for Gold With ASTER.* Earth Observation Magazine, 38-41.

Devkota, S., & Paudel, L. P. (2012). *Petrology and Genesis of the Bhainskati Iron Ore Deposit of Palpa District, western Nepal*. Bulletin of the Department of Geology. Tribhuwan University, 63-68.

DMG. (2011). *Mineral Resources of Nepal.* Kathmandu: Government of Nepal.

Gautam, P., Hosoi, A., Regmi, K. R., Khadka, D. R., & Fujiwara, a. Y. (2000). Magnetic Minerals and Magnetic Properties of the Siwalik Group Sediments of the Karnali River Section In Nepal. *Earth Planets Space*, 337-345.

Goetz, A. F., & Rock, B. N. (1983). *Remote Sensing for Exploration: An Overview. Bulletin of the Society of Economic Geologist,* 573-590.

Hashim, M., Pournamdary, M., & Pour, A. (2011). *Processing and Interpretation of Advanced- Space-Borne Thermal Emission And Reflection Radiometer (ASTER) Data For Lithological Mapping in Ophiolite.*

Hunt, G. R. (1977). Spectral Signatures of Particulate Minerals in Visible and Near Infrared. Geophysics, Vol 42, 501-513.

Kaphle, K. P. (2013). Minerals Mines and Mining Activities in Nepal. *Environment and Natuiral Reources* (pp. 282-300). Kathmandu: Nepal Academy of Science and Technology.

Kargi. (2007). Principal Components Analysis for Borate Mapping. *International Journal of Remote Sensing*, 1805-1817.

Kayastha, N. B. (1992). Stratigraphy of the Lower Tertiary Rocks of Nepal Himalaya. *Journal of Nepal Geological Society*, 21-30.

King, H. M. (2020). Retrieved from Geology.com: https://geology.com/rocks/iron-ore.shtml

Kotnise, G., & Chennabasappa, S. (2015). Application of Remote Sensing Techniques in Identification of Lithological Rock Units in Southern Extension of Kolar Schist Belt from Chigargunta, Chittoor District, Andhra Pradesh to Maharajagadai, Krishnagiri District, Tamil Nadu. *International Journal of Innovative Science, Engineering & Technology.*

Li, A. (2013). *Structural Evolution of the Himalayan Thrust Belt, West Nepal.* Houston: The Faculty of the Department of Earth and Atmospheric Sciences, University of Houston.

Massironi, M. L., Bertoldi, P., Calafa, D., Visona, A., Bistacchi, D., & Giardino, A. (2008). Interpretation and Processing of ASTER Data For Geological Mapping And Granitoids Detection in the Saghro Massif (Eastern Anti-Atlas, Morocco).

Geosphere 4, 736-759.

Paudel, D. P. (2019). Present Status and Utilization of the Mineral Resources in Nepal. *The Third Pole: Journal of Geography*, 85-96.

Pendock, N. (1993). Gold Exploration in Greenstone Belts by Use of Landsat TM. *Remote Sensing: An Operational Technology for the Mining and Petroleum Industries.*

Partington, G. A. (2010). Exploration Targeting Using GIS: More than a Digital Light Table. *AIG 'Geo-Computing* 2010', 83-89.

Rahele Moradi, M. B. (2017). *Remote Sensing Detection of Altered Zones Associated with Cu-Mo Mineralization in North of Zahedan, SE Iran Using Landsat-8 Data.* Bulletin of the Earth Sciences Application and Research Centre of Hacettepe University, 275-294.

Rajendran, S., Kumar, K. V., & Bhaskaran, G. (2007). Discrimination of Low-Grade Magnetite Ores Using Remote Sensing Techniques. *Journal of the Indian Society of Remote Sensing,* 153-161.

Sabins, F. F. (1997). Remote Sensing Principles and Interpretation. *Remote Sensing Principles and Interpretation.* (p. 494). New York: W.H. Freeman and Company.

Safaria, M., Pourb, A. B., & Hashim, A. M. (2017). Targeting Hydrothermal Alterations Utilizing Landsat-8 and ASTER Data in Shahr-E-Babak, Iran. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Volume XLII, 153-157.

Sah, R. B., & Paudyal, K. R. (2019). Geological Control of Mineral Deposits in Nepal. *Journal of Nepal Geological Society*, 189-197.

Sakai, H. (1983). *Geology of the Tansen Group of the Lesser Himalaya in Nepal.* In Memoirs of the Faculty of Science Series D (pp. 27-74). Kyunshu: Kyushu University.

