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Cover Page

Newly established statue at the premises of the Land Management Training Centre reflecting the core function of the center. It also reflects that this current issue of the Journal is the first issue that is “issue no 1”.

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EDITORIAL

It is my and Land Management Training Centre's great privilege to present the first issue of the Journal of "Land Management and Geoinformatics Education", an annual publication of Land Management Training Centre to begin with. The journal aims to include research and informative articles in the sector of Land Management and Geomatics Education. I believe, the journal will help to the reader to gain or enhance their knowledge on geoinformatics and land management in general and with specific focus on its development in of it in Nepal.

The first issue of the journal contains a wide variety of interesting and worth reading articles on different topics viz. "Comparison of Machine Learning and Classical Algorithms based on Supervised Classification for Forest Types Discrimination using RapidEye Imagery by Sanjeevan Shrestha, Effects of Service-Specific On-the-Job Training- A Case Study of the Digital Cadastre and Office Management Training Programme by Bhuwan Ranjit, Assessing the Overall Accuracy of UAV Photogrammetry: A Methodology for Different Combination of Imagery Parameters and Terrain Type by Basant Awasthi, Management of Public Land for Urban Open Space: In Case of Disaster Risk Reduction by Sanjaya Manandhar, Outburst Flood Hazard Assessment of Tsho-Rolpa Glacial Lake by Sanjeevan Shrestha and Vulnerability Assessment of Indigenous Communities to Climate Change in Nepal."

I would like to express sincere appreciation to Mr. Ganesh Prasad Bhatta, the Executive Director and the Chairperson of the Advisory Committee for his valuable guidance and kind forewords. Likewise, I am very much thankful to all the contributing authors, members of the advisory Committee, members of editorial Committee, all guest editors and to all who have contributed for the publication of the journal. I do hope to receive similar cooperation in the future too.

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

Tanka Prasad Dahal
Editor-in Chief
July, 2019

FOREWORDS

It is indeed a matter of immense pleasure for me to present the first issue of the "Journal of Land Management and Geomatics Education" on the 51st anniversary of this Center. Let me take a moment to thank and congratulate entire staff of the Center and extend sincere thanks to those who have contributed, in the past in different capacities, to bring the center to this level.

In the history of Surveying and Mapping education in Nepal, formal education began with the establishment of Survey Training Centre (Nāpi Tālim Kendra) in July, 1968. The Center has been playing a key role in producing the human resources for different levels as per the need of the Government of Nepal over the years. Initially, the Center was established to fulfill the then requirements of land surveyors (amin) to carryout systematic cadastral survey in the country. The center was mandated to produce land surveyors (amin) by conducting Amin Training of eight months duration. Candidates willing to get enrolled in the training were required to pass the 8th Grade of high school education. Soon after the commencement of the Amin Training, Junior Surveyors' Training of one year duration was introduced to produce Surveyors or Survey Inspectors. In November 1971, after three years of the establishment of the Center, Senior Survey Training of one year duration was added in order to produce human resources who could work as Survey Officers.

Realizing the impact it had in the field of surveying and mapping, Government of Nepal upgraded the then Survey Training Center to Land Management Training Center in July, 2000, and gave the additional responsibility to conduct training courses for the capacity development in the land management sector, apart from Surveying and Mapping.

Convinced with the need of the time to run the academic programs in the field of Surveying and Mapping in the country, the center joined hands with Kathmandu University to run under graduate courses in Geomatics Engineering. Both the Institutions agreed to begin Bachelor of Engineering in Geomatics Engineering. This collaboration has been continued with the additional programs such as Master Degree in Land Administration and Geoinformatics, and Diploma in Geomatics Engineering. Council of Technical Education and Vocational Training (CTEVT) is also a partner of the collaboration for the Diploma course.

A number of short-term refresher courses are also being offered at the center to enhance the capacity of the civil personnel working in the sector of Surveying and Mapping, and Land Administration in the country. The recent target of the center is to contribute in the capacity development of the Local Government in land management sector.

The center has set its vision to be the "Center of Excellence in Land Management and Geomatics Educdtion". In order to meet this vision, the center is working towards enhancing the capacity of the center itself. The Centre has initiated research works in the relevant fields mainly focusing on the institutional development and policy reform. As a part of it, it is my great pleasure to announce that the center is publishing this journal as its first scientific journal by the name "Journal of Land Management and Geomatics Education". It will be published annually and we will ensure that it meets the international standard.

I would like to express my sincere appreciation to the fellow colleagues, the members of Advisory Committee, the Editorial Committee for their invaluable contribution in bringing out this issue. More importantly, I extend my sincere gratitude to all the Guest Editors for their invaluable efforts on reviewing the papers. Special thanks are due to Er. Sanjeevan Shrestha for his tireless efforts to bring the Journal in stipulated time. At the same time, I would like to thank all the authors for their resourceful professional contribution. I would expect such kind of support and professional contribution in the upcoming issues too. I further encourage my fellow colleagues from the Centre as well as the professionals of Land Management and Geomatics to contribute to the journal by providing quality articles in the future.

I am confident that you will find this journal a 'must read' one.

Enjoy Reading!

Ganesh Prasad Bhatta
Executive Director
Land Management Training Centre
July, 2019

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Original Articles

COMPARISON OF MACHINE LEARNING AND CLASSICAL ALGORITHMS BASED ON SUPERVISED CLASSIFICATION FOR FOREST TYPES DISCRIMINATION USING RAPIDEYE IMAGERY

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ABSTRACT

Remote sensing imageries has been used for the classification and recognition of forest cover types. New machine learning algorithm have emerged in the last few years, but so far, there is a few studies only have compared their performance and reliability. In this study, pixel-based image analysis approaches for classifying forest cover types are thoroughly compared using three supervised classification algorithms: maximum likelihood (ML) as traditional classifier; support vector machine (SVM) and random forest (RF) as a machine learning classifier. The main objective here is to highlight that a reliable comparison of several classifiers must rely not only in overall accuracy and kappa statistics but also in other metrics (McNemar test; ROC etc.) that assess the classifiers' performance. To this end, multiple metrics used in order to establish more concrete results concerning the classifiers behavior and efficiency. Hence, overall classification accuracy in thematic map produced by ML was statistically significantly different compared to map produced by machine learning algorithms i.e. SVM ($p = 0.0013$) or RF algorithm ($p = 7.229e-5$). However, there was not a statistically significant difference ($p > 0.05$) in classification accuracy between map produced using SVM and RF algorithm. Additionally, AUC value for ML algorithm is also the least (AUC = 0.7321), followed by SVM (AUC = 0.8376) and RF algorithm (AUC = 0.8716). Overall, SVM and RF seem to be superior than ML classifier in forest cover classification in terms of accuracy and performance. But there is no advantage to preferring one machine learning algorithm over another algorithm.

KEY WORDS

Forest cover classification, Pixel based supervised image analysis, Maximum likelihood, Support vector machine, Random forest, Classification accuracy and performance

1. INTRODUCTION

Tree species diversity is a key parameter for forest ecosystems, various ecological issues and in sustainable forest management (Immitzer, Atzberger & Koukal, 2012). Flora diversity monitoring provides essential information for the development of forest inventory as well as biomass estimation. Traditional forest inventories and other field-based data acquisition methods are time consuming, so it is nearly impossible to acquire tree species information over large area. Remote sensing data and image processing tools have extensively been used in mapping and monitoring of spatial distribution of forest species (Li, Im & Beier, 2013). The characteristics of remote sensing technology to provide synoptic view of a large area at high level of detail (both high spatial and spectral resolution) has increased its potential for forest species mapping (Immitzer, Atzberger & Koukal, 2012).

For successful forest mapping, it is imperative to select an appropriate classification model. Numerous classification algorithms such as sub-pixel, object based and machine learning approaches have been used for forest species mapping (Li, Im & Beier, 2013). Previously, classical probabilistic based algorithms (e.g. maximum likelihood) were used abundantly; but the applicability of these algorithms is not reliable due to its nature to deal with normally distributed data (Belgiu & Drăgu, 2016). Non-parametric machine learning algorithms has been gaining popularity for classification purposes, as they are not relied on arbitrary data distribution.[1] Among others, random forest and support vector machine are considered as some of the most widely used algorithms for classifying highly dimensional data (Li, Im & Beier, 2013).

So far, there has been an adequate number of studies comparing different algorithms for land use classification purposes. Specifically, Huang et al. (2000) proceeded to a comparative assessment of some of the most popular classifiers, namely, maximum likelihood (ML), neural network (NN), decision tree (DT) and support vector machine (SVM), highlighting the superiority of SVM over the others. On the other hand, Pal (2005) used RF and SVM algorithms and concluded that they performed equally for land cover classification. In another project targeting to crops classification, the comparison of SVM, ANN, RF and ML showed that the SVM classifier (both for radial basis function as well as polynomial kernel) performed better, followed by ANN, RF, and ML (Nitze et al., 2012).

RF, SVM and ML classification algorithms, among others, have been used in discrimination of forest types. Random forest classifier has been used in classification of forest types with significant levels of accuracy. For instance, Immitzer et al., 2012 applied random forest algorithm for discriminating ten tree species in Austria, adopting both object-based and pixel-based classification method, underlining the superiority of object-based over pixel-based classification. On the other side, the added value of the SVM classifier has been depicted in forest fuels discrimination, when applied on LiDAR and multispectral data. The two-stage classification process, combined with additional information such as the mean height of LiDAR data as well as the vertical allocation of the fuel types, provided high levels of accuracy reaching a percentage of 88.2% (Garcia et al., 2011).

Furthermore, Li et al. (2013) proceeded to a comparative assessment of three types of classifiers, namely, DT, RF and SVM, for forest classification and change detection, based on Landsat images, concluding that RF and SVM performed better than DT in terms of accuracy and change detection, highlighting at the same time the influence of topographic peculiarities in change analysis. In the same context, Sesnie et al. (2010) applied both RF and SVM classifiers for forest types classification presenting low classification accuracies for both classifiers (less than 67%). SVM performed slightly better than RF. However, when the authors combined ancillary data such as NDVI, TM bands and elevation information, the total accuracies were dramatically improved reaching approximately 85% accuracy. Hence, they concluded that the combination of machine learning algorithms and different types of ancillary data may yield to reliable results.

Here, it should be emphasized that there are some cases where ML performed better than more advanced and sophisticated algorithms. Specifically, Shafri et al. (2007) compared the performance of four classifiers such as ML, Spectral Angle Mapper (SAM), ANN and DT. Relatively surprisingly, ML yielded the best results followed by ANN, DT and last the SAM in terms of accuracy. As the author emphasized, the superiority of ML compared to more sophisticated classifiers may be attributed to the high degree of heterogeneity of the study domain. Another potential explanation could be the significant number of the training samples which made the ML to perform better (Shafri et al., 2007).

It should be highlighted the fact that even though there are few studies about the comparative effectiveness of these classifiers in classification projects, most of them are focused on purely land cover classification. Thus, it is observed that there is a research gap in a concrete comparison of robust algorithms in forest types classification. In addition, most of the researchers examine the efficacy of classifiers in terms of overall accuracy and kappa statistics. However, these statistical indices alone may lead to reproducible techniques but with the possibility of low efficiency in other study areas, due to the fact that a comprehensive comparison should include (beyond the conventional ones) additional tools such as: the comparative performance evaluation (through ROC curves); the McNemar's test. The comparison of performance of multi-classifier are often assessed using same training and test samples. In such a case, assumption of independence of sample, followed by kappa statistics is violated; and shouldn't be used to evaluate statistically significant difference in map accuracy (Foody, 2004). In that case, McNemar's test for paired sample nominal scale data is used by many researchers to assess if there is a statistically significant difference between two classifiers or not (Duro et al., 2012). The exploration of relative importance of variables used can be fruitful to reduce the dimensionality of image space and hence increase the efficiency of each classifier. For this situation, the exploitation of capability of RF algorithm to generate a graph of variable importance can produce multiple benefits.

That is, the primary objective of this paper is to explore the detailed comparative efficiency of a classical probabilistic algorithm, namely, ML and advanced machine learning algorithms (i.e. SVM and RF) for forest type discrimination. For this, medium resolution (5 m) Rapid-Eye satellite imagery in a forested area in Nepal is taken. The classifier comparison is done adopting multiple reliable criteria in terms of both accuracy and performance as this kind of combination is absent in the literature, since most of them are focused on the algorithm's comparison in terms of accuracy only.

2. METHODS

2.1 Study Area

The study area is located on the southern part of Nepal, which consists of the entire Kapilbastu district and a specific region of Rupandehi district of Lumbini zone. It covers 2620 square kilometer area. The elevation in the study area ranges from 85 m to 1280 m. The prevalent forest types of the study region primarily constitute of Sal, Sisau, mixed broadleaves and some parts are covered by bamboo and Acacia Auriculiformis. Mixed broadleaves forest types comprise of Masala, Bakaino, Amala, Karma, Siris, Kayar, Asna Abarro and Bajhi. Besides forested area, the study domain is covered by water bodies, cultivation fields and human settlements, labelled as "other" for the classification purposes.

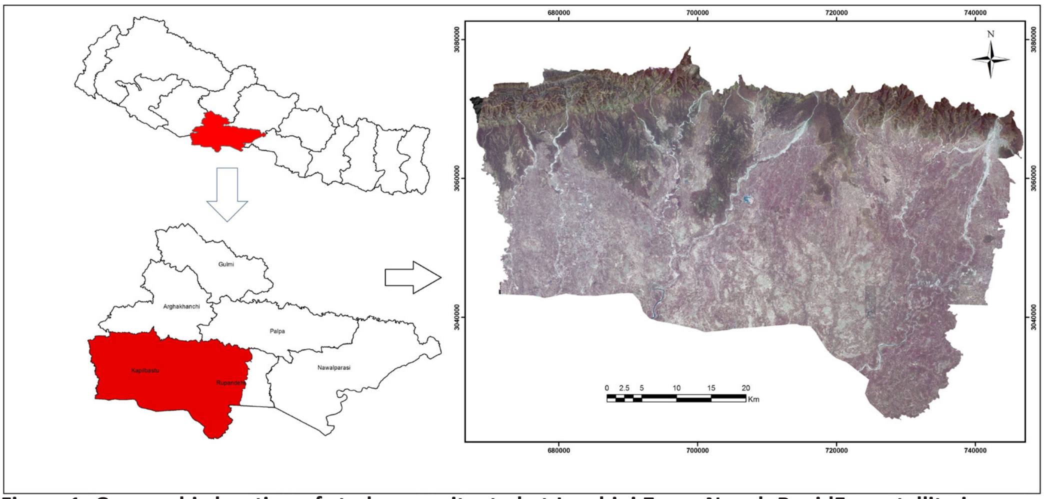

Figure 1. Geographic location of study area situated at Lumbini Zone, Nepal. RapidEye satellite imagery (5m) false colour composite (R = red edge, G = Red, B= green)

2.2 Data

2.2.1 Remotely sensed imagery and training samples

RapidEye imagery data -retrieved during a commercial optical earth observation mission- collected on November 2014, was provided by the Forest Resource Assessment (FRA) project, conducted in Nepal. RapidEye satellite constellation offers imagery having a large coverage with a 77-km swath width, frequent revisit interval (5.5 days at nadir), high spatial resolution [6.5 m at nadir (RapidEye Basic), 5 m (RapidEye Ortho products)] and multispectral capabilities in a single sun synchronous orbit at an altitude of 630 m. It provides five optical bands, namely blue, green, red, red edge and near infrared (NIR), ranging between 440-850 nm. Red edge band is the most useful band, especially for vegetation analysis purpose. The delivered scene was composed of 16511 rows and 12321 columns, and it was free of cloud and haze.

Ground truth sample points of number 471 for five forest types were collected (in situ measurement) using a handheld GPS at the acquisition date of satellite images that was used to determine the forest type. This was also made available by the Forest Resource Assessment (FRA) project.

2.2.2 Ancillary dataset

The Digital Elevation Model (DEM) was prepared using topographic layers (contour and spot height) and made available by the Survey Department, Ministry of Land Management, Cooperatives and Poverty Alleviation of Nepal. Along with elevation layer, slope and aspect dimensions were calculated from DEM and included as variables in the classification process.

2.3 Methodology

2.3.1 Preprocessing of satellite imagery

The preprocessing stage of the acquired images was conducted in QGIS 2.16. Radiometric processing was applied to the RapidEye multispectral imagery, and the Normalized Difference Vegetation Index (NDVI) layer was computed following the procedure done by (Ogashawara, Da & Bastos, 2012). Relative atmospheric correction rather than absolute atmospheric correction of the imagery was performed due to lack of simultaneously ground based spectral data, or appropriate meteorological data available in the study area. For relative atmospheric correction, dark object subtraction method was used to remove atmospheric scattering effects.

The five bands of RapidEye multispectral imagery were placed in a single data set with the calculated NDVI layers, DEM and other related landscape variables (slope and aspect). The combined data set or "image stack" consists of 9 predictor variables.