Salem, S., & Gammal, E. E. (2015). *Iron ore Prospection East Aswan, Egypt, Using Remote Sensing Techniques. The Egyptian Journal of Remote Sensing and Space Sciences,* 195-206.

Shirazi, A., Hezarkhani, A., & Shirazy, A. (2018). Remote Sensing Studies for Mapping of Iron Oxide Regions, South of Kerman, IRAN. *International Journal of Science and Engineering Applications*, 45-51.

Xiao, D., Le, B. T., Mao, Y., Jiang, J., & Liu, L. S. (2016). Research on Coal Exploration Technology Based on Satellite Remote Sensing. *Journal of Sensors.*

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Web Mapping on Land Cover Change of Kathmandu, Lalitpur and Bhaktapur District

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KEYWORDS

Land Cover, Web Service, Thin Client, Web GIS, Web Interface

ABSTRACT

Land cover change is rapidly following path of environmental degradation, imbalance on ecosystem. Kathmandu, Lalitpur and Bhaktapur district has experienced a very high trend of urbanization and land use land cover change. Mapping this trend is absolutely necessary for sustainable development as well as conservation of the ecosystem. While there are desktop applications for making this mapping and analysis possible, upgrading to the web is the best possible way in order to interact with public as well as much easier way of data visualization, data analysis and data dissemination. This paper portrays the design and implementation process along with the visualization of a WebGIS platform via thin client architecture. A dynamic web map portal has been developed concerning the land cover change of Kathmandu, Lalitpur and Bhaktapur district. Among the several Free Open Source server software, OpenGeo Suite has been adopted for the project because it has a robust and flexible design that allows us to reliably handle and publish geospatial data. PostgreSQL/PostGIS, QGIS, Geoserver, Leaflet, and Apache Tomcat has been utilized as the web server in this suite. A fully functional website has been developed in order to host the maps and its components. WMS layers has also been published using Geoserver and styled as can be displayed on the web map portal. Leaflet plugins has been used with the help of which different tools like Zoom, Pan, Full Screen View and Distance Calculator are made available on the portal.

1. INTRODUCTION

1.1 Background

People are increasingly choosing to reside in cities and their surrounding areas because they are considered to offer better job prospects, better healthcare, and a higher level of education. As a result, the global urban population reached 55 percent in 2018, and is expected to reach 68 percent by 2050 (Kookana, et al. 2020). The dynamics of land use/land cover (LULC) at broad scales have been altered, either directly or indirectly, as a result of the fast expansion of built-up urban regions (Sarif et al. 2020). Considerable knowledge of gradual or abrupt natural changes, as well as factitious changes in the earth's surface, provides significant insight into the interplay between the natural environment and human activity (Bakr, et al. 2010). Taking in consideration of the tremendous amount of LULC change been speculated from the analysis of different research done by Ishtiaque et al. (2017), Rimal et al. (2018), Wang et al. (2020) and Li A et al. (2017), the project idea of portraying the land cover map prepared by different sources into an arranged, spectacular and user friendly dynamic web map portal emerged. While there are desktop applications for making this mapping and analysis possible, upgrading to the web is the best possible way in order to interact with public as well as much easier way of data visualization, data analysis and data dissemination. With the help of web mapping technology, user can collect information regarding land cover change between time period 2000 AD, 2010 AD and 2021 AD as well as perform some spatial analysis to an extent. The web map thus integrated into the web portal are also extractable through PDF following the idea of data dissemination to the public. The rapidly increasing urbanization and land use and land cover conversion from mostly agricultural land to commercial land by people in Kathmandu, Lalitpur and Bhaktapur made the necessity of the project research and web map portal design so that not only public but also concerned authorities like policy maker, urban planner as well as environmental specialists make necessary concerns and modifications in the way the land is being used and land cover being changed in the name of development and urbanization. For this particular project we have used Land Cover Maps and not Land Use Maps. The project deals with mapping the land cover change of Kathmandu, Lalitpur and Bhaktapur Districts following the thin client architecture of WebGIS.

1.2 Objectives

The main objective of this study is to develop Web Map Portal Concerning the Land Cover Change of Kathmandu, Lalitpur and Bhaktapur District.

The secondary objectives are:

- To design a client server architecture framework.
- To create mapping functionality for the Web Maps with the help of Leaflet plugin.
- To publish WMS layers using GeoServer with a specific style.

1.3 Study Area

The study area of the project is Kathmandu, Lalitpur and Bhaktapur district of Nepal. The latitude of Kathmandu, is 27.700769, and the longitude is 85.300140 and lies on an altitude of 1337m. Similarly, Lalitpur is largest city of Nepal after Kathmandu and Pokhara, and it is located in the south-central part of Kathmandu Valley, a new metropolitan city of Nepal. The latitude and longitude of Lalitpur is 27.6588° N, 85.3247° E. Similarly, Bhaktapur is a city in the east corner of the Kathmandu Valley in Nepal about 13 kilometers'. Its latitude and longitude is 27.6710° N, 85.4298° E respectively. Because of its location in the Himalayas, its diverse physiographic diversity, and its status as one of South Asia's fastest expanding cities, this study region was chosen. It had a population of 1.11 million in 1991 which more than doubled to 2.52 million by 2016. (Sarif, et. al. 2020).

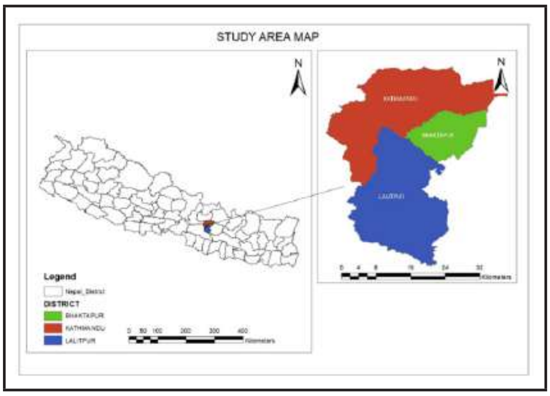

Figure 1: Study Area Map

2. DATASETS

The following were data used in the WebGIS platform.

- Land cover Map
- The Administrative Divisions Map
- The National Land Transport Network Map

The source of land cover maps was taken from ICIMOD for the year 2000 AD and 2010 AD with spatial resolution of 30 m. The source for the land cover map for the year 2021 was land cover map taken from Esri Living Atlas with spatial resolution 10m. The Administrative Divisions Map and the National Land Transport Network Map were downloaded from Open Data Nepal.

3. METHODOLOGICAL APPROACH

3.1 Design Process

Web GIS generally comprises of "three-tier architecture" which allows flexible separation of Logic Tier from the Data Tier and Presentation Tier. The three-tier model necessitates modular software with well-defined interfaces. When it comes to selecting the right web application, this modularity provides a lot of flexibility because each layer can be upgraded or changed independently of the others in terms of technology (Tiwari and Jain, 2013). This WebGIS platform is designed on the basis of thin client architecture.

The System Architecture consists of following functional part:

1. **Spatial database** that can provide random access to large data sets, query processing that understands spatial relationships.
2. **Desktop software** that can provide direct editing and visualization of data in the database. For data management, quality control, and ad hoc reporting.
3. **Cartographic map renderer** reads spatial data from the database, applies styling rules and outputs map images
4. **Application server** provides a programming framework for custom applications.
5. **Map tile server** stores pre-rendered image tiles and serves them up quickly to make maps refresh faster.
6. **Web map component** that can provide a map component inside a web browser.

Spatial Database facilitates with random access to large datasets as well as query processing that understands spatial relationships for example PostgreSQL, MySQL and others. The Database module is setup on the server to store spatial and a-spatial data. It mainly uses both the object-relational database management system PostgreSQL and its spatial information processing extension PostGIS. (Charoenbunwanon et al., 2016)

Desktop Software provides option for data visualization as well as direct editing and analysis of data in the database or any external data in the system, which can directly be analyzed by the admin or the data being manipulated through the web system with the help of client. GIS software is used to store, retrieve, manage, display, and analyze various forms of geographic and spatial data. GIS software allows user to create maps and other visual representations of geographic data for analysis and presentation.

Rendering a map is the process of collecting raw geographical data and turning it into a visual map. The term is frequently used to refer to the creation of a raster image or a series of raster tiles, but it can also refer to the creation of vector-based map outputs. Cartographic Map Renderer reads spatial data from the database, applying some styling rules and outputs map images.

Application server provides a programming framework for custom applications. An application server is a type of platform middleware that is used nowadays. It's system software that sits between the operating system (OS) on one hand, external resources (such a database management system (DBMS), communications, and Internet services) on the other, and users' applications on the third. The application server's job is to act as a host (or container) for the user's business logic, allowing for easier access to and performance of the business application.