2.3.2 Sampling data and accuracy assessment

Stratified random sampling scheme was adopted while taking in situ measurements for acquiring adequate samples for each forest type. The essential samples for the non-forested area was taken by visual inspection of the original RapidEye images, since the high spatial resolution of the image made this process an easy task. In total, 471 samples for six forest cover types, namely Sisau, Sal, Masala, Bamboo, Acacia auriculiformis, Mixed Broadleaves and other were used. Following, these samples were then divided into training and testing set using proportional stratified random sampling, which allows for both set of data to retain the overall class distributions of the six selected land cover types which are present in the original data set. As suggested by Rodriguez-Galiano et al., (2012), two third portion of samples (314) were used to train the classification algorithms leaving one third samples (157) as a test dataset for assessing classification accuracy and statistical comparisons between classifiers. Model building and tuning of individual structural parameters of each classifier were conducted in the adopted classification algorithms using repeated cross validation techniques based on the training data set only.

For assessing the accuracy of the classified map which derived from remote sensing imagery, two techniques are mostly used, namely, overall accuracy and Kappa statistics (Congalton, 1991). Overall accuracy is a descriptive statistic, interpreted as the proportion of correctly classified pixels in relation to user and producer accuracy (Duro et al., 2012). Kappa statistics is a discrete multivariate technique of accuracy assessment, which functions as a measure of agreement between reference data set and classification results. This is commonly used in assessing statistical difference for classification purposes as well (Congalton, 1991; Duro et al., 2012). The performance of multiple classification algorithms is often evaluated by using the same training set and testing samples (Foody, 2004). For this reason, assumption adopted by previous techniques are violated as number of samples being compared are not independent and statistical comparison using kappa coefficient is not significant (Duro et al., 2012; Foody, 2004). In that case, McNemar's test for paired sample nominal scale data is used by many researchers to assess if there is a statistically significant difference between two classifiers or not (Recognition & Bradley, 1997), and is therefore adopted here, so that we may proceed to the appropriate comparisons.

It is imperative to compare the classification algorithm, not only by assessing the accuracy of result, but also by the performance of each classifier during classification. The use of Receiver Operating Characteristics (ROC) curve has increasingly been used in evaluating and comparing algorithms, calculating the goodness of fit, due to the fact that the simple classification accuracy itself is often a poor metric for measuring performance (Recognition & Bradley, 1997). As ROC curve is a two-dimensional representation of a classifier performance, it is necessary to convert ROC performance to singular scalar value representing expected performance. A common method is to calculate the area under the ROC curve, abbreviated as AUC (Recognition & Bradley, 1997). Evaluation of each classifier's goodness of fit was conducted by interpreting AUC value and classifiers with the highest AUC were considered of high performance.

For each classification, a confusion matrix is calculated, along with overall accuracy, Kappa statistics, user's accuracy and producer's accuracy. The McNemar's test was performed to assess whether or not there exists statistically significant difference between different classification algorithms. In terms of performance analysis, each models' goodness of fit was evaluated based on the area under ROC curve of each algorithm. Test dataset was used for performing accuracy assessment, statistical comparison, and performance evaluation. In addition, classification time was also estimated as part of comparison of performance efficacy for each classifier.

2.3.3 Model building and tuning of classification algorithm

Model building, tuning and accuracy assessment is the repetitive and simultaneous process, which were performed using R (R Core Team, 2016). Several add-on packages were retrieved for the implementation of different classifiers in the study area. In order to implement classification based on ML technique, the 'RStoolbox' package was exploited (Leutner and Horning, 2017). The classification model using RF algorithm is based on 'randomForest' package (Liaw and Wiener, 2002). For the classification through SVM algorithm, the 'e1071' package was retrieved (Meyer et al., 2017). All classification models were developed using the 'caret' packages (Kuhn, 2016) for single consistent environment for training and parameters tuning.

All the tuning parameters that were used for the adopted algorithms were compared and adjusted in order to optimize classification performance using cross validation technique. Tuning parameters were considered optimal when the algorithms achieve the highest classification accuracy during cross validation. The final classification output was relied on these optimal parameters.

ML is a parametric supervised classification technique and relied on the Bayes theorem. Briefly, after the determination of the number of land cover types, the training samples of each predetermined land cover are collected. In order to establish the seperability boundaries between classes, the Jeffries-Matusita (JM) distance can be adopted. Based on the training samples (pixels), the mean vector and covariance matrix of every class is computed and every pixel is assigned into one of the determined classes, otherwise it takes an unknown label (Ahmad and Quegan, 2012). So, this process is more automated without the need of intervening in the structural parameters of the classifier.

Principally, SVM uses kernels functions for establishing the decision rules, and as Huang et al. (2002) cite, "to map non-linear decision boundaries in the original data space into linear ones in a high dimensional space". The effectiveness of SVM is primarily relies on the kernel types and parameters determining the limits of decision rules. In this study, the radial basis function (RBF) kernel was used for support vector machine based classification model, as preferred by Huang et al. (2002). The two most important tuning parameters for SVM model using RBF kernel are cost and sigma. Increasing cost function produces overfitted model and increases the prediction error; whereas increasing sigma has huge influence on overall classification accuracy which is aftermath of changing the shape of the separating hyperplane Huang et al. (2002).

Random forest classifier is an ensemble classifier which consists of a combination of tree classifiers in order to make specific prediction (Rodriguez-Galiano et al., 2012). The development of a decision tree in RF algorithm is mainly dependent upon the choice of attribute selection at each split in the tree building process (mtry) and the number of trees (Ntree) (Belgiu & Drăgu, 2016; Pal, 2005). Default number of tree (500) in R packages was selected because it is reported that the errors are stabilized before this number of classification trees and have negligible influence on overall classification accuracy (Belgiu & Drăgu, 2016; Duro et al., 2012). Mtry is believed to have “sensitive” influence on the performance of RF classifier (Duro et al., 2012). Usually, the value of Mtry is set to be the square root of the number of predictor variables used (Belgiu & Drăgu, 2016).

2.3.4 Image classification

Using the optimized parameters for each algorithm, the classification of the image of the study area was conducted, so that the final forest cover map to be developed. Post classification clean up procedure of the final forest cover map was not performed. The results were used for accuracy assessment and to compare the performance of the aforementioned algorithms for forest cover classification.

3. RESULTS

3.1 Sensitivity analysis

ML classification model is automated without structural parameters, so there is no need for parameter tuning. The classification accuracy achieved by ML amounts to 80.13%. On the other hand, the highest classification accuracy value (92.25%) for RF was obtained with mtry value as 3. However, it should be noted that for RF classification

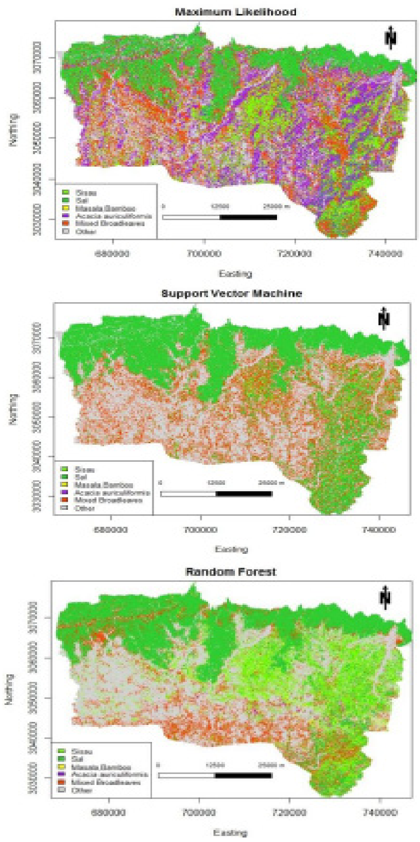

Figure 2. Comparison of image classification: (a) ML based classification; (b) SVM based classification; (c) RF based classification

model, several values of mtry tuning parameter (2, 3, 4, 5, 6) were examined keeping ntry as a constant (500). Finally, concerning SVM model, the combination of two critical parameters (cost and gamma) were adjusted accordingly. The candidate values that participated in the classification procedures for both critical parameters were 0.01; 1 and 100 for cost variable and 0.1; 1 and 10 for gamma variable. The optimal parameters are the default parameters (cost = 1, gamma = 1) along with the cost = 100 and gamma = 0.1, with highest classification accuracy value to be obtained at 88.35%. Models with optimal parameters were used to produce the classified map, associated accuracy assessment and map comparisons.

3.2 Thematic map comparison using visual inspection

Figure 2 depicts the classification result of the three adopted algorithms.

Table 1. Confusion matrices and associated classification accuracies based on test data. OA = overall accuracy, PA = producer’s accuracy, UA = user’s accuracy, K = Kappa statistics

Maximum Likelihood Classifier

Class	PA(%)	UA(%)
Sisau	75.00	75.00
Sal	87.5	87.50
Masala, Bamboo	50	66.67
Acacia auriculiformis	7.14	25.00
Mixed Broadleaves	53.33	44.44
other	100	87.69
OA	80.13	
K	71.61	

Support Vector Machine Classifier

Class	PA(%)	UA(%)
Sisau	76.92	83.33
Sal	84.62	98.21
Masala, Bamboo	50.00	66.67
Acacia auriculiformis	100.00	25.00
Mixed Broadleaves	80.00	44.44
other	96.97	98.46
OA	88.35	
K	87.97	

Maximum Likelihood Classifier

Class	PA(%)	UA(%)
Sisau	84.62	91.67
Sal	93.33	100.00
Masala, Bamboo	50.00	66.67
Acacia auriculiformis	100.00	25.00
Mixed Broadleaves	93.33	77.78
other	96.97	98.46
OA	92.25	
K	93.03	

The two machine learning algorithms produced a visually more coherent map than ML algorithm. The major difference among the three classification algorithms was observed on the eastern and central part of the study domain. Especially, RF algorithm classified the forest cover as Sisau forest type in the greatest part of the eastern territory; whereas SVM algorithm classified it as Sal.

The scenario for ML algorithm is different, as it classified this forest cover as mixture of Sisau, mixed broadleaves and Acacia broadleaves. In addition, RF and ML algorithm classified the central part of the area as Sisau whereas SVM classified it as mixed broadleaves. It is also obvious that ML classifier suffered in a significant degree by salt and pepper effect than the other algorithms.

3.3 Accuracy assessment and statistical comparison

Accuracy assessment consisted one of the last stages for each classification procedure in order to evaluate the efficiency of each optimized model prediction against the test data. Table 1 shows the detailed confusion matrix based on the test data, accompanied by the estimation of overall accuracy, user accuracy, producer accuracy and kappa statistics.

The general trend of overall classification shows that ML algorithm presented the lowest overall classification accuracy (80.13%) followed by SVM (88.35%) and RF algorithm (92.25%). Similar trend was observed for kappa statistics, where ML, SVM and RF algorithm yielded to 71.61%, 87.97% and 93.03% respectively.

At the same time, the respective percentages for user's and producer's accuracy are very high (above 80%) from all classification algorithms regarding the forest types: "Sisau", "Sal" and "other". However, the successful discrimination of the third and fourth class (forest type: "Masala Bamboo", "Acacia auriculiformis") was difficult, since the number of sample points for these two forest types was neither representative nor adequate for our purpose (emphasizing the fact that the area of these types are relatively small compared to others'). Interestingly, the fifth class ("Mixed Broadleaves") appeared to be better represented by RF algorithm presenting high user's and producer's accuracy, whereas both ML and SVM algorithm produced unsatisfactory results.

On the other hand, it should be highlighted that the incorporation of ancillary data increased the classification accuracy. For RF algorithm, the incorporation of ancillary data increased the classification accuracy about 8% (92.25%) compared to the initial classification using only the spectral information (the five bands) (84.88%), whereas the respective accuracy for SVM increased about 4% (88.35%) compared to the initial condition (the five bands) (84.88%). On the contrary, ML algorithm had no effect on accuracy percentage even after the incorporation of ancillary data.

It should be underlined that the reduction of dimensionality

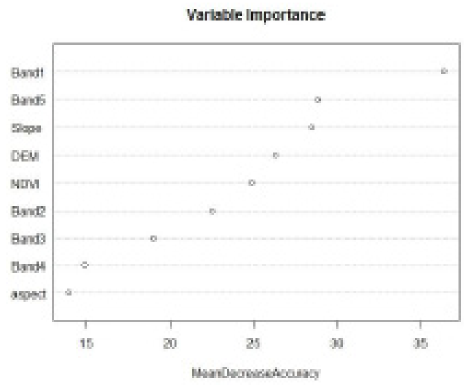

Figure 3. Variable importance graph resulted from RF algorithm

of image space, incorporating the result from variable importance graph using RF algorithm in figure 3, decreased the classification accuracy. Four variables "Green Band", Red Band", "Red Edge Band" and "Aspect" was selected having least mean decrease accuracy and classification

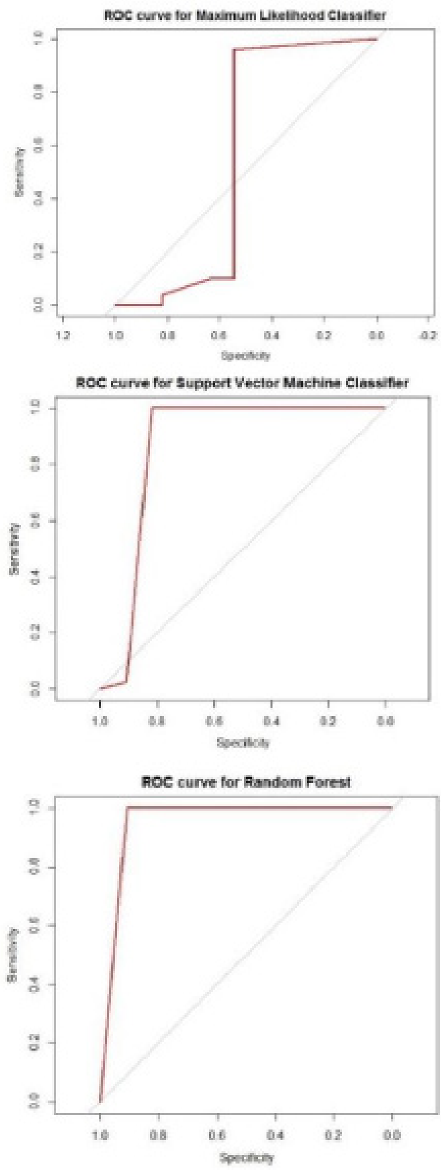

Figure 4. ROC curve for: (a) maximum likelihood; (b) support vector machine and (c) random forest classifier

was performed using optimized algorithm. Classification accuracy decreased to 81.01% and 80.38% for RF and SVM classifiers respectively. However, this fact had a reverse effect for ML algorithm, increasing the accuracy by 1% (80.13%). So, it was considered better for ML classifier to keep just those variables, since the accuracy percentages amounted to slightly higher levels. On the other hand, for both machine learning algorithms, the totality of variables was selected due to the fact that all these variables increased the classification accuracy.

Finally, concerning the comparison between different classification predictions, the McNemar test indicated that the observed difference between the two machine learning algorithms (RF and SVM) was not statistically significant ($p = 0.2278 > 0.05$). However, it should be emphasized that the difference was statistically significant ($p < 0.05$) in classification accuracy between ML and RF algorithms ($p = 7.229e-5$) as well as between ML and SVM classifiers ($p = 0.0013$).

3.4 Performance comparison

A ROC curve along with AUC value for each algorithm was generated to evaluate the overall performance in term of goodness of fit of the classifiers, as depicted in Figure 4. RF algorithm provided very satisfying results in terms of performance and this fact is confirmed by the shape of ROC curve. The goodness of fit of SVM classifier is comparable to RF, presenting almost similar ROC curve with RF's. Nevertheless, ML algorithm showed the worst performance compared to other two machine learning algorithms. Moreover, the general trend of AUC value confirms once more that ML classifier was the least efficient (AUC = 0.7321), followed by the SVM (AUC = 0.8376) and RF algorithm (AUC = 0.8716).

4. DISCUSSION

In general, the classified forest cover maps, as produced by RF and SVM algorithms, provided similar and more coherent depiction of forest cover maps within the study. But ML classification produced some salt and pepper effect which made the map less discernible.

The inclusion of ancillary data such as NDVI, elevation, slope and aspect increased the overall classification accuracy for both machine learning algorithms; whereas reduction of dimensionality of image space after determining important predicting variables increased the accuracy for ML classifier.

The comparison of overall classification accuracy (overall accuracy and kappa statistics) between algorithms suggests that there is a small improvement in accuracy (4%) when using RF over SVM algorithm. But, there seems to be a significant improvement in accuracy while choosing machine learning algorithms over classical parametric algorithms i.e. improvement by 8% for SVM and by 12% for RF classifiers. However, the size of test data was small (157) to assess such difference. So, we can consider the trend found as tentative. Despite the low sample size of test data, McNemar's test revealed that there is no statistical significant difference between classification accuracies achieved by applied machine learning algorithms (RF and SVM). However, statistically significant difference ($p < 0.05$) was observed for classification accuracy achieved by RF and SVM algorithms when compared to ML classifier.

Other studies have indicated that both RF and SVM can achieve similar classification accuracies outperforming the corresponding accuracy of ML. Duro et al., (2012) reported that pixel based classification using RF and SVM algorithms produced statistically similar overall classification accuracy classifying agricultural landscapes. Otukei & Blaschke (2010) found that SVM performed better than classical ML algorithm. In the same context, Sesnie et al. (2010) performed classification of rainforest types using SVM and RF classifiers and found to perform comparatively well.

The area under ROC curve (AUC) also suggested that there is a small improvement in goodness of fit of models using RF algorithm rather than using SVM; but there is a larger difference in goodness of fit produced by both RF and SVM when compared to ML. However, ML algorithm showed better results in time execution for the whole process of image classification (modeling and predicting) than the respective times of RF and SVM.

It is argued that classification accuracy is a critical parameter for selecting the appropriate classifier for image classification. But in such circumstances where there is no statistically significant difference in classification accuracy between RF and SVM algorithms, other preferences may take precedence. RF is simple in parameter tuning as it only may change one parameter for optimizing algorithm; whereas in SVM classifier should be supplied with combination of two important parameters for optimization. Moreover, RF is preferred for its accessibility to variable importance (Sesnie et al., 2010). The performance of RF in terms of time execution is also slightly higher than that of SVM's.

The paper tried to conduct comparison of different classifiers taking into consideration multiple aspects of algorithms dynamics and weaknesses, since most of the researchers are primarily focused on overall/user/producer accuracy and/or kappa statistics ignoring the weak points of these methods (without invalidating the importance of the respective methods) (Mallinis et al., (2006), Rogan et al., (2002)). Hence, it was preferred to be conducted a thorough comparative analysis of the most used classifiers in remotely sensed data of medium spatial resolution, applying multiple metrics and exploring the corresponding strong and weak points of each classifier. This practice may strengthen the arguments of adopting one over the other classifier not only in the current study area but also in similar projects.

5. CONCLUSION

Pixel based classification of forest cover using classical ML and two machine learning algorithms i.e. SVM and RF algorithms was performed. Machine learning algorithms can enhance quality of output in pixel-based forest cover classification than classical approach, as machine learning approach produced classification accuracies that were statistically significant different compared to classical approach. But there is no statistical significant difference in classification accuracy between the two adopted machine learning algorithms. The performance of machine learning classifiers concerning the goodness of fit is also higher than classical approach. However, machine learning algorithms are much time consuming than classical parametric approaches. Visual inspection of thematic products resulted from the three algorithms shows that they are capable of producing forest cover maps with satisfying classification accuracies; however, ML classifier is more prone to salt and pepper effect. So, machine learning algorithms seem a bit superior than classical ML for forest cover classification in this study area. However, there appeared to be no advantage in selecting a particular machine learning approach.

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EFFECTS OF SERVICE-SPECIFIC ON-THE-JOB TRAINING: A CASE STUDY OF THE DIGITAL CADASTRE AND OFFICE MANAGEMENT TRAINING PROGRAMME

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ABSTRACT

Government of Nepal (GoN) has provisions for promoting civil servants both on evaluation of competency and internal competitive examination basis. In the competency based system, non-gazetted I and II class employees' performance is assessed on a yearly basis and are awarded points by their supervisors. Non-gazetted II and I class employees who secure the highest points are promoted as non-gazetted I and gazetted III class officer respectively. On the job training (OJT) is one of the criteria to get points/marks for promotion. "The civil servants who have successfully completed on-the-job training (OJT) spanning 30 days are awarded two points." These two points can become really valuable and significant to outperform the rest of their colleagues and get promoted. Personal Training Academy (PTA) was the only institution conducting such training for non-gazetted employees of all services. On 27th of December 2016,Land Management Training Centre launched the In-service training (30 days) on Digital Cadastre and Office Management for non-gazetted I and II class employees and became the second institution in Nepal that offers OJT trainings to civil servants

The remarkable feature of this training is that out of ten services of Government of Nepal (GoN), only Survey Group under Nepal Engineering Service can participate. Further, innovative feature of this training is that it incorporates service-specific course contents in addition to subject matter focusing on office management. Participants can obtain technical knowledge on carrying out digital cadastral survey, updating and maintaining digital cadastral database and delivering all cadastral services effectively in a digital environment using Land Information System (LIS). However, participants could gain only knowledge on office management from the OJT delivered by the PTA. So, the aim of this paper is to evaluate the effectiveness of service-specific OJT with employees' performance. Critical analysis of data collected through a 10-item questionnaire from 45 attendees of the training and their employer was carried out. The employees' performance was analysed considering the following factors: career satisfaction, productivity and responsiveness to meet organizational objectives.

The study showed that the establishment of additional training institutions in each service sector providing OJT awarding points for promotion is imperative for increasing enthusiasm in civil servants. Such training clearly improves the performance of civil servants because it enhances their skills and knowledge to master their current job and most importantly boost their confidence on their employer's concern about their career progression. The outcomes of this research recommend to start OJT dedicated to each service of GoN.

KEY WORDS

On-the-job training, Digital Cadastre, Land Management, Employees' performance

1. INTRODUCTION

The modern public service can be traced back to 1770 when Nepal was formed by the unification of small kingdoms. At that time, the royals exercised all powers to appoint civil servants and the important positions were decorated by the courtiers and their offspring and families. Nepal witnessed its first revolution in 1950, when the people overthrew the oligarchic Rana administration. The change to democratic government drove the establishment of the Public Service Commission (PSC) of Nepal in 15 June 1951 and recruited civil servants at all levels. This granted the common Nepalese privilege of working as prominent civil servants (Thapa, 2010). After the passage of Public Service Act 1975, civil service became formal. In May 1998, the Public Service Act was amended by the parliament which incorporated issues on promotion, performance evaluation and training of public servants.

Civil servants are recruited either by open competition or by promotion. The proportion, however, differs for gazetted and non-gazetted employees. For non-gazetted I and II class positions, 60% of the vacant positions are fulfilled by open competition while the remaining 40% comes from promotion. Out of the 40% promotional seats, 20% is filled in by evaluation of a candidate's competency and the rest by an internal competitive examination. Meanwhile, for gazetted III class position, 70% of the vacant post is filled in by an open competition while the remaining 30% comes from promotion. Among the 30% promotional seats, 10% is filled in by the evaluation of a candidate's competency, 10% by internal competitive examination and the remaining 10% by evaluation of a candidate's work performance and experience.

For the evaluation of competency, the work efficiency of each civil servant is evaluated by a committee chaired by a member of PSC, granting a maximum of 100 marks. The scores are awarded as follows: forty points for work performance evaluation; thirty points for seniority; twelve points for educational qualification; sixteen points for service in geographical region and two points for training (Civil Service Act, 2049 (1993), 2007). The two points for training is only awarded to civil servants who successfully undertook an on-the-job training (OJT) spanning 30 days from institutions recognized by the Government of Nepal (GoN).

On-the-job (OJT) for the civil servants dates back to the Rana administration period. With the rise of democracy, the greater need of training was felt to enrich the civil servants with new skills, knowledge and attitudes. In 1959, the National Institute of Public Administration was proposed to provide pre-service and in-service training for government employees. Even though approved by the GoN, it could not come into existence. In 1962, an administrative board headed by a senior permanent secretary was formed to conduct training of the civil servants. Until the establishment of the Central Training Department (CTD) in 1967, the Department of Public Administration was responsible for undertaking training of newly recruited gazetted III class officers. Subsequently, the training of government employees were entrusted to three institutions (i) the training wing of the Ministry of General Administration (ii) the Panchayat Training Centre under the Ministry of Panchayat and Local Development and (iii) the Centre for Economic Development and Administration (CEDA) of Tribhuwan University. During 1970's, due to insufficient trained human resources, numerous national development plans implemented did not meet their targets. The necessity of a permanent national level institution dedicated to produce trained personnel continuously and coherently was much felt (Tuladhar, 2007). Consequently, under the Nepal Administrative Staff College (NASC) Act, 1982, NASC was established on 27th September, 1982. It is the only national level autonomous organization which provides training to employees from all levels of the GoN (NASC, 2018). NASC provides in-service, pre-service and refresher training courses to all levels of civil servants. Later in 8 February 2010, the Personnel Training Academy (PTA) functioning under the Ministry of General Administration was entrusted to train all of the non-gazetted officers (Personnel Training Academy, 2018). PTA has been conducting a 30-day long OJT on Office Management for non-gazetted I and II class civil servants which is approved by GoN to grant two points for promotion.

Land Management Training Centre (LMTC) is a department under the Ministry of Land Management Cooperatives and Poverty Alleviation (MoLMCPA) which was established in 1968. The mission of LMTC is to develop itself as a centre of excellence for Geo-information education and professional development. LMTC is commissioned to produce qualified and competent human resource and conduct research in the field of Surveying and Mapping, Land Administration and Geo-information. The centre trains survey technicians and land administrators at different skill levels through various types of training programmes in Surveying and Mapping, Land Administration and Management and various digital mapping technologies. It carries out two 12 month long training programmes: Senior Survey Training and Junior Survey Training. The centre also provides academic courses for Diploma in Geomatics Engineering, Bachelor in Geomatics Engineering and Master in Land Administration in collaboration with Kathmandu University. Additionally, LMTC administers short-term flexible professional courses in Geographic Information System, Land Information System, Land Administration and Management, Land Use Planning and Zoning, Digital Cadastre and Remote Sensing as per governmental needs for capacity building. Over the past 50 years, LMTC has produced more than 9000 graduates from these programmes (Land Management Training Centre, 2018).

There are over 83000 civil servants working in ten services namely, Administration Service; Economic Planning and Statistics Service; Education Service; Engineering Service; Agricultural Service; Forestry Service; Health Service; Judicial Service; Miscellaneous Service and Parliamentary Service. The biggest proportion is composed of non-gazetted civil servants requiring the highest demand of OJT for the non-gazetted level. But, PTA delivers the training to only few selected candidates each year from all ten services. Seventy-one non-gazetted civil servants were provided OJT training in the year 2014. In 2015, PTA trained 115 non-gazetted civil servants (Personal Training Academy, 2015). There is increment in the training opportunities; however, it is insufficient to meet the demand. And the need for establishing OJT opportunities from other institutions became apparent. Until late 2016, PTA was the only institution conducting a 30-day long OJT. Therefore, in 27 December 2016, LMTC launched an in-service training on Digital Cadastre and Office Management spanning 30 days for non-gazetted I and II class employees.

Amongst the several trainings provided by LMTC, the most recent OJT training on Digital Cadastre and Office Management has stood out. The striking feature of this training is that: out of ten services of GoN, only employees from the Nepal Engineering Service, Survey Group can participate.

The office management training incorporates following contents: writing skills; working skills; IT skills; personality development; ethics, morality and good governance;

government accounting system and basic management skills (Public Training Academy, 2018). Another innovative feature of the OJT training of LMTC is that it incorporates service specific course contents in addition to subject matters focusing on office management. Participants can obtain technical knowledge on carrying out digital cadastral survey, updating and maintaining digital cadastral database and delivering all cadastral services effectively in a digital environment using Land Information System. Meanwhile participants could gain only knowledge on office management from the OJT delivered by the PTA. So, the aim of this paper is to study whether service specific OJT is necessary and how it affects employees' performance.

2. METHODS

2.1 Pre-evaluation Questionnaire Survey

This research was conducted amongst the non-gazetted I and II class employees who have completed the OJT on Digital Cadastre and Office Management conducted by LMTC. Presently, there are 70 successful trainees. Before the commencement of the training, pre-evaluation questionnaires were handed out to each participant to be filled up by the latter. Out of all the participants, we selected 45 respondees who have time enough (more than six months) to apply the skillsets gained from the OJT in their respective District Survey Offices.

The pre-evaluation questionnaire contains 10 items assessing the trainees' proficiency: whether they have working knowledge on using a computer and GIS software; willingness to deliver services digitally; tasks they can deliver digitally; infrastructure and working environment at their office; their supervisor's attitude towards implementing digital technology and their knowledge on a number of office management related tasks. Weights were assigned to each multiple choice questions as in Table 1.

2.2 Post-evaluation Questionnaire Survey

For unbiased evaluation, same set of questions were handed out to the respective supervisors of the selected 45 survey participants. Weights were assigned to each multiple choice questions as illustrated in Table 2.

2.3 Grading

We used quantitative approach to analyse the data because "quantitative results also emphasize the qualitative results" (Kumar, 2000). For each participant's response, the total value according to assigned weights was calculated. The values were then converted into percentage. Relative marks of "A", "B" and "C" were calculated according to minimum value, maximum value and their interval was divided by 3 to get the grade interval.

Accordingly, for each employer's response, the total value was computed according to the assigned weights and was then converted into percentages. The difference of the minimum and maximum value was divided by 3 to get the grade interval for "A", "B" and "C" marks.

2.4 Contingency table and chi-squared (χ^2)

The sample size (45) being sufficiently large in comparison to the population (75), it was appropriate for the chi-square test. For this, the two way table (contingency table) for observed frequencies (O) and expected frequencies (E) were computed. The contingency table of observed frequencies was prepared by calculating the number of respondent falling under the above designated grading system. The expected value was calculated by the formula E = (row total*column total)/grand total.

Then, the value of chi-squared (χ^2) was evaluated using Equation (1) given below:

$$\chi^2=(O-E)^2/E \quad (1)$$

Afterwards, the degrees of freedom was computed.

Degrees of freedom= (total row-1)*(total column-1) (2)

Here, the total row and total column means the number of rows and columns of the contingency table respectively.

2.5 Hypothesis Testing

Chi-square test is one of the most utilized statistical tools that answers the question whether the categorized variables are associated or different with each other (Franke, Ho, Christie, & Franke, 2011).

The following null hypotheses (H_0) and alternative hypotheses (H_1) were proposed:

H_0: There is no relationship between training and post training performances.

H_1: Employees perform better after training.

The critical value of χ^2 was tabulated for level of significance (10%, 5%, 2.5%, 1% and 0.1%) using the values of χ^2 from the table provided in (MedCalc Software bvba, 2018).

If the calculated value of χ^2 is greater than the tabulated critical value of χ^2, H_0 is rejected meaning, at a certain level of statistical significance, there is a relationship between training and post training performances. Otherwise, H_0 is accepted showing no relationship between training and post training performances.

3. RESULTS AND DISCUSSION

Table 1 illustrates for each pre-evaluation question, the number of responses per category. Table 2 shows for each post-evaluation question, the number of responses per category. Before the training, only 20% of the trainees had knowledge on operating a computer and even less (7%) had knowledge on using a GIS software. After the training, the trainees with knowledge of computer and GIS raised tremendously to 80%. Prior to the training, 44% of the trainees did not know to perform any task delivered by

Table 1. Pre-evaluation survey results

Questions for evaluating performance

S.N.	Questions	Category	Weight for each category	Response	Weight per question
1.	Do you have working knowledge on using a Computer?	a. No	2	15	10
		b. A little bit	5	21	
		c. Yes	10	9	
2.	Do you have knowledge on using a GIS software?	a. No	2	5	10
		b. A little bit	5	37	
		c. Yes	10	3	
3.	Do you desire to deliver the services of your institution digitally?	a. Yes	5	45	5
		b. No	2	0	
4.	Which of the following tasks can you perform in a digital environment?	a. Map Print	For none: 2	20	10
		b. Trace Print	For one: 3	14	
		c. Split Parcel	For two: 5	9	
		d. Merge Parcel	For three:7	0	
			For four(all): 10	2	
5.	Is the infrastructure and working environment in your office conducive in implementing digital technology?	a. Yes	5	21	5
		b. No, but it can be	3	24	
		c. No and it cannot	2	0	
6.	Do you think your boss is positive to implement digital technology?	a. Yes	5	36	5
		b. No	2	0	
		c. No, but I can convince	3	9	
7.	Were you previously involved in writing Annotate and acquainted with the process of decision making of Governmental Institution?	a. No	2	29	10
		b. A little bit	5	16	
		c. Yes	10	0	
General Questions (No Weight)					
8.	Do you think, an employee is motivated by getting such training opportunity?			a. Very much	41
				b. A little bit	3
				c. No	1
9.	Can such capacity building trainings increase the loyalty of employee towards their institution?			a. Very much	30
				b. A little bit	13
				c. No	2
10	Your feedback on the training?				

the survey offices digitally. This figure significantly dropped to just 1%. So, after the training most of the trainees delivered at least one services digitally. Similarly, after the training, the percentage of trainees who were able to write annotate and understand the decision making process of Governmental Institutions increased to 82% from 64%.

For each response, the total value was calculated and converted to percentage. From the pre-evaluation survey, the minimum value was found to be 34.55 while the maximum value was 81.82 shown in Table 3. The calculated grade interval was 15. This grade interval was used to compute the limits of each grade. In table 3, the calculated limits of each grade can be seen.