Map Tile Server stores pre-rendered image tiles and serves them up quickly to make maps refresh faster. A tiling server is GeoWebCache. It acts as a proxy between a map client and a map server, caching (saving) tiles as they are requested, avoiding repeated request processing and saving a significant amount of time. GeoWebCache is a standalone solution that may be used with various map servers and is integrated with GeoServer.

Web Map Component provides a map component inside a web browser. Maps contain a wealth of information, and understanding how to read and interpret them is essential. Every map has a set of features that make it easier to understand the information it contains. The title, direction and legend (or) key of symbol are the main necessary parts of a map.

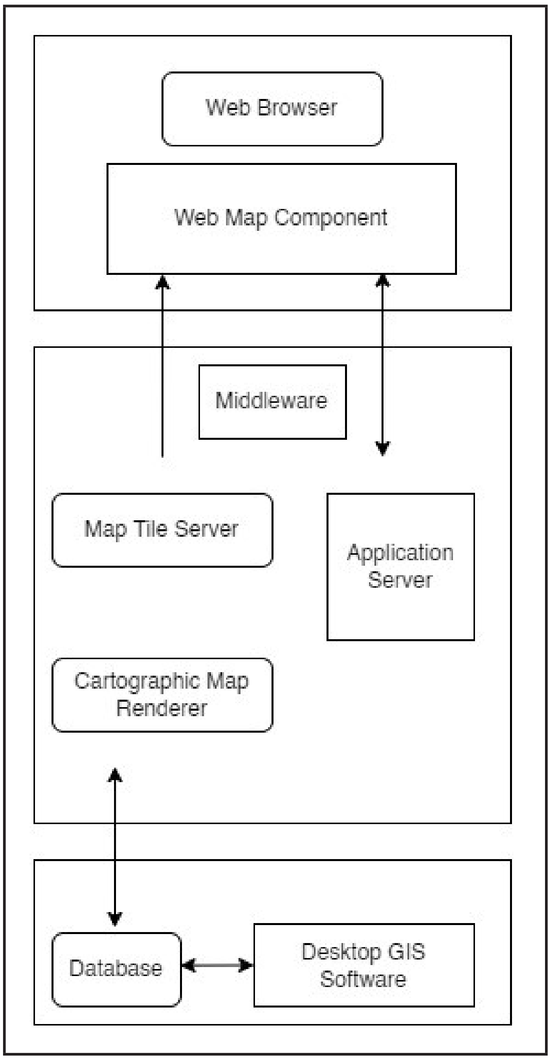

Figure 2: WebGIS System Architecture

The figure portrays the typical system architecture of WebGIS.

3.2 Implementation Process

3.2.1. Server Side Implementation

Geoserver was deployed under an Apache Tomcat servlet container. GeoServer is a server-side application that reacts to Leaflet requests from web browsers and generates geographical web objects dynamically. The Java-based program is the OGC's Web Feature Service (WFS) and Web Coverage Service (WCS) reference implementation. A workspace called Project was created in a GeoServer for the project. In this workspace, many stores were built, and shape files were imported from local disks. Then, several layers were built and published, each with SLD styling and SRS boundaries established. The most common way to specify styling in GeoServer is to use XML SLD style documents. To indicate how GeoServer layers (featuretypes) should be presented, style documents are connected with them. A style document defines a single named layer as well as its user style. Metadata components for the layer and style can include a name to identify them, a title to show them, and an abstract to describe them in detail. One or more feature type styles exist within the top-level style, acting as "virtual layers" to determine rendering order. The next step involved preparing all of the layers with non-spatial information and creating a spatial data base using the PostgreSQL/PostGIS database. PostgreSQL and PostGIS manage the creation, maintenance, and use of a database that includes spatial and attribute data. To import a shape file into the loader utility program pgAdmin 4, PostGIS Bundle 3 for PostgreSQL (Shape-file and DBF Loader Exporter) was used. The attribute data was then obtained on the web page through the database utilizing a backend Node JS rest API. Using the PostGIS bundle, several layers are imported, each with an attribute table reflecting the land cover and the total area covered by the different land covers in different years, such as 2000, 2010, and 2021.