Similarly, for the post-evaluation survey, 45.55 and 100 were the minimum value and maximum value shown in Table 4. The calculated grade interval was 18. Using this grade interval, the limits of each grade were determined and the results can be seen in table 4.

Then, the observed contingency table and expected contingency table were made. Table 5 shows the observed contingency table while Table 6 shows the expected contingency table.

Calculation of the value of chi-squared from the two contingency tables is shown in Table 7. Afterwards, the degrees of freedom was calculated and was found to be 4.

The tabulated critical value of χ^2 for 4 degrees of freedom and selected levels of significance are shown in table 8.

Table 2. Post-evaluation survey results

Questions for evaluating performance

S.N.	Questions	Category	Weight for each category	Response	Weight per question
1.	Does s/he have a working knowledge on using a Computer?	a. No	2	0	10
		b. A little bit	5	9	
		c. Yes	10	36	
2.	Does s/he have knowledge on using a GIS software?	a. No	2	0	10
		b. A little bit	5	9	
		c. Yes	10	36	
3.	Is s/he desire to deliver services of your institution digitally?	a. Yes	5	45	5
		b. No	2	0	
4.	Which of the followings tasks can s/he perform in a digital environment?	a. Map Print	For none: 2	1	10
		b. Trace Print	For one: 3	7	
		c. Split Parcel	For two: 5	8	
		d. Merge Parcel	For three:7	4	
			For four(all): 10	25	
5.	Is the infrastructure and working environment in your office conducive in implementing digital technology?	a. Yes	5	37	5
		b. No, but it can be	3	8	
		c. No and it cannot	2	0	
6.	Are you positive to implement digital technology?	a. Yes	5	45	5
		b. No	2	0	
		a. No	2	1	
7.	Is s/he involved in writing Annotate and acquainted with the process of decision making in Governmental Institution?	b. A little bit	5	37	10
		c. Yes	10	7	
General Questions (No Weight)					
8.	Do you think, an employee is motivated by getting such training opportunity?			a. Very much	37
				b. A little bit	5
				c. No	3
9.	Can such capacity building trainings increase the loyalty of employee towards their institution?			a. Very much	25
				b. A little bit	15
				c. No	5
10	Your feedback on the training?				

Table 3. For Pre-evaluation, calculated grade interval based on percentage of scores

		Grade	Interval
Minimum Value	34.55	C	34-49
Maximum Value	81.82	B	49-64
Average Value	54.30	A	> 64

Table 4. For Post-evaluation, calculated grade interval based on percentage of scores

		Grade	Interval
Minimum Value	45.45	C	45-63
Maximum Value	100	B	63-81
Average Value	83.43	A	>81

Table 5. Contingency table of observed frequencies

		Post-evaluation			Total
		A	B	C	
Pre-evaluation	A	5	0	0	5
	B	26	0	0	26
	C	5	1	8	14
Total		36	1	8	45

The calculated value of χ^2 is 24.91 as seen in Table 7. By comparing the calculated χ^2 value with the critical value of χ^2 in Table 8, it can be seen that for all levels of significance, the calculated value of χ^2 is greater than the critical value of χ^2. In such condition, H0 hypothesis that there is no relationship between training and post training performance is rejected. This shows, employees perform

Table 6. Contingency table of expected frequencies

		Post-evaluation			Total
		A	B	C	
Pre-evaluation	A	4	0.1111	0.8889	5
	B	20.8	0.5778	4.6222	26
	C	11.2	0.3111	2.4889	14
Total		36	1	8	45

Table 7. Calculated value of χ^2 from the contingency tables

(O-E)	$(O-E)^2$	$(O-E)^2/E$
1	1	0.25
-0.11	0.01	0.11
-0.89	0.79	0.89
5.20	27.04	1.30
-0.58	0.33	0.58
-4.62	21.36	4.62
-6.20	38.44	3.43
0.69	0.48	1.53
5.51	30.37	12.20

Value of $\chi^2 = 24.91$

Table 8. Critical value of χ^2 for 4 degrees of freedom

Degree of freedom	Level of Significance (α)				
	10%	5%	2.5%	1%	0.1%
4	7.779	9.488	11.143	13.277	18.467

better after the training.

Effectiveness of the training is gratifying. It was found that the participants are doing their jobs better after the completion of the OJT. The OJT supplements effective and efficient service delivery because the participants deliver cadastral services in the digital environment using Land Information System (LIS). Also, this has improved accountability, a key element of good governance, as the digital system keeps log of each person performing each task which is very difficult in paper based system. The participants are motivated to update and maintain digital cadastral database and deliver cadastral services digitally because of faster service delivery and less errors compared to paper based system resulting in improved public satisfaction.

Even though the OJT is mostly popular due to the promotional points, it also increased employee's performance and productivity. Thus participants can not only obtain 2 points for training but also have increased chances of scoring high points for the work performance evaluation further increasing their chances to outperform their peers and get promoted.

4. CONCLUSION

The outcomes of this study demonstrated the OJT of LMTC is commendable and it is undoubtedly necessary to start OJT dedicated to each services of GoN. The immediate benefit of service-specific OJT is the reduced competition and higher chances of civil servants to get nominated for the training. However, in the long run, such training improves the productivity of the civil servants and their responsiveness in meeting organizational objectives because of the assurance that their employer is concerned about their career progression. The performance of the graduates of the training is enhanced because of acquired service-specific knowledge to master their current job.

From 28 May 2008, Nepal became a federal democratic republican (Thorpe, 2009). However, the new government is working rigorously to implement federalism inside the nation. Proliferation of federalism can be an additional challenge for incorporating the OJT and further study should be directed on how to implement the training in the federal level.

5. ACKNOWLEDGEMENTS

We would like to acknowledge Land Management Training Centre (LMTC) for the support and guidance in the successful completion of this research, especially, for the tremendous input on information about participants of the OJT and their institutions

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ASSESSING THE OVERALL ACCURACY OF UAV PHOTOGRAMMETRY: A METHODOLOGY FOR DIFFERENT COMBINATION OF IMAGERY PARAMETERS AND TERRAIN TYPES

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ABSTRACT

The onboard Global Positioning System (GPS) and Inertial Measurement Unit (IMU) technology on the UAVs are not capable enough to provide the optimum level of accuracy in photogrammetric results. The inclusion of GCPs is the key factor to improve the accuracy of the results. This paper assesses the accuracy of UAV based photogrammetric products in three different sites over different sets of flight parameters. The parameters that were concerned in the study were image overlap, number of GCPs and their distribution. The images from three different sites (Plane Area, Corridor and Area with Undulating Terrain) were processed and tested for different number and configuration of GCPs. The effect of overlap change was analyzed for undulating terrain only. The acquired results were compared amongst each other and the most accurate configuration of GCP for each terrain type was determined. Die shaped GCP configuration was found to provide the optimal accuracy in case of plane area. Furthermore, it resulted out that three GCPs as the general assumption for georeferencing a surface were enough for small area (about 12,800 sq.m.) and the GCP number showed linear nature with the increment in area to be surveyed. In case of corridor mapping, it was observed GCP distributions dependency on the corridor length with GCPs alternating each side of the linear feature, separated by an offset distance along that feature. The study showed the optimum number of GCPs to be four along the corridor feature being mapped. Finally, the assessment revealed that the GCPs should be established in positions covering all elevations with minimum of five GCPs in die shape. The accuracy of Digital Surface Model (DSM) and Orthomosaics were highly influenced by the image overlap, number of GCPs and their configuration. The choice of optimum number of GCPs following a suitable pattern would lead to generate most accurate photogrammetric products and hence make UAV survey time and cost effective.

KEY WORDS

UAV, Photogrammetry, GCP Pattern, Image Overlap, Accuracy

1. INTRODUCTION

The use of UAV for topographical mapping is common these days. The use of photographs in such mapping, benefit not only in accuracy but in better visualization of topography and efficient planning too. The image overlap and GCPs is key factor affecting the accuracy of photogrammetry. These factors shows high variation for different terrain types. So, it seems essential to research on plane area, corridor and Area with Undulating Terrain.

Unmanned Aerial Vehicle (UAV) as data acquisition medium and survey measurements is being attractive for surveying applications. The surveying applications however demand higher accuracy which is unable to be achieved without the usage of precise ground control points (GCP). The inclusion of GCPs in the process to get photogrammetric products further enhances the accuracy to a level better than depending only on onboard Global Positioning System (GPS). The GPS and Inertial Measurement Unit (IMU) technology on the UAVs are not capable enough to provide the optimum level of accuracy in photogrammetric results. This is mainly because of the commercial grade GPS equipped on UAV and hence provides an accuracy up to 2m. As a result, each photo captured along with the output from UAV and photogrammetric processing can have a maximum error of 2m (Udin & Ahmad, 2014).

Precise GCPs shall be established throughout the project area in accordance to accommodate the accuracy. These GCPs are the points located on the ground having known horizontal and vertical position. The same points are marked on the images later during the image processing so that we can achieve the desirable accuracy. Apart from this, the image overlap is another factor that needs to be taken into consideration. There is always a lack of proper guidelines for setting these parameters. The number of GCPs, image overlap is always restricted to some extent considering the limited time and budget of the project.

So, this study stands as an attempt to find a valid answer regarding the optimum number of GCPs, distribution pattern and image overlap on different kinds of study area.

1.1 Related Work

The overlapping degree of UAV aerial imagery is an important parameter in judging the quality of aerial photography (Coffman & Salazar, 2015). The combination of GPS/INS in UAV increased the accuracy of UAV to determine point of measurement as discussed in (Cesetti, et al., 2011). For direct gereferencing, on board GPS data are used while ground check points are being used for evaluation (Skarlatos, Procopioub, Stavrouc, & Gregorioua, 2016). This act helps in enriching the horizontal accuracy whereas the vertical accuracy still remain unaffected (Cesetti, et al., 2011). It shows the importance of indirect georeferencing, i.e. establishing the Ground Control Points (GCPs). A minimum of three GCPs is required but increasing the number of GCPs will lead to higher accuracy of the final results (Oniga, Breaban, & Statescu, 2018). The optimum number of GCPs and their distribution pattern vary with the area and the type of feature to be mapped (Tahar, 2013), (M, Jain, Srinivasa, & S, 2016).

2. METHODS

The methodology follows the data preparation, data collection, data processing, result, analysis and discussion. The figure 1 below shows the overall methodology used in the study.

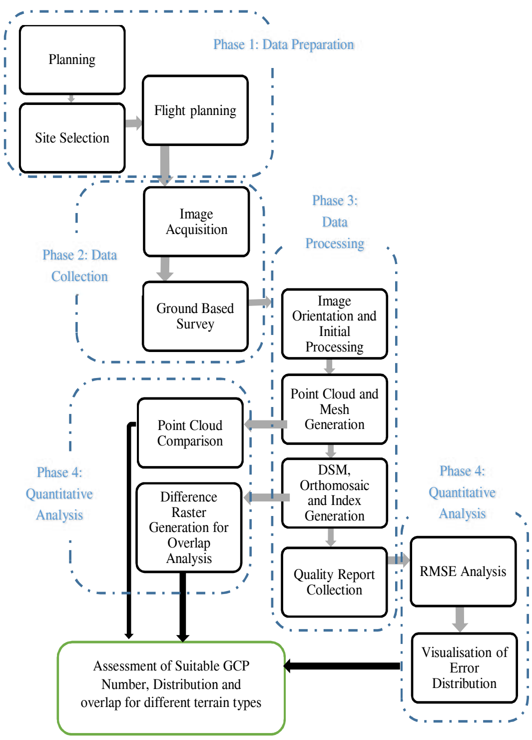


Figure 1. Workflow of the methodology of the study

Among the different parameters involved in image acquisition using an UAV, a set of configurations to be analyzed were prepared. The number of GCPs, flying height, UAV velocity and flight plan were kept constant for change in overlap assessment was carried out. Two missions were conducted with varying overlap keeping no change in the rest of the parameters. Usually, increase in overlap percentage would always provide the better-quality outputs. So, the study was conducted with only changing the overlap percentage and analyzing for the change in accuracy. The change in image overlap was tested only for Area with Undulating Terrain.

For the accuracy assessment with the variation in number of GCP; like the former method, all other parameters such as image overlap, UAV velocity, height of flight etc. were kept the same. The analysis was carried out over different topography; therefore, three different sites were taken and the acquisition of images, processing and analysis for each was done exclusively. For the acquisition of image, during flight planning, the flight parameters viz. overlap, height of flight, camera velocity etc. were properly set such that it covers all permutations of number of GCPs and distribution configurations. The images were acquired in such a manner so that desired Ground Sampling Distance (GSD) was obtained. The geolocation of GCPs were determined using ground-based surveying methods (i.e. Differential GPS survey). The reason behind conducting high precision DGPS survey was to set a network of control points for the process of geo-referencing the images.

The acquired images were then processed in the available image processing software package. The image processing algorithms followed the steps from tie point matching, building sparse and dense point clouds, geo-referencing the point clouds and finally result out the orthomosaic, digital terrain models as well as the quality report of processing. The quality reports obtained for each configuration were later used for the analysis purpose.

The Root Mean Square Errors (RMSE) from the quality reports were evaluated and visualized using graphs. Also, the point clouds obtained from the processing software were subjected to analysis using image processing software to obtain a qualitative representation of the differences among them. In addition to this, the DSM representing two different image overlap were analyzed using the image differencing technique to visualize the detected change in surface models.

2.1 Study Area

The three sites were selected based on the varying topography as mentioned in table 1. The figure 1 shows the map of project area.

Table 1. Sites used for study

Site	Location	Area (m^2)
Site 1: Plane area	Ravi Opi, Dhulikhel	12,800
Site 2: Corridor	Punyamata River, Panauti	108,400
Site 3: Area with Undulating terrain	Kathmandu University, Dhulikhel	368,500

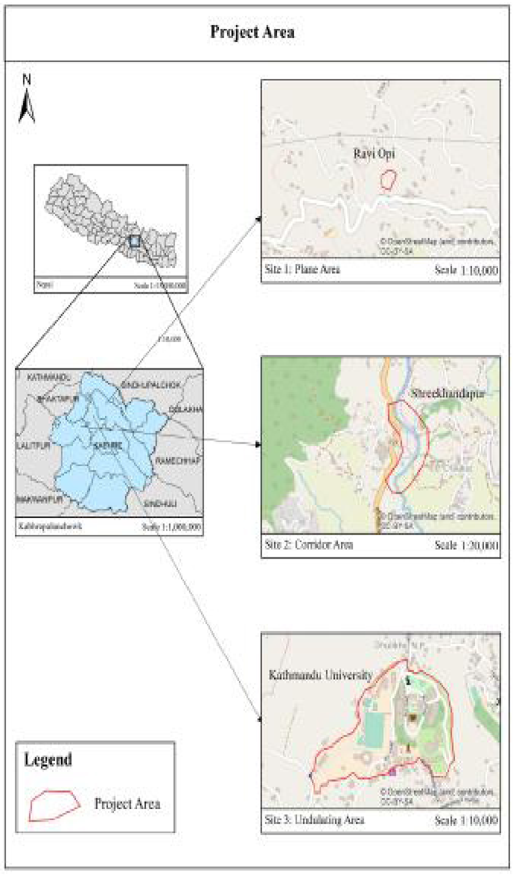


Figure 2. Project Area: (a) Plane Area (b) Corridor and (c) Area with Undulating Terrain*

(*Scales are appropriate for A4 (8.27”X11.69”) paper only)

2.2 Process

2.2.1 Number of GCPs and their Distribution Pattern

Map Pilot application was used for flight planning during image acquisition. The height of flight, image overlap, flight mission and area were manually set in the application for each site. DJI Phantom 3 Advanced was used for image acquisition. The camera lens used was of Field of View (FOV) 94° 20 mm (35 mm format equivalent) f/2.8 focus at ∞ and the image size was 4000x3000. The images were acquired with an overlap of 80/60 for all the sites and the flight height was 25m, 40m and 50m (i.e. above ground level) for Site 1, Site 2 and Site 3 respectively. The images were captured with a GSD of 1.33 cm / 0.52” for Site 1, 2.03 cm / 0.8” for Site 2 and 4.08 cm / 1.6” for Site 3 respectively.

The Ground based survey was performed by static Differential Global Positioning System (DGPS) survey using Stonex S8 Plus receiver. GNSS Solution was used for processing the raw observation data files. The distribution of control points was made on the basis of different topography as shown in table 2.

Table 2. Number of Control Points

Site	Total Ground Stations	Ground Control Points	Check Points
Site 1	13	3-7	6
Site 2	15	3-9	6
Site 3	20	3-9	11

The GCP distribution for all of these sites was made as depicted in the figure 3 (a, b & c). A various pattern of GCP were used the decision of using such distribution was made on the basis of change in study area.

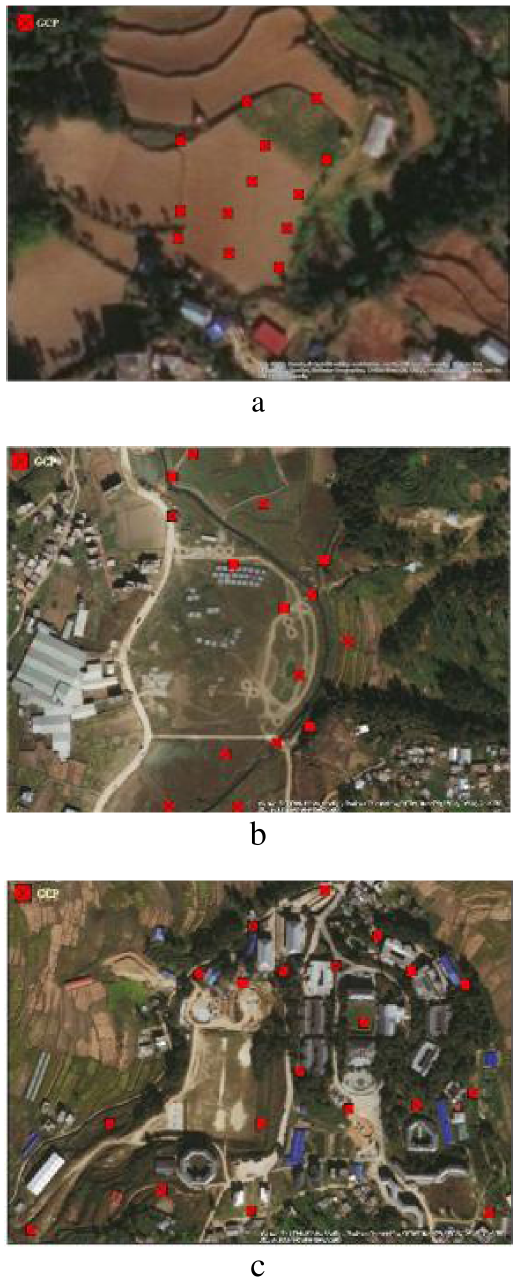


Figure 3. GCP Distribution in (a) Site 1: Plane Area (b) Site 2: Corridor and (b) Site 3: Area with Undulating Terrain

Furthermore, the different GCP configuration used in each of these areas were as following:

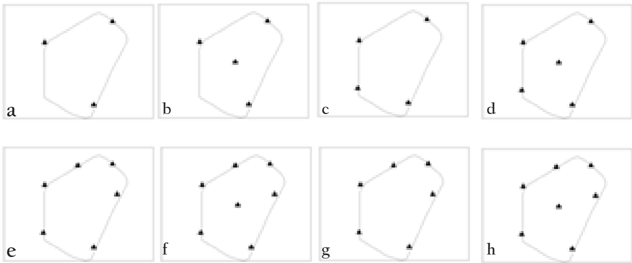


Figure 4. Set of Different GCP Configurations used for (a) Site 1: Plane Area (a) 3 GCP, (b) 3 GCP with 1 at center, (c) 4 GCP, (d) 4 GCP with 1 at center, (e) 5 GCP, (f) 5 GCP with 1 at center, (g) 6 GCP, (h) 6 GCP with 1 at center

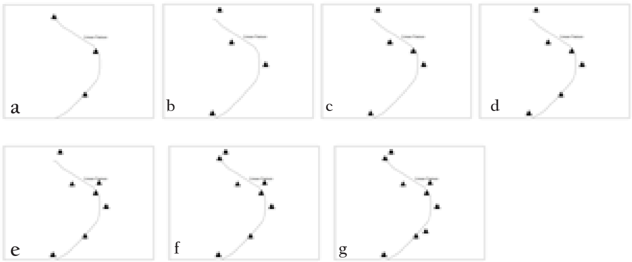


Figure 5. Set of Different GCP Configurations used for (a) Site 2: Corridor (a) 3 GCP, (b) 4 GCP, (c) 5 GCP, (d) 6 GCP, (e) 7 GCP, (f) 8 GCP, (g) 9 GCP

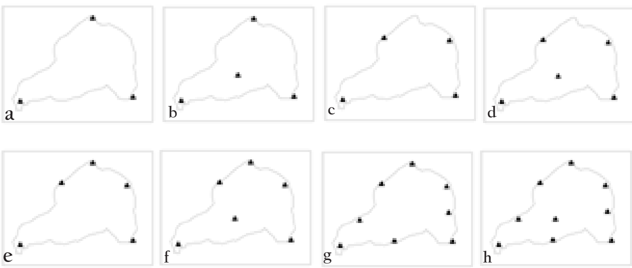


Figure 6. Set of Different GCP Configurations used for (b) Site 3:Area with Undulating Terrain (a) 3 GCP, (b) 3 GCP with 1 at Center, (c) 4 GCP, (d) 4 GCP with 1 at Center, (e) 5 GCP, (f) 5 GCP with 1 at Center, (g) 8 GCP, (h) 8 GCP with 1 at Center

2.2.2 Image Overlap

For overlap analysis, two sets of images were taken over Site 3; one with 80-60 percent overlap and other with 70-50%. All the parameters other than this were kept same during the acquisition of images.Also, the same set of GCPs were selected during the processing. These set of images were processed by the Pix4D Mapper and quality report were analyzed.

3. IMAGE PROCESSING, ANALYSIS AND RESULTS

The captured imageries for all sites were processed using a commercial photogrammetric software package known as Pix4DMapper. The Control Points were registered and referenced using the co-ordinates obtained by DGPS survey during exterior orientation. For each of the sites, configuration of these control points as different sets of GCPs and Check points were selected. Different attempts of image processing were carried out for each of the configurations for all the sites. So, the orthomosaic and Digital Surface Model (DSM) for each of the site were processed with the configuration having maximum number of GCPs following the general assumption that more the number of GCP more the accuracy to some extent. The orthomosaic and DSM for the sites with the configuration having maximum number of GCPs were obtained as shown in Figure 7and Figure 8respectively.

This study utilized a UAV system for large scale mapping of three different land cover types.

Figure 7. Orthomosaic of (a) Site 1: Plane Area (GCP Configuration with 7 GCPs: 6 along the boundary and 1 at the center), (b) Site 2: Corridor (GCP Configuration with 9 GCPs: 6 alternating the feature separated by an offset and 3 along the feature), (c) Site 3: Area with Undulating Terrain (GCP Configuration with 9 GCPs: 8 along the boundary and 1 at the center)

As the study was aimed at investigating the effect of image overlap, number and distribution of GCPs for various sites and determining the optimum number of GCPs, pattern and overlap, for a particular land cover of a certain area, a quantitative and qualitative analysis technique was used. This qualitative and quantitative technique was utilized using the results obtained from the image processing.

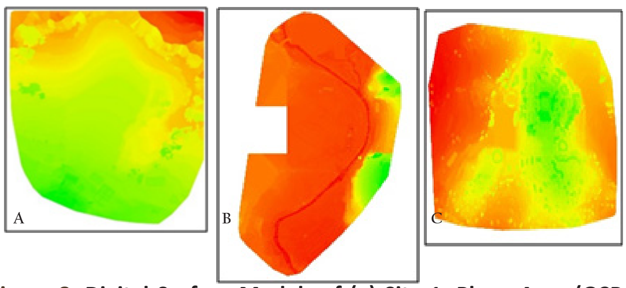


Figure 8. Digital Surface Models of (a) Site 1: Plane Area (GCP Configuration with 7 GCPs: 6 along the boundary and 1 at the center), (b) Site 2: Corridor (GCP Configuration with 9 GCPs: 6 alternating the feature separated by an offset and 3 along the feature), (c) Site 3: Area with Undulating Terrain (GCP Configuration with 9 GCPs: 8 along the boundary and 1 at the center)

3.1 Quantitative Analysis

Residual errors for each platform were examined to analyze the accuracy of the photogrammetric products. An equation to calculate the errors in photogrammetric product is shown in equation.

$\epsilon = y_i - \mu$

Where,

ϵ = Error

yi = Ground Truth Value

μ = Estimated Value

3.1.1 GCP Analysis

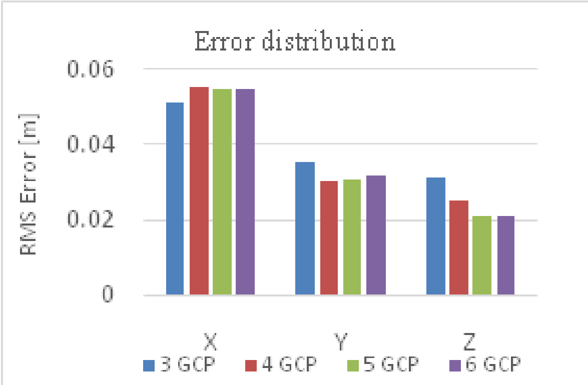
i) Plane Area

The site was covered with a total of 13 control points; all of which were used as ground control points and check points. The errors in X & Y and X, Y & Z were found as following:

Table 3. Root Mean Square Error (RMSE) in X & Y and in X, Y & Z for different GCP configuration in Site 1: Plane Area

GCP Configuration	RMS Error in X and Y (m)	RMS Error in X,Y and Z (m)
3 GCPs	0.044	0.040
3 GCPs with a central GCP	0.044	0.039
4 GCPs	0.045	0.039
4 GCPs with a central GCP	0.045	0.039
5 GCPs	0.044	0.038
5 GCPs with a central GCP	0.044	0.038
6 GCPs	0.045	0.038
6 GCPs with a central GCP	0.045	0.038

The errors in X,Y and Z in the above patterns were found to range from a total of 4.0 cm to 3.8 cm and errors in X and Y were found to range from 4.5 cm to 4.4 cm. The decrement in error was found to be very sluggish. For such an area, the densification of GCPs therefore were not found to be key player. The addition of GCPs only increased the cost of the project. The use of minimal number of GCPs is hence recommended for such a small area. The graphs developed from the error distribution were as following:



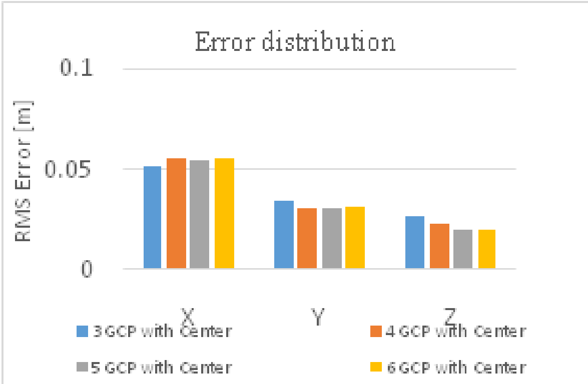


Figure 9. Root Mean Square Error (RMSE) in X & Y and in X, Y & Z for different GCP configuration in Site 1: Plane Area

The above graph shows, for a small plane area, the addition of a GCP in the central region was not found to play a major role in accuracy. Thus, such GCPs could be omitted for a similar site. In such cases, only the few GCPs covering the study area could be used. However, it should be noted that number of GCPs showed dependency on the study area.

ii) Corridor Mapping

The site was covered with a total of 15 control points; all of which were used as ground control points and check points. The errors in X & Y and X, Y & Z were found as following:

Table 4. Root Mean Square Error (RMSE) in X & Y and in X, Y & Z for different GCP configuration in Site 2: Corridor

GCP Configuration	RMS Error in X & Y (m)	RMS Error in X, Y & Z (m)
3 GCPs	0.111	0.182
4 GCPs	0.109	0.160
5 GCPs	0.109	0.159
6 GCPs	0.082	0.136
7 GCPs	0.116	0.129
8 GCPs	0.112	0.119
9 GCPs	0.113	0.113

The errors in X,Y and Z in the above patterns were found to range from a total of 18 cm to 11 cm and errors in X and Y were found to range from 11.6 cm to 8.2 cm. The reduction in error was found to be slow but steady. For mapping such a linear area, the densification of GCPs increased the accuracy of the product. The addition of GCPs along the length of the linear feature increased the accuracy of the product which showed evidence in terms of decrement in RMSE value at an almost constant rate. The use of GCPs is therefore seemed dependent upon the accuracy required for a particular project. The pattern found most suitable for such a site was GCPs distribution in analternating way on both side of the linear feature and if possible, along the body of the feature. Increasing the number of GCPs sideways of the feature was not observed to increase the accuracy by a significant amount.

Also, we could see an enhanced accuracy in X and Y after the usage of 7th GCP onwards, which might be due to the fact that the horizontal accuracy of the 7th GCP might be erroneous. However, when viewed in overall positioning (horizontal and vertical), the accuracy pattern can be seen to follow the previous pattern, further strengthening the fact that addition of GCPs resultedin an increment in accuracy.

The analysis of the different GCP configuration suggested that the accuracy of photogrammetric works increases as the number and overlap increase. However, the increment in accuracy over increment in number of GCPs showed saturation after certain limit.

The figure 10 showed the error distribution graph with varying RMSE values due to change in number of GCPs as following:

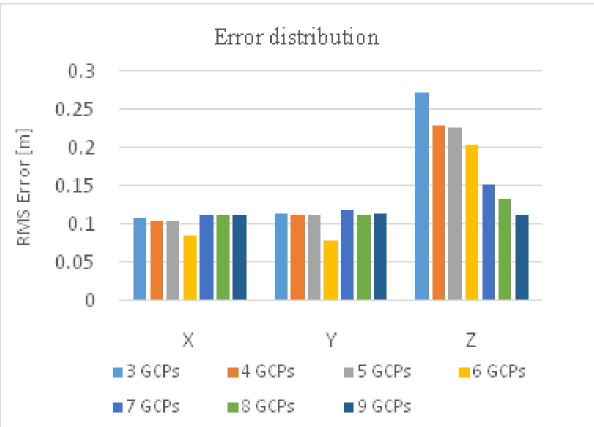


Figure 10. Error Distribution Graphs generated using RMSE values for different GCP distribution in Site 2: Corridor

From the above graph, we can see the comparable RMS Errors in case of X and Y. However,itwas found to have significant difference in RMS Errors in case of Z. With 3 GCPs along the feature, there was about 27 cm error and it goes on decreasing with increase in number of GCPs and was minimum for 9 GCPs. Therefore, the major concern for error was coined in Z i.e. elevation values. Even for Z, the decrement of error was considerable for up to a certain point, in our case 4 GCPs. On increasing the number of GCPs to 5 the decrease in error was minimal and this trend continued. Hence, for the site, 4 GCPs seemed to be adequate for obtaining accuracy comparable to the accuracy obtained by the use of higher number of GCPs.

Therefore, we could say, the optimum number of GCPs for a similar linear feature is 4 GCPs along the length of the feature in case there is a single turning along the linear feature. An additional GCP will be required for mapping a feature with an additional turning as the values of X and Y will be affected by turnings.

iii) Area with Undulating Terrain

The site was covered with a total of 20 control points; all of which were used as ground control points and check points. The errors in X and Y and X, Y and Z were found as following:

Table 5. Root Mean Square Error (RMSE) in X & Y and in X, Y & Z for different GCP configuration in Site 3: Area with Undulating Terrain

Table 5. Root Mean Square Error (RMSE) in X & Y and in X, Y & Z for different GCP configuration in Site 3: Area with Undulating Terrain

GCP Configuration	RMS Error in X & Y (m)	RMS Error in X,Y & Z (m)
3 GCPs	0.140	0.586
3 GCPs with a central GCP	0.139	0.194
4 GCPs	0.138	0.195
4 GCPs with a central GCP	0.134	0.156
5 GCPs	0.154	0.173
5 GCPs with a central GCP	0.137	0.151
8 GCPs	0.127	0.148
8 GCPs with a central GCP	0.114	0.132

The errors in X,Y and Z in the above patterns were found to range from a total of 58 cm to 15 cm and errors in X and Y were found to range from 16 cm to 12 cm. The decrease in error follows a similar pattern of saturation of decrement of errors as the GCPs increase. On increasing the number of GCPs the pattern continued through 3 GCPs to 5 GCPs with an additional GCP at the center (6 GCPs), so the trend would be the same for higher number of GCPs. As we have a total of 9 GCPs, for selecting the reference configuration, we selected the configuration of 8 GCPs with a central GCP. The following graphs showed error distribution in all cases:

The above graphs showed the importance of positioning a GCP in the central region of the area. There was sudden decrease of error for every set of patterns when an additional GCP was added in the central area. From the first graph (3 GCPs with 1 at Center) we could clearly see the decrease in error in Z from approx. from a unit meter to quarter of it. The errors in only X and Y tend to decrease in a steady manner, however when the errors in Z were also considered we could see the steepest slope in decrease in RMS Errors with only 3 GCPsconfiguration. Also, from graph showing error in X,Y and Z comparing the patterns of 3 GCP with center and 4 GCP without center, we couldobserve more accuracy with the inclusion of GCP in central position despite constant number of GCP. This clearly revealed the importance of central GCP in distribution pattern. The finding from it was that the inclusion of central GCP decreases error gradually on increasing the number of GCPs. The optimum accuracy could be meet by placing more GCPs in the boundary if in case the placement of central GCP seems impossible. However, there would be fewer GCP requirement if we could place the central GCP.