3.2.2. Client Side Implementation

The land cover datasets are served via Geoserver as WMS layers and the vector datasets as WFS layers. These layers are then rendered using Leaflet. The client uses the browser web to request spatial data from the server WMS. A completely functional and responsive website, as well as a map portal for viewing, sharing, and manipulating the web map, were created for this purpose. HTML, CSS, and the Bootstrap framework were used to create the website. The OGC's GetMapRequest capability was used to provide spatial data from the mapping server to the user. Control functionality such as zooming in and out of the map, full screen map view, panning the map view, toggle between different layers as well as switching backdrop provided by Leaflet map providers, calculating distance between different locations, exporting map as a PDF in different map view modes such as Portrait, Landscape, Auto, and Custom was added using Leaflet, which is a JavaScript API for building rich Web-based geographic applications. Statistical data from the Landcover classes was included in the web page by producing a pie-chart and a column graph in Excel and Adobe Illustrator as can be seen on *Figure 5*. *Figure 3* represents the Web Map Portal as viewed on the browser of user while the *Figure 4* represents the attribute table fetched automatically from the PostgresSQL database.

The web map portal has a land cover map that illustrates the land cover change of Kathmandu, Lalitpur and Bhaktapur in the years 2000, 2010, and 2021, as seen in the diagram. On the right side of the screen there is the map gateway, which consists of a map container. The layer control button on the right side of the map container allows users to toggle between different map layers and back drop map views using the leaflet map provider. The area of land cover classes in different time frames is included on left side of the screen. The area of the land cover classes is dynamic, as it is retrieved from the database using the attribute table of our map. Zooming in and out of the map, panning the map, calculating the distance between different locations within the map view, and exporting the web map as a pdf in Landscape, Portrait, Custom, and Auto modes are all included as different functionality in the map portal.

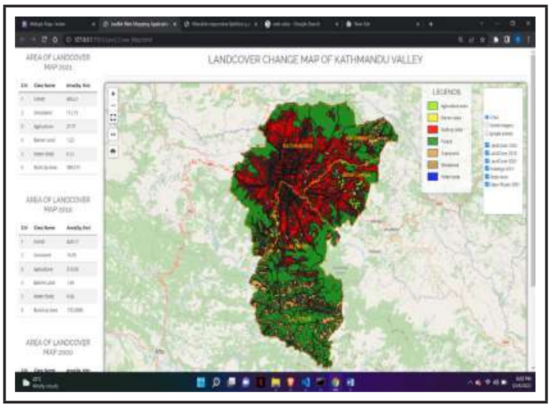

Figure 3: Web Map Portal

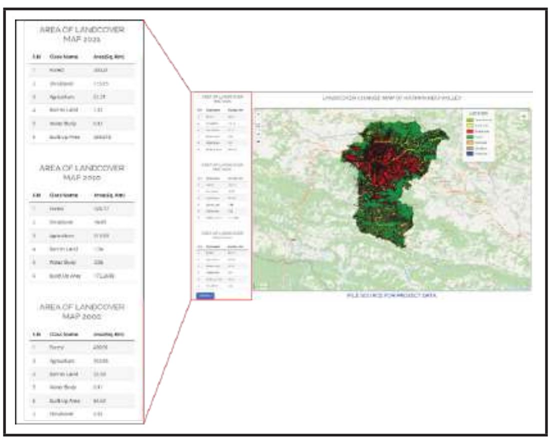

Figure 4: Attribute Table of Map

The following three figures as in Column Graph Diagram (Figure 5, Figure 6, Figure 7) below show the top four land cover classes in 2000, 2010 and 2021 AD respectively. The X-axis represents the land classes and Y-axis represents the area in square kilometers.