The increment in number of GCPs would decrease the error magnitude to certain extent which after that reached the saturation stage meaning that the errors would be almost constant. This could be interpreted as "Increasing GCPs after a certain extent has minimal effect of the accuracy of photogrammetric product". The configuration with 4 GCPs along the boundary with an additional central GCP (altogether 5 GCPs) was found to be the most efficient configuration both in terms of economy and accuracy. Hence, based on the observation, it would be wise to state that the optimum number of GCPs would be 5 assuming one being placed at the central location of the study area.

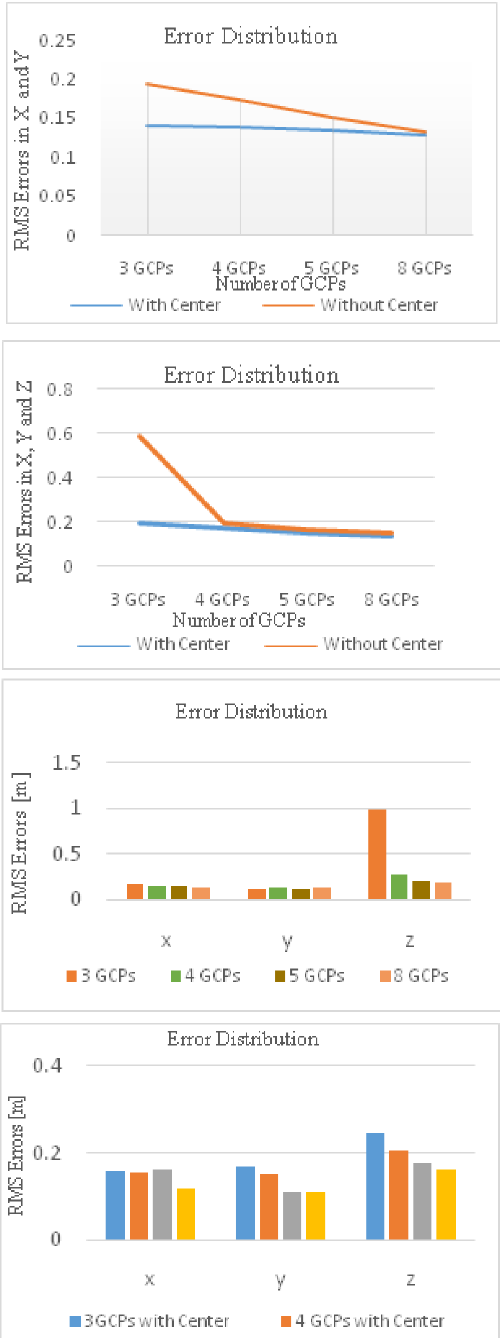


Figure 11. Error Distribution Graphs generated using RMSE values for different GCP distribution in Site 2: Area with Undulating Terrain

3.1.2 Overlap Analysis

The RMSE found in X and Y for the image sets 80-60 & 70-50 were as following:

Table 6. Root Mean Square Error (RMSE) in X, Y & Z for overlap 70-50 & 80-60 for Site 3: Undulating Terrain

Overlap 70-50	Error X [m]	Error Y [m]	Error Z [m]
RMS Error [m]	0.153	0.124	0.135
Overlap 80-60	Error X [m]	Error Y [m]	Error Z [m]
RMS Error [m]	0.149	0.106	0.121

The errors accumulated for the image sets of overlap 70-50 were 15.3 cm, 12.4 cm and 13.5 cm for X, Y and Z respectively and those for overlap 80-60 were 14.9 cm, 10.6 cm and 12.1 cm respectively. The errors decrease by a small amount when the overlap was subjected to change. The accuracy improved slightly with higher frontal and side overlap among the images.The improvement in accuracy was not very significant but less overlap meant less cost, storage as well as time. The error information during the process are depicted in the form of a graph as:

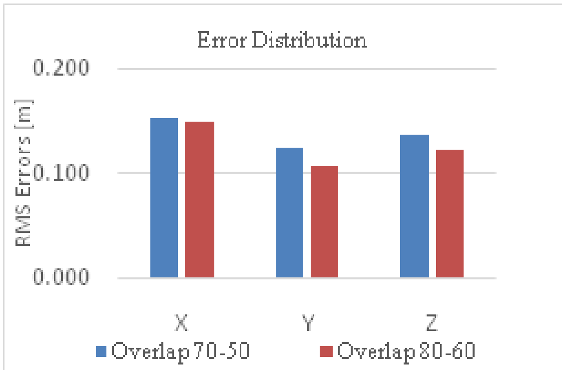


Figure 12. Graph showing Error Distribution between Image sets acquired at overlap 70-50 and 80-60 for site 3: Area with Undulating Terrain

Figure 12 reflected clear picture of improvement of accuracy with the increased overlap percentage. Having said this one must make consideration of time and budget of the project prior to overlap percentage value selection. For a similar terrain, a lower overlap (70/50) might be more suited as it would give a good accuracy at a low cost.

3.2 Qualitative Analysis

3.2.1 GCP Analysis

The configuration giving the highest accuracy was selected as the reference configuration. The point clouds processed from all the other configuration were compared with the reference configuration for each land cover type. The distance between the point clouds were calculated using open source Cloud Compare software and shown as an absolute distance map. It computes the distances of each of its points relatively to the reference cloud.

i) Plane Area

The configuration with 6 GCPs along the boundary and an additional one at the center was chosen as reference point cloud. The outlying areas along the boundary of the site can be seen as the major zones of error. The resulted distance maps are represented as following:

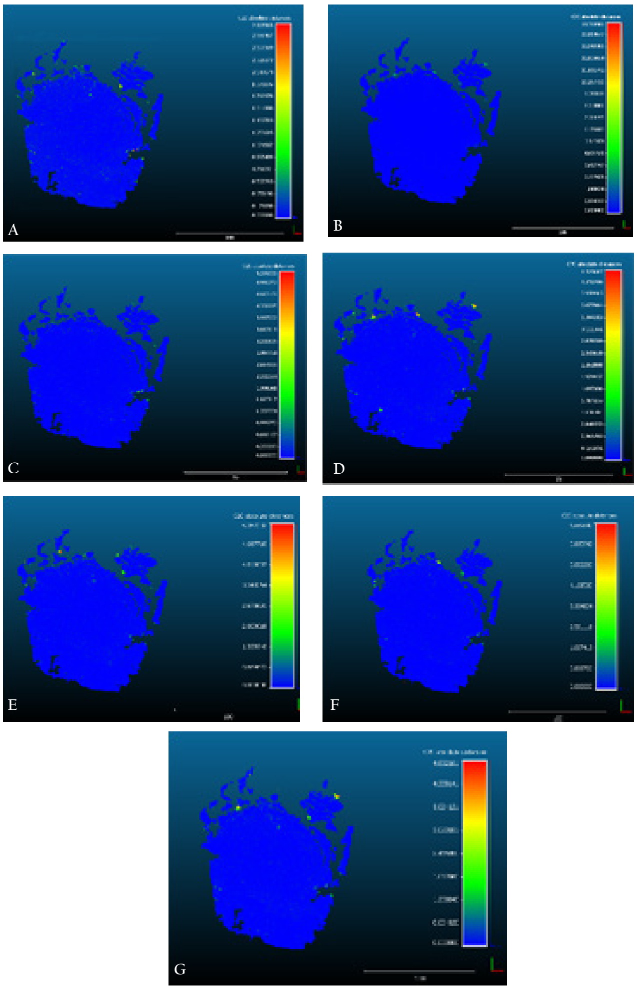


Figure 13. Absolute Distance Map for GCP Configuration with (a) 3 GCPs, (b) 3 GCPs& 1 at center, (c) 4 GCPs, (d) 4 GCPs& 1 at center, (e) 5 GCPs, (f) 5 GCPs & 1 at center (g) 6 GCPs

ii) Corridor Mapping

The configuration with 9 GCPs (i.e. 6 were alternating the sides of the feature separated by an offset and 3 were along the feature) was chosen as reference. The extremities of the area were found to be the major zones of error due to absence of referencing line. The resulted distance maps are represented as following:

iii) Area with Undulating terrain

The configuration with 8 GCPs along the boundary and an additional one at the center was chosen as reference. The man-made features of Kathmandu University at high altitudes was seen to be the major zones of error. The distance maps are shown in Figure 15.

The green zones are erroneous zones that represent the deviation from the reference point cloud. These were mostly visible in the 3 GCP configuration mainly in the central region. This could be due to the absence of any referencing line in the central region as the line joining GCPs did not cross over this region. This was readily accommodated by an additional GCP at the center. Furthermore, usage of same number of GCPs (4) along the boundary showed errors still prevalent in the central regions. This phenomenon suggested GCP location to be more significant than its quantity. The increase in accuracy on increasing the number of GCPs could be clearly seen as the light blue zones dominated other colors in the maps with larger number of GCPs. The saturation of accuracy while adding GCPs could be seen in these maps too.

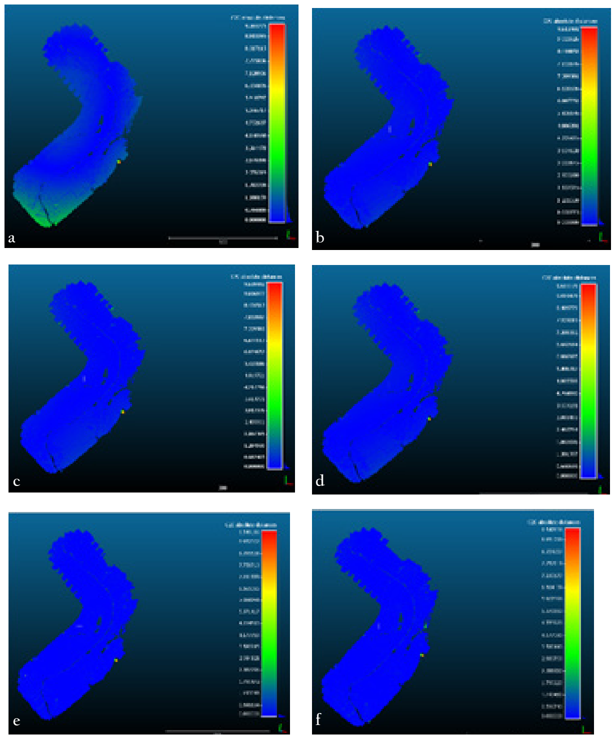


Figure 14. Absolute Distance Map for GCP Configuration with (a) 3 GCPs, (b) 4 GCPs, (c) 5 GCPs, (d) 6 GCPs, (e) 7 GCPs, (f) 8 GCPs along the feature

b) Overlap Analysis

The point clouds of image set with overlap 80-60 and 70-50 were extracted from Pix4D Mapper and the absolute distance of these point clouds were calculated using Cloud Compare. The resulting absolute distance map is as shown in figure 16.

The green zones depicting high magnitude of error were due to the difference in area selection during flight planning for these sets of images. Due to the mismatch in area of concern, even though they were of the same site, errors seemed to be prevalent in very high magnitude even up to 128m. However, this is not the case and the total area of analysis is the central part of this absolute distance map. This site contained a large area with undulating terrain so all effects of change in accuracy due to a reason would be apparent. Fora terrain where tie points are in sufficient number, overlap do not play a major role which is shown by

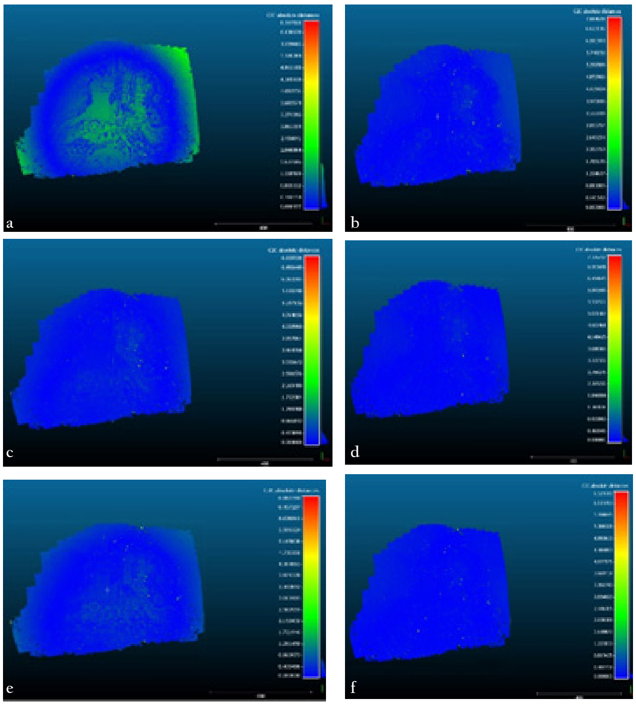


Figure 15. Absolute Distance Map for GCP Configuration with (a) 3 GCPs, (b) 3 GCPs & 1 at Center, (c) 4 GCPs, (d) 4 GCPs & 1 at Center, (e) 5 GCPs, (f) 5 GCPs & 1 at Center

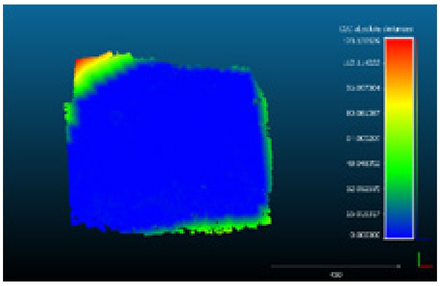


Figure 16. Absolute Distance Map where distance was computed between point clouds of the same site (i.e. Site3) with mentioned overlap

the less magnitude of cloud distance. The effect of overlap change may be more apparent for large homogenous area with very few tie points.

DSM Comparison

The Digital Surface Models obtained from the two sets were compared with each other using GIS software. A difference raster was generated by subtracting the DSM of image set with overlap of 70-50 from the image set with overlap of 80-60. The results obtained were as following:

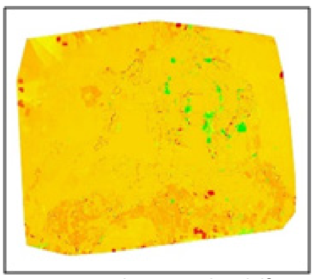


Figure 17. Difference raster showing the difference between two DSMs; one with overlap 70-50 and the other with 80-60

From the above result, we could see very little difference in the end product obtained from two image sets acquired using two different overlaps. The aggregate errors in elevation was found to be up to 5 meters. The higher value of errors could be due to the fact that the images were acquired at different times and some objects in the site were moved in between taking the photos.Therefore, using the smaller overlap of 70-50 can suffice for an area similar to site 3.

4. DISCUSSION

The image overlap, number of GCPs and suitable pattern for a certain terrain type was assessed in the paper. People often consumes more time discussing and planning on establishment of GCP. The determination of number of GCPs and the distribution pattern for the particular site can now be easily visualized though this paper.

The idea of introducing a central GCP(s) was very much useful for the better results. As we can see, by introducing a single GCP in center how we can easily get the better accuracy. Also, distribution of GCPs in linear feature should be alternating the feature, so that it is evenly distributed. Similarly, distribution of GCPs covering all elevation range is also the key factor for the better accuracy in undulating terrain.

All the imagery parameters could not be discussed in this research work. Other parameters also affect the accuracy of photogrammetry results. The image overlap was studied only for Site 3: Area with Undulating Terrain. However, the image overlap does not have significant role if there are higher number of key points. Also the plane area and corridor, mapped in this research must be studied in large scale as the number of GCPs addressed in this paper is not sufficient for large area.

5. CONCLUSION

The analysis of different results obtained from various configurations of numbers and patterns and GCPs were successfully carried out. This study has demonstrated the effects of variation in accuracy of photogrammetric products for three different sites when different sets of GCPs were used in different patterns.

The most suitable arrangement of GCP for plane area was found to be more or less die shaped i.e. GCPs along the boundary with an additional central GCP. The increase in number of GCPs along the boundary increases the accuracy but not in a way that is economicallybeneficial. There are no clear differences in accuracy results with the utilization of three GCPs pattern compared with slight denser GCP pattern (i.e. six GCPs). This statement helped to draw conclusion that increasing the number of GCPs would not always lead to provide better results. The cost and labor required for increased number of GCPs would not be accommodated by the increase in accuracy. Considering the area and type of terrain in Site 1, we concluded the best GCP pattern to be three GCPs well distributed along the boundary for a similar site.

The GCP arrangement made in such a way that they are alternating each side of the linear feature being mapped separated by an offset distance alongside it was observed to be the appropriate one in case of corridor mapping. The inclusion of GCPs along the feature showed better suit in the case but this context might not be similar for all types of linear features such as rivers. The conducted research for this site showed a gradual increase in accuracy with the addition of a greater number of GCPs.There should be consideration of project budget and accuracy while devising the optimum number of GCPs to be used for a given area. For the case of our study area, it was noticed that the optimum number of GCPs was four along the feature. The optimum number of GCPs for any corridor mapping is the same with a couple of additional GCP for each mission with certain deviations from the preceding mission placed exactly on the mission overlap area.