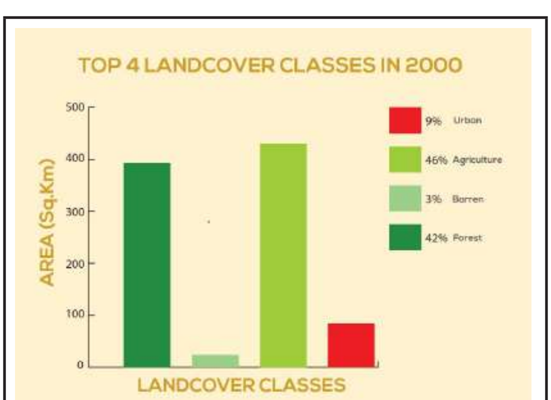

Figure 5: Column Graph Diagram of Land Cover Classes in 2000

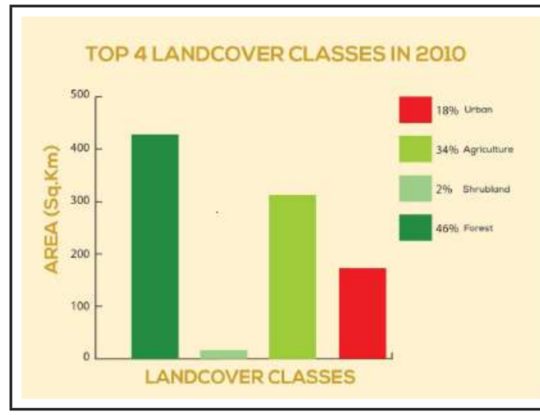

Figure 6: Column Graph Diagram of Land Cover Classes in 2010

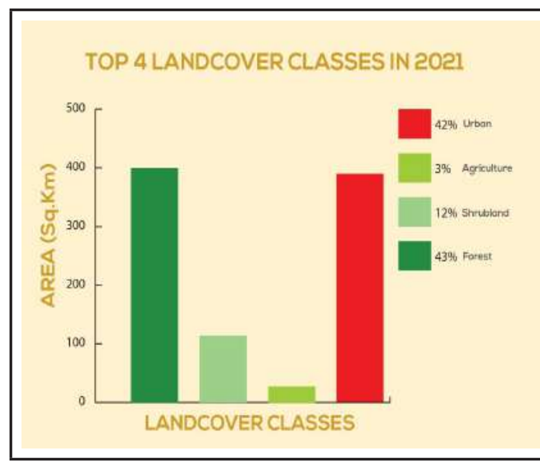

Figure 7: Column Graph Diagram of Land Cover Classes in 2021

The comparative Column Graph Diagram as in Figure 8 represents the statistical data of land cover classes. The urban land cover occupied 9% of total land area in 2000 AD, 18% of total land area in 2010 AD and 42% of total land area in 2021 AD. The agricultural land cover occupied 46% of total land area in 2000 AD, 34% of total land area in 2010 AD and 3% of total land area in 2021 AD. The shrub land cover occupied 3% of total land area in 2000 AD, 2% of total land area in 2010 AD and 12% of total land area in 2021 AD. The forest land cover occupied 42% of total land area in 2000 AD, 46% of total land area in 2010 AD and 43% of total land area in 2021 AD respectively.

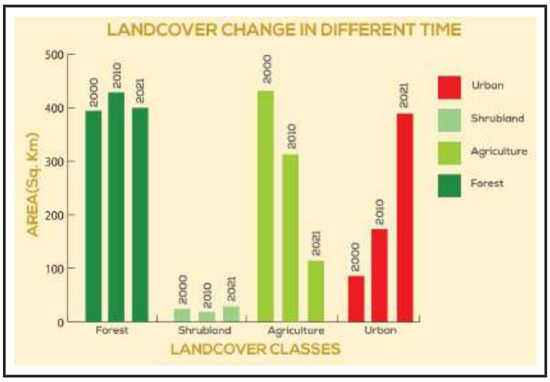

Figure 8: Comparative Column Graph Diagram of Land Cover Classes.

4. CONCLUSION

LULC change is rapidly following path of environmental degradation, imbalance on ecosystem. Kathmandu, Lalitpur and Bhaktapur has experienced a very high trend of urbanization and land use land cover change. Mapping this trend is absolutely necessary for sustainable development as well as conservation of the ecosystem. The web map portal helps in accessing the web maps with applied WebGIS cartography where users can visualize the web maps, browse through different mapping interface and download either raw map data or the maps with predefined cartographic components styled as visible on the portal. A fully functional website has been developed in order to host the maps and its components. WMS layers has also been published using Geoserver and styled as can be displayed on the web map portal. Leaflet plugins has been used with the help of which different tools like Zoom, Pan, Full Screen View and Distance Calculator are made available on the portal. The web mapping platform unlike paper based maps aims to raise discussion over the growing land cover change in Kathmandu, Lalitpur and Bhaktapur District as well as initiate startups for remedy to haphazard land use and land cover change in the Kathmandu, Lalitpur and Bhaktapur in the future with just few clicks and internet available.

REFERENCES

Bakr, N., Weindorf, D.C., Bahnassy, M.H., Marei, S.M. and El-Badawi, M.M., (2010). Monitoring land cover changes in a newly reclaimed area of Egypt using multi-temporal Landsat data. *Applied Geography*, *30*(4), pp.592-605.

Charoenbunwanon, N., Wakita, K. and Bandibas, J.C., (2016). Web-Based Mineral Information System of Thailand Using Free and Open Source Software and Open Geospatial Consortium standards: A Case Study of ASEAN Region. *Geoinformatics*, *27*(2), pp.31-39.

Ishtiaque, A., Shrestha, M. and Chhetri, N., (2017). Rapid urban growth in the Kathmandu valley, Nepal: Monitoring land use land cover dynamics of a himalayan city with landsat imageries. *Environments*, *4*(4), p.72.

Li, A., Lei, G., Cao, X., Zhao, W., Deng, W. and Koirala, H.L., (2017). Land cover change and its driving forces in Nepal since 1990. In *Land cover change and its eco-environmental responses in Nepal* (pp. 41-65). Springer, Singapore.

Rimal, B., Zhang, L., Keshtkar, H., Haack, B.N., Rijal, S. and Zhang, P., (2018). Land use/land cover dynamics and modeling of urban land expansion by the integration of cellular automata and markov chain. *ISPRS International Journal of Geo-Information*, *7*(4), p.154.

Sarif, M., Rimal, B. and Stork, N.E., (2020). Assessment of changes in land use/land cover and land surface temperatures and their impact on surface urban heat island phenomena in the Kathmandu valley (1988–2018). *ISPRS International Journal of Geo-Information*, *9*(12), p.726.

Tiwari, A. and Jain, D.K., (2013). Geospatial framework for dengue using open source Web GIS technology. In *Joint International Workshop of ISPRS WG VIII/1 and WG IV/4 on Geospatial Data for Disaster and Risk Reduction Nov21-22, Hyderabad, India*.

Wang, S.W., Gebru, B.M., Lamchin, M., Kayastha, R.B. and Lee, W.K., (2020). Land use and land cover change detection and prediction in the Kathmandu District of Nepal using remote sensing and GIS. *Sustainability*, *12*(9), p.3925.

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6. Replacement of Professional Photogrammetric Workstations with Low Cost or Free of Charge Photogrammetric Software and Services for Image Triangulation and Image Matching
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1. Importance of Geo-informatics Professional Organizations of the World
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2. Influential Factors of Geo-Information Sharing
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3. Integrated Approach for Building Extraction from InSAR and Optical Image using Object Oriented AnalysisTechnique
By Bikash Kumar Karna, Ashutosh Bhardawaj

4. Multihazard Mapping of Banepa and Panauti Municipalies
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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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1. Bye-Bye EQ2015,11:56AM
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2. A Review of Geodetic Datums of Nepal and Transformation Parameters for WGS84 to Everest 1830
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3. Connecting space to village SERVIR Himalaya at work for bringing earth observation to societal benefits
By Birendra Bajracharya

4. Education and Research Enhancement in Land Administration Sector at Kathmandu University
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5. Flood Hazard Mapping and Vulnerability Analysis of Bishnumati River
By Susheel Dangol, Arnob Bormudoi

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

7. Nigeria-Cameroon Border Demarcation
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8. S in Geoinformatics Profession
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1. A Secure Service Oriented Architecture Based Mobile SDI Model For Mineral Resources Management In India
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2. Capacity Building In Geo-Information Sector(A Case Of Kathmandu University)
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3. Community Land Governance And Its Conflicting Theories
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10. Role Of Land Professionals And Spatial Data Infrastructure In Disaster Risk Reduction: In The Context Of Post 2015 Nepal Earthquake: General Review
By Ganesh Prasad Bhatta, Susheel Dangol, Ram Kumar Sapkota

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

12. Parcel Fragmentation And Land Consolidation
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1. Roadmap for Re-establishment of Geospatial Relationship of the Control Points and Features in Nepal due to Gorkha Earthquake 2015
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2.Concept in Determining the Height of Mount Everest (Sagarmatha)
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3. Integrated Approach of Risk Sensitive Land Use Zoning: A Case Study of Banepa Municipality
By Lekha Nath Dahal

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

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

6. Survey of Location Sensing Techniques
By Abhasha Joshi

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

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

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

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

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

Journal 17 (Published in 2075 B.S.)

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

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

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

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

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

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

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

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

2. Application of Geographic Information Infrastructure: In the context of restructuring the country
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3. Address System in Korea
By Byungyong Kwak, Susheel Dangol

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

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

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

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

8. Precise Point Positioning (PPP): Method and its Geodetic Usage
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1. Application of Geo-information Technology in Nepal "During and Post" COVID -19
Reshma Shrestha, Rehana Shrestha & Bhuwan Ranjit

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

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

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

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

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

Journal 20 (Published in 2078 B.S.)