The best fit arrangement of GCPs for undulating terrain followed a die shape (i.e. GCP at the central region and other GCPs well distributed along the boundary). On following this arrangement, one should be assuredabout the fact that the GCPs in the chosen pattern covered all elevations range.

The plot showing accuracy variations with different GCP pattern practice showed saturation on the increment in accuracy with increased number of GCPs. The saturation was seen on accuracy for a pattern with four GCPs along the boundary and one at the center. This indicatedthe optimum number of GCPs to be used is five (with one GCP at center and rest along the boundary) and GCPs arrangementmust be made in die shape for such type of terrain.

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MANAGEMENT OF PUBLIC LANDFOR URBAN OPEN SPACE IN CASE OF DISASTER RISK REDUCTION

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ABSTRACT

Being a hotspot for geophysical and climatic threats, Nepal seriously faced recent 'Earthquake Disaster-2015', and the citizens of Nepal realized mostly absence and low adequacy of open spaces for temporary residence and shelter for aftershock period. They strongly felt the importance of open spaces for reduction of risk on such disasters in crowd and un-managed cities. The risk is believed to be increasing very rapidly mainly due to the growth in population, informal settlement and lack of urban built-up standards especially in urban and urbanizing areas.Public land are generally badly managed throughout the world because of its low national primacy agenda and insufficient policy, process and institutional framework. Badly managed state land and low primacy agenda is not only decreasing its efficiency but increasing encroachment options also. Public land management is a critical factor for ensuring better Urban Open Space -UOS management. Public land management is important part to providing adequate access of land to plan standard urban design, which can able to manage standard requirement of open spaces for urban cities. The management of public land not only supports in management of open space but can support in Disaster Risk Reduction -DRR with providing the necessities of smart cities. This paper try to discuss on significance of public land management in minimum requirement of open space for such Disaster Risk Reduction -DRR.

KEY WORDS

Public land management, Urban open space, Disaster risk reduction

1. INTRODUCTION

Public land management is crucial issue to providing adequate access of land to plan standard urban design, which can able to manage standard requirement of open spaces for urban cities.

1.1 Recent Earthquake in Nepal

Two major earthquakes smash in year-2015 in Nepal, first on April 25th in Gorkha district, and later on May 12th with the epicenter in Sindhulpalchowk district about near location of capital city Kathmandu valley. These two major quakes and numeral of unceasing reverberations have extremely foiled the life of publics. The data distributed by International Organization for Migration, IOM-2015 shows that more than 8800 people died. More than 8.1 million persons are directly affected 39 districts of Nepal's 75, around 2.8 million people living in the 14 most severely affected districts, over 1279,330 houses damaged and 505,577 houses destroyed.

1.2 Lack of information about suitable open space to quick shelter

The lack of information and communication about suitable open space to quick shelter, will enforce the question, that where are these open spaces located? Beforehand can save lives and increase communities resilience to disasters. When disaster hit, people can immediately go to these sites to get the aid they need. Further investment in establishing a better management of open spaces shall include organized and well equipped sites. These open spaces should go beyond just allocating the space and focus on the underlying risk even in non-affected areas to develop a holistic approach for risk reduction in Kathmandu Valley.

1.3 Feeling for requirement of open space

After the devastate quake, people often get confused of sheltering their houses for their suspected residential structure, which may not be earthquake proof and resistant. So, after people whose houses are not damaged or partially damaged lived in a tent in front of their house, whereas the people whose houses were partially or completely damaged or reside in a risky area ran to all the identified open spaces or any other open areas. But they have no alternate to living in open space with running from concrete crowd and low strength and suspected high rise buildings. Then they feel the role of open spaces, which play crucial requirement in increasing population and settlements.

People has acknowledged that the availability of these open spaces provided them with immediate safety. Slowly, those people living in rented houses started returning back to their houses in districts outside Kathmandu Valley because of the fear of another major earthquake, or their rented house being cracked or destroyed. Some returned back to accompany and rescue their family in the earthquake hit districts. After the first earthquake, International Organization of Migration Nepal-IOM conducted a rapid assessment of open spaces in Kathmandu and found that about only 83 open spaces in Kathmandu Valley. Another rapid assessment was conducted by IOM from 29 to 30 April after the fifth day of the earthquake. It was found that 33 open spaces were still being used holding 30,904 internally displaced populations from 5,529 Households(Nepal, 2013).

These open spaces gave shelter not only to the people from Kathmandu Valley but also of residents who have fled from other districts, with the majority of residents from Sindhulpalchowk, Dolakh, Kabhre, Dhading, Nuwakot and Gorkha. So, it is clear that how open space helps community resilience with physical resilience, holistic well-being of individuals and helping them recover from the earthquakes

2. REVIEW ON ROLE OF PUBLIC LAND MANAGEMENT

Public land management is a critical factor for safeguarding good governance in the land administration of a country. Weak governance in managing public property resources shows unlimited consequences on various sectors i.e. economic development, poverty alleviation, the environment, political legitimacy, peace and security, and development cooperation (Zimmermann, 2008). Land management is broader than land administration. It covers all activities associated with the management of land and natural resources that are required to fulfill political objectives and achieve sustainable development. Land management is then simply the processes by which a country's resources are put to good effect(UNECE, 1996).

One of the best ways to understand a system is to disturb it(Bryant & Allan, 2013). The calamities shows the system problems and need of modification of system. We should able to get positive learning from it. The rush for searching open spaces for shelter during earthquake disaster shows clear essential of open space. Well-maintained parks and open spaces enhance the quality of life by providing picturesque views and refreshment opportunities. As a result, nearby landowners also gets an increase in real property values and marketability for their property also. State Land Management is the management of all State /public land(Thiel, 2009). Public land is base of development of any country to its social, economic and environmental perspective. Public land is highly important for public benefit. If it is properly managed and preserved, it can be an important resource for inhabitants and allow for sustainable development based on a fair balance of social needs, economic activity and environmental management(Grover, 2008).

Open Space can be define as any parcel of land maintained in a basically unbuilt state and reserved for public or private uses, including, but not limited to habitat protection, water quality protection, passive recreational uses, livestock grazing or field crop production(Services, 2006). Disasters have always been a result of human communication with nature, technology and other living entities. Sometimes unpredictable and sudden, sometimes slow and lingering, various types of disasters continually affect the way in which we live our daily lives(USAID, 2011).There are mainly two classes of open space, one is natural open space and another is developed open space whose main source may be public land. The ecological resilience approach is a good model for public space design because, even though it may entail a lot of design research, it suggests that interferences can be battered and relatively minimal, generated from the bottom-up, with whatever is at hand. This kind of design is about adjusting, encouraging innovation and redundancies, making space, exploring new ways and relationships between community and place(Bryant & Allan, 2013).

3. METHODS

This paper is based on spatial data of public land of study area. It uses the limited questionnaries to support qualtitative data for public land requirement assessment. It uses related cadastral maps and imagery to create public land database.

3.1 Study area and data collection

The study area was selected in Ward no 11 of Banepa Municipality. It was suitable for the study because the area is located between two major earthquake epicenters and todays it is growing as emerging urban settlement near capital city of Nepal.Banepa, the historical town, about 26km east from Kathmandu situated in Bagmati, Central, Nepal and geographically locates on 27° 38' 0" North, 85° 31' 0" East, which is shown in figure 1.

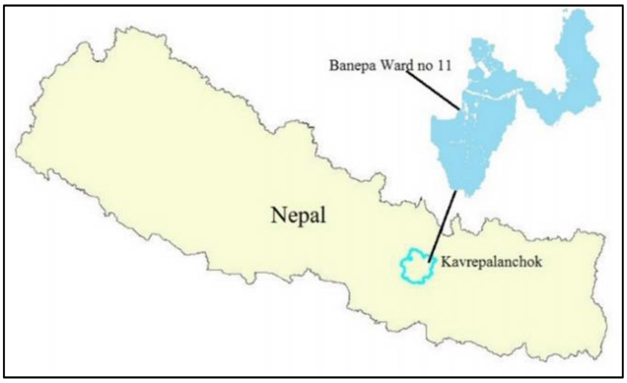

Figure 1. Study Area

The questionnaire used within specified cluster sampling method to get information about shelter options in 50 households. The result found that, mainly 36% households stayed on tent in others private land, 26% selected as tent in

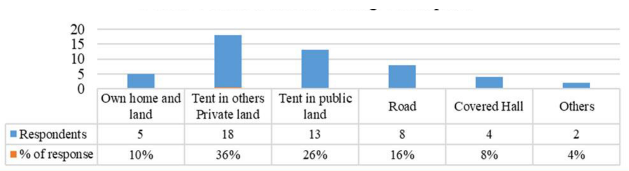

Figure 2. Public selected shelter during Earthquake

public land, 16% as road shelter option during earthquake as shown in figure 2.

3.2 Data presentation and analysis

There are 126126 m^2 public land in study area. In which only 56111 m^2 are found as barren or open public land. There is also sloppy forest in north side of study location as area of 1041566 m^2. But the legislation of Nepal, it is classified as state land and no public can directly use and enjoy it. Forest are restricted and protected resource in Nepal and committed to maintaining more than 40% area of national land area. In total public land about 44% land exist as Barren or open public land, 27% consist as road, 18% as stream, 2% as pond and government buildings and 7% used and bounded in purpose of Nursery, which is shown in Table 1. In study area, the suitable open space for use in disaster is barren land.

The listed road, stream, pond, building, nursery and forest are low or not suitable in case of sheltering in pre and post disaster period. There are easy access of highway and roads in about more part of public land in study area. They are also suitable to sheltering and performing different social recreational activities. Most of public land including forest area are out of access of road, inaccessible of services and slope ground nature.

But lack of sustainable vision of local government, communities and stakeholders, the suitable for open space public land are allocating in so called different development and local activities. The maximum part of public land suitable for open spaces, parks and recreational area are already covered or used for other purposes i.e. for vegetable market and covered hall which replaced the community football and playground, same as for Red cross buildings and building for Journalist etc. which is shown in table 2.

There may be distinct positive impact of such allocation of the good characterize public lands in study area. But most of respondent do not agree that ongoing allocation of public land use are sustainable. In study area, about 23994 m^2 of public land are allocated for different social purposes where 32118 m^2 public land which locates in inaccessible and slope nature are remains, which is shown in table 3.

That data table shows that there are inconsistent and no plan in distribution and allocation of public land. The result

Table 1. Statistics for public land

S.N.	Public Land Type	Area (m^2)
1	Barren (open public land)	56111
2	Road	34192
3	Stream	22786
4	Pond	2172
5	Building	2670
6	Nursary	8194
	Total	126126

Table 2. List of total used public land

S.N.	Description	Area (m^2)
1	Vegetable market and covered hall	7320
2	Red cross building and office of journalist	6905
3	Animal development area (Pashubikash-ratmate)	1445
4	Bhakteshor school	1112
5	Road	672
6	Ward office	165
7	Road	1162
8	Kavre multiple campus	3615
9	Road	1598
	Total Area	23994

Table 3. List of total remained public land

S.N.	Description	Area (m^2)
1	Chandeshwori Stream (Khola)	58
2	Kuikel Village (Gau)	8669
3	Chandeshowri forest east	8864
4	Khatri Village	1667
5	Ratmatepunyamata river side	700
6	Vegetable market and covered hall	1266
7	Red cross building and office of journalist	5166
8	Chandeshwori forest west	2748
9	Road	1598
	Total Area	32118

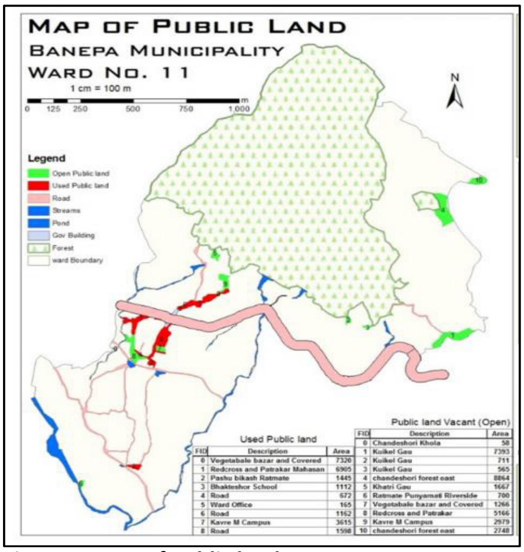

Figure 3. Map of public land

can be analyze as there may be lack of open space and public land access for purpose of parks, children entertainment spots, recreational area and spots for sheltering when disaster occurs.

4. DISCUSSION ON URBAN OPEN SPACE AND DISASTER RISK REDUCTION

Open spaces are defined as those areas of green space where people and companies can spend leisure time, undertake a range of formal and informal events or just have a break. Open spaces, sport and recreation provision strengthens people's quality of life. The development of open space new or improvement of existing spaces, does not simply improve the physical landscape but improves and impacts on the cultural, ecological and economical value of the neighboring area (Council, 2011). Considering the necessity of open space for time of disaster, it values both of pre disaster period and likely as post disaster period.

Efficient public land management supports to allocation of required positional urban space. Effective allocation and use of public land is one of the important part of land management. So, proper public land management positively supports to urban open space management which is an important part of reduction of disaster risk by providing different shelter options and related services to disaster victims and common public. The relational composition of public land management, urban open space management and disaster risk reduction can see in Figure 5.

The social value of public space is the opportunity such places offer for interacting with others. The social relations that occurs in public places is significant as it often represents communication and concession between non-homogenous users who may otherwise have little opportunity or reason to interact. Public spaces are symbols

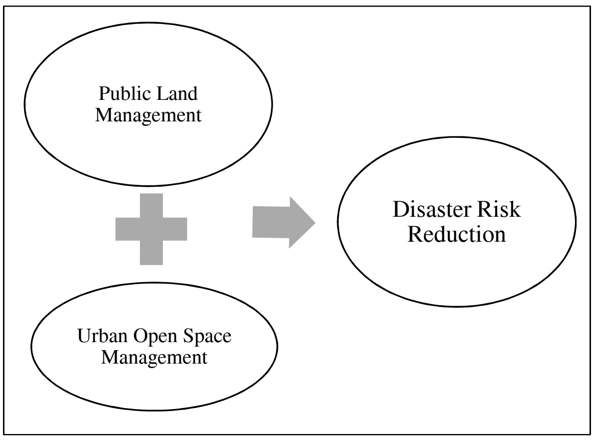

Figure 4. Relational public land management, urban open space management and disaster risk reduction diagram

of the larger collective identity and signal standards and traditions of the culture. They can signal the character of a city as well as provide a source of common character and community superiority for the urban area(Holub, 2011).

Today the idea that high-quality public open space land should be a fundamental right rather than a facility for urban areas. It is a sentiment that is being reflected in cities. Many cities, from the largest to the smallest have placed an increased importance on planning for and executing open space plans (Holub, 2011). Throughout the United States and developed countries, there are broad public support for development of parks and open space protection. The Open Space Strategy is a conceptual framework that offers overall direction for site selection and preservation activities. Sound prevention and reduction of disaster risk are based on risk-informed decision-making, which requires freely available, openly accessible science-based risk information, including on disaster fatalities and socio-economic impact, hazards, exposure and vulnerability(Nations, 2014).

4.1 Disaster Risk Reduction

The concept and practice of decreasing disaster risks through regular efforts to analyze and manage the fundamental factors of disasters, including through reduced experience to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for confrontational events(Turnbull, Sterrett, & Hilleboe, 2013). In case of study area, respondent were distressed in selection of temporary shelter during continuous aftershock. They could not found proper shelter to live for disaster period but they were staying anywhere they finds first and changing shelter location optionally. They were enormously feeling lack of proper open space to temporal shelter.

Pre-announcement of disaster will help to early warning and it is good aspect to support in rescue and relief in

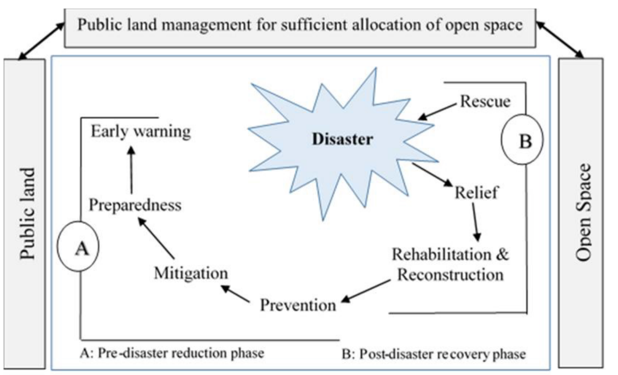

Figure 5. Link of public land to open space with the traditional disaster management cycle, adopted from (USAID, 2011)

post disaster. The need for disaster risk management to be an essential component of development plans and poverty eradication programs is now well accepted among experts(UNISDR, 2012).