1. **Analyzing Trend and Pattern of Agricultural Drought: A Case Study of Karnali and Sudurpashchim Provinces**
Naresh Bista, Dikpal Mahat, Sachin Manandhar, Binayak Regmi, Uma Shankar Panday, Shashank Karki

2. **Analyzing Urban Growth Pattern and Driving Factors Using Remote Sensing and GIS: A Case Study of Banepa Municipality, Nepal**
Rabina Twayana, Sijan Bhandari, Reshma Shrestha

3. **Assessing the Accuracy of Remotely Sensed Forest Maps for Nepal**
Menaka Hamal and Rajesh BahadurThapa

4. **Flood Modeling Assessment: A Case of Bishnumati River**
Noor Dangol

5. **Fusion of Radar and Optical Data for Land Cover Classification Using Machine Learning Approach**
David Nhemaphuki, Kiran Thapa Chetri, Sanjeevan Shrestha

6. **Geo-Information Modeling of Soil Erosion for Sustainable Agriculture Land Management in Sambhunath Municipality**
Bikash Kumar Karna, Shobha Shrestha, Hriday Lal Koirala

7. **Measurement of Height of Mt. Sagarmatha**
Susheel Dangol, Prakash Joshi, Suraj KC, Mahesh Thapa, Bigyan Banjara, Shanker KC & Stallin Bhandari

8. **Online Service Delivery in Survey Offices: Step towards e-Land Administration**
Susheel Dangol, Prakash Joshi, Tanka Prasad Dahal

9. **Preparation of High-Resolution DTM and Orthophoto Using LiDAR in Nepal**
Er. Abhash Joshi & Er. Sumeer Koirala

Nepal Remote Sensing and Photogrammetric Society (NRSPS)

Executive Committee

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NRSPS Member as President of ISPRS-SC

Laxmi Thapa, one of the lifetime member of NRSPS is elected as president of ISPRS-Student Consortium. She will lead the consortium Board of Directors from 2022-2026. Ms Thapa was elected as the president with 97% of total voters of 143.

Photo Source: http://sc.isprs.org/home.html

NRSPS Chairman Participation in Different Program

President of NRSPS Rabin Kaji Sharma participated in General Assembly of Nepal Institution of Chartered Surveyor, held on 2nd Poush 2078. Similarly, he also joined a half day program to observe Global Surveyor's Day in the capacity of president of NRSPS, organized by Nepal Institution of Chartered Surveyor and Survey Department on 7th Chaitra 2078.

Publication of Newsletter and launching of website

The society published the X volume of newsletter, the annual publication of NRSPS with the theme of Unmanned Air Vehicles. Similarly, the society also launched the updated website of the society which can be accessed at www.nrsps.org.np

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
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Member

Ms. Jyoti Dhakal
Member

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Vice President
Mid-Western Development Region

Mr. Karansingh Rawal
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Far-Western Development Region

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

Background

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

Objectives

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

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

Organizational Structure

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

Membership Criteria

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

Nepal Geomatics Engineering Society (NGES)

contactgeomatics@gmail.com

ExecutiveCommittee

President

Er. Sharad Chandra Mainali

Vice-President

Er. Umang Raj Dotel

Secretary

Er. 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

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.

WHY ARE WE REGISTERED?

NGES Nepal Geomatics Engineering Society has been officially registered under the organization Registration Act 2034. This Society has been founded with the objectives of

- Development of Geomatics Engineering field necessary for development of the country.
- Conduction of program for the welfare of the Geomatics engineer
- Conduction of Capacity building program for Geomatics Engineers
- Coordinating with different national and international organization for welcoming the technological advancement for the benefit of the society
- Contribute in the field of geomatics necessary for the overall development of nation

Call for papers

The editorial board requests for papers related to geo-information science and earth observation for the publication in 22nd issue of the Journal on Geoinformatics, Nepal.

Last date of submission is 30th March 2023.

For more information, please contact editorial board

Survey Department

P.O. Box 9435, Kathmandu Nepal

Tel: +977 1 4106508, 4106957, Fax: +977 1 4106757

email: info@dos.gov.np

Instruction and Guidelines for Authors Regarding Manuscript Preparation

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

Page size: A4

Format: Single line spacing with two columns.

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

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

Body text font: Times New Roman "11".

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

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

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Keywords: Four to five keywords on paper theme

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