As defined by the South African Disaster Management Act 57 of 2002 about disaster management, it is as a continuous and integrated multi-sectorial, multidisciplinary process of planning, and implementation of measures, aimed to avoiding or reducing the risk of disasters, alleviating the harshness or consequences of disasters, emergency preparedness, a rapid and effective response to disasters and post-disaster recovery and rehabilitation (USAID, 2011). Traditional disaster management cycle includes rescue, relief and rehabilitation and reconstruction in post disaster recovery phase and prevention, mitigation, preparedness and early warning includes in pre disaster reduction phase in a cyclic way which can see in Figrue-6. The figure shows the importance of public land management for sufficient allocation of open space in cyclic phases of relief and basically in rehabilitation and reconstruction phase. It also plays a vital role in post disaster recovery as prevention, mitigation and preparedness phase.

4.2 Disaster Risk and open space governance

In case of disaster risk governance, it is need to be guided by the general principles and objectives of inspiring disaster risk management as a policy priority; creating political commitment as a multi-sectorial accountability, assigning responsibility for disaster losses and impacts. In case of open space governance it is important to allocating necessary open space and related resources for disaster risk reduction which is able to imposing the implementation of disaster risk management and reduction. It is also important the combination of multi-stakeholder involvement, increasing gender understanding, and enabling participation by civil society and the private sector(USAID, 2011).

Developing countries, particularly small islands and least developed countries like Nepal are extremely affected by different disasters in different periods. There was a clear message that developed countries are also vulnerable to such severe disasters with memorizing the Great East Japan earthquake and tsunami. Unsustainable development practices, environment degradation, poverty as well as climate inconsistency and extremes have led to an increase in both natural and man-made disaster risk at a rate that poses a threat to lives and development efforts(UNISDR, 2012).

To improve accountability, transparency and responsibility in public land assets and associated activities, there should be clear vision for proper use and conservation of public land.

5. CONCLUSION

Public land management is a critical factor for ensuring good governance in the land administration of a country. There are common factors i.e. socio-economic, political and environmental factors involved in poor public land management. There is typically ambiguity in authoritative roles and responsibilities, a lack of accountability or methodology in the systems of allocation, appropriation, disposal or use of public land, and a lack of information on state assets. Most of urban open space generates with proper management of public land and some portion may be managed from compulsory purchase and public private partnership.

Proper availability of open spaces i.e. parks, recreational area not only supports to emergency shelter in disaster period but more valuable to increasing urban worth. So, the availability of public land in urban area is important part where the allocation and proper use of public land is most important. It should be consider in sustainable use of public land but not use and waste in unjustifiable activities.

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OUTBURST FLOOD HAZARD ASSESSMENT OF TSHO-ROLPA GLACIAL LAKE

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ABSTRACT

Glacier lake outburst floods (GLOF) are common natural hazards in the Himalaya region and have repeatedly caused the loss of human lives as well as severe damage to local infrastructure. In this study, GLOF hazard of Tsho-Rolpa glacial lake was assessed using dam break and hydrodynamic modelling. The empirical formula was used to calculate the peak discharge after dam break for which volume of the lake is calculated using the remote sensing technique. Peak discharge for dam break is calculated for three different scenario i.e. maximum collapse, moderate collapse and minimum collapse. The peak outflow discharge of a Tsho-Rolpa lake is estimated to be 3489.78 m^3/s, 9459.20 m^3/s and 27523.46 m^3/s for minimum, moderate and maximum collapse respectively. Finally, preparation extent of glacial lake outburst flooding and flood hazard map along with assessment of exposure land use was carried out. The simulated results of outburst flood discharge, peak flow, maximum flow depth, sediment concentrations and riverbed variations can be useful for effective preventive measures, river basin management and infrastructure planning in the river basin. Moreover, it can be also useful to raise awareness of local people and preparedness for outburst flood disasters.

KEY WORDS

Glacial-lake Outburst flood, Flood modelling, Potential flood volume, GLOF exposure, Flood inundation

1. BACKGROUND

1.1 Introduction

Flash floods are severe floods that occur with little or no warning. They are characterized by little time lapse between the start of the flood and peak discharge. Flash floods are dangerous because of the suddenness and speed with which they occur. They are triggered by extreme rainfall, glacial lake outbursts, or the failure of dams – whether man-made or caused by landslides, debris, ice, or snow (ICIMOD, 2007).

Glacial lakes are potentially unstable because their end moraines are composed of unsorted and unconsolidated boulders, gravels, sands, and clays. Furthermore, they are frequently reinforced by frozen cores (permafrost) that, like the glaciers themselves, are now beginning to melt. As the volume of a lake that is accumulating behind an end moraine increases, hydrostatic pressure builds up to put additional stress on the moraine dam causing it to become more unstable. Eventually it may fail and release much, or all, of the lake water. Depending on the manner in which the dam fails, the ensuing outbreak of water can be sudden and highly dangerous to people and infrastructure located downstream. The surging flood water will often have the energy to entrain large masses of loose material (boulders, gravel, sand, and clay, as well as any broken masonry or torn out trees) as it is propelled down-valley. The resulting cataract is known as a glacial lake outburst flood (GLOF) (ICIMOD, 2010).

Glacial lake outburst floods (GLOFs) represent a serious natural hazard in Himalayan countries. Glacial lakes are potentially dangerous sources of GLOFs, and represent a serious natural hazard in Himalayan countries. Despite the development of various indices aimed at determining the outburst probability, an objective evaluation of the thousands of Himalayan glacial lakes has yet to be completed (Fujita et. al., 2013).

Recent climate changes have had a significant impact on the high-mountain glacial environment. Rapid melting of glaciers has resulted in the formation and expansion of moraine-dammed lakes, creating a potential danger from GLOFs. Most lakes have formed during the second half of the 20th century. During the past decade, Himalayan glaciers have generally been shrinking and retreating faster while moraine-dammed lakes have been proliferating. Although the number of lakes above 3500 msl has decreased, the overall area of moraine-dammed lakes is increasing. Understanding the behavior of glaciers and glacial lakes is a vital aspect of GLOF disaster management(Bajracharya & Mool, 2010).

The accelerating retreat of the glaciers not only reflects their generally negative mass balance but is consistent with the rapid expansion of the moraine-dammed lakes. When acted upon by external forces such as earthquakes, heavy rainfall, rapid melting of glaciers and dead ice, and snow/ice/rock avalanches, these lakes can become extremely dangerous, easily forming outburst mudslides, which can potentially spread to the river basin and develop into GLOF disasters. These hazards and losses can be prevented and reduced by providing reliable information to the public about the flood risk through flood simulation maps. Therefore, there is an urgent need to strengthen integrated risk management of glacial lake outburst disasters with multiple objectives and modes (Wang & Jiao, 2015).

Within the past fifteen years, glacial lake outburst floods have become an active topic of discussion within the development community focused on Nepal. Such floods endanger thousands of people, hundreds of villages, and basic infrastructure such as trails and bridges. The flood risk is also a major impediment to hydroelectric development in several river basins. Unlike most other mountain hazards in Nepal, reducing the possibility of outburst floods is technically feasible. The first attempt within Nepal to reduce the hazard of one lake by artificially lowering its water level was partially completed in June 2000. Completing this task and beginning work on other hazardous lakes will require difficult decisions about risk by downstream residents and substantial investment from the international aid community (Kattelmann, 2003).

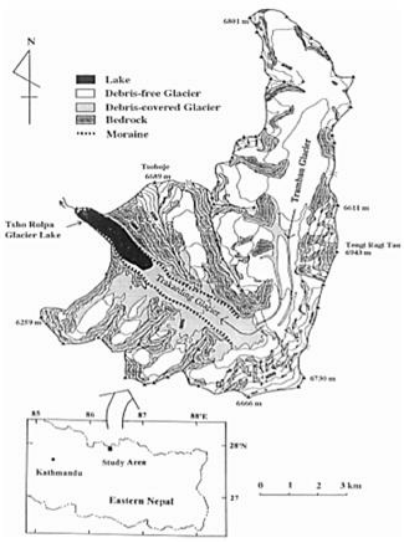

Figure 1. Drainage basin of Tsho-Rolpa Lake. (Source: Chikita, 1999)

Among the potentially dangerous glacial lakes, there has been speculation about the outburst of Tsho-Rolpa Glacial Lake since long years. This speculation is supported but the work of Bhandari et. al, 2000 shows the trend of Tsho-Rolpa lake expansion, which is visualized in the figure 2. This suggests that, in 1957-59, area was about 0.23 km2and increased upto 1.52 km^2 in 2003. It shows that area of lake is increased by 560.87 percentages in 46 years.

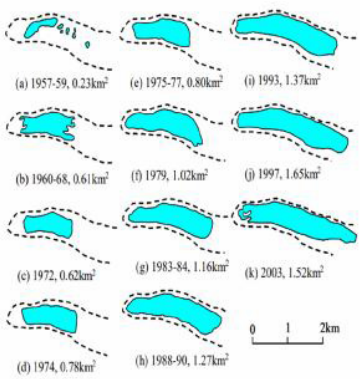

Figure 2. Formation of Tsho-Rolpa Glacial Lake (Source: Bhandari et. al., 2000)

This paper uses the Geospatial tools of remote sensing and geographic information systems (GIS) to visualize the extent of glacial lake outburst flooding and also to analyze the flood maps and hazard mapping of potential Tsho- Rolpa lake.The simulated results of outburst flood discharge, peak flow, maximum flow depth, sediment concentrations and riverbed variations can be useful for effective preventive measures, river basin management and infrastructure planning in the river basin.

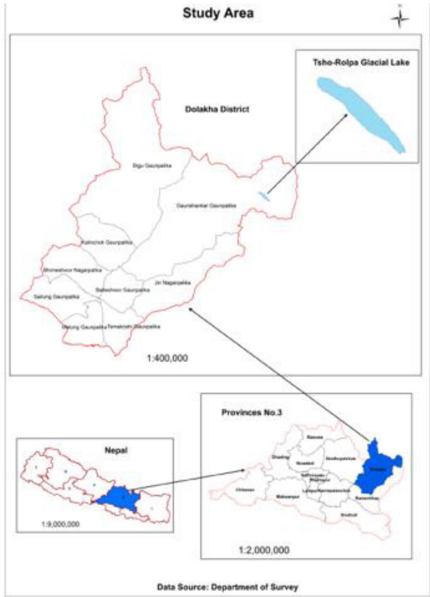

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Figure 3. Location Map of Tsho-Rolpa Lake

2. STUDY AREA

Tsho-Rolpa (also Chho-Rolpa) is one of the biggest glacial lakes in Nepal. The lake, which is located at latitude 270 51' N, Longitude 860 28' E and an altitude of 4,580 m (15,030 ft.) occupying 1.537 sq. km area in the Rolwaling Valley, Dolakha District, has grown considerably over the last 50 years due to glacial melting in the Himalayas. The Trakarding glacier feeds the Tsho-Rolpa glacial lake and that feeds the Rolwaling and Tamakoshi River in the Dolakha District of Nepal. The length and breadth are 3.45 km and 0.5 km respectively, maximum depth of the lake is 135 m and average depth is 55 m (ICIMOD, 2018). The location map is shown in figure 3.

3. DATA

The remote sensing image (Landsat 8, Multispectral band, 30 m resolution)was acquired from USGS (United States Geological Survey) (http://glovis.usgs.gov/). The original coordinate system of image was in WGS 84 which was transformed into spheroid based Everest 1830 based Modified Universal Transverse Mercator (MUTM) projection system.

4. METHOD ADOPTED

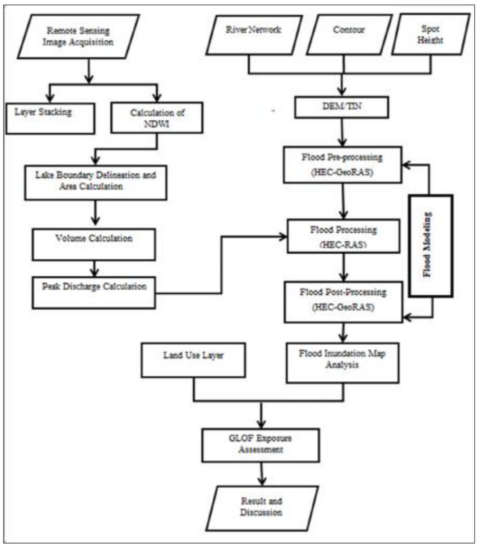

Figure 4. Flow chart of overall methodology.

4.1 Lake Boundary Delineation and Area Computation

The acquired landsat imagery is used to calculate Normalized Difference Water Index (NDWI) using the following formula in equation 1 as

$NDWI=[X_{green}-X_{nir}]/([X_{green}+X_{nir}])$. (1)

Where X_{green} = Band 3 and X_{nir} = Band 5 of landsat 8 imagery.

After calculation of NDWI, the image was reclassified in two classes, i.e. non water bodies class for '-1 to 0' and water bodies class for '0 to +1'. The water bodies are then extracted. Finally, the lake boundary is delineated, and surface area is calculated.

4.2 Calculation of mean depth and potential flood volume

The calculated surface area of Tsho-Rolpa lake is then used to calculate the mean depth of the lake and hence volume using the empirical formula stated in equation 2 and 3.

D_m =55×A×0.25 (2)

$PFV=min[Hp;Dm]\times A$ (3)

Where, A = Area of lake (km^2) ;D_m= Mean depth of the lake (m) and Hp = Potential lowering height .

4.3 Calculation of peak discharge after GLOF

For the breach peak discharge, relationships like Kirkpatrick, SCS attempt to relate height of water behind a dam at failure time (H_w) to the peak outflow discharge (Q_p). On the other hand, some other relationships like the ones given by Evans mainly relate volume of water behind a dam at failure time (Vw) to the peak outflow discharge (Q_p), while Hagen (1982) models focuses on the multiplication between height of water behind a dam and volume of the water at failure time ($V_w \times H_w$) as the main reason for the peak outflow discharge (Q_p).

Table 1. Breach peak outflow equations.

Investigator	Equation
Kirkpatrick	$Qp = 1.268(H_w +0.3)^{2.5}$
SCS	$Qp = 16.6(H_w)^{1.85}$
Reclamation	$Qp = 19.1(H_w)^{1.85}$
Evans	$Qp = 0.72(V_w)^{0.53}$
Hagen	$Qp = 1.205(H_w \times V_w)^{0.48}$
Costa	$Qp = 0.763(H_w \times V_w)^{0.42}$

(Source: Omid et. al, 2015)

Three different scenario of dam breach is assumed i.e. full dam collapse, moderate dam collapse and partial dam collapse with 55m, 25m and 10m breach height respectively. The lake volume behind the dam for each scenario is calculated. Taking this into consideration, peak outflow discharge for each scenario is calculated using different empirical relationship presented in table 1. Finally, peak outflow discharge of for each scenario is computed taking arithmetic mean of the outflow discharges calculated.

4.4 Flood Inundation and Hazard Mapping

4.4.1 DEM/TIN Creation

As an initial phase of the flood modeling after GLOF, the secondary data was collected. They comprise of contour layer, spot height, river network, land use data etc. from Survey Department of Nepal. The hydrologically corrected DEM (Digital elevation Model)with a 20 m grid was derived by contour, river network and spot height data using topo to raster tool. Likewise, we also created TIN (Triangulated Irregular Network) from that prepared DEM.

4.4.2 Flood Preprocessing

The geometric and hydraulic information was extracted using HEC-GeoRAS Software in GIS interface. The stream centerline, flow paths, banks were digitized based on topographic maps and Google image. The preprocessing phase accomplished using DEM and remote sensing images in ArcGIS interface with HEC-GeoRAS. In this process, we created stream line, river banks, flow paths and X-sections. The reach lengths to be considered for GLOF simulation started at the outlet of moraine dams and terminated at the boundary of the buffer zone. The reach length thus derived was 27.92 km and river cross-sections were established at 200 m intervals. Altogether, 146of 500 m wide cross sections were delineated for GLOF simulation. The properties of river and cross section required for geometric properties for flood simulation is extracted.Then, preprocessing GIS data was exported "GIS2RAS.sdf"format for flood processing. The flood modeling was done using HEC-RAS software.

4.4.3 Flood Modeling

Analysis System (HEC-RAS) model set up under steady flow conditions. All the cross-sections were considered as flow change points in HEC-RAS steady flow data, and the peak discharges at these crosssections were given as flow input at the respective points. This is accomplished by giving the peak outflow discharge at the point of dam breach. Three scenario of dam breach is considered, and simulation is done for respective scenario. The output of respective simulation resulted in relatively smooth highest flood levels (HFLs) along the river reaches. The HFLs data for all cross-sections were exported back to HEC-GEO RAS as 'sdf' format.

4.4.4 Flood Post-processing

HEC-GeoRAS, which has internal algorithms to generate inundation and flood depth maps, which was visualized during post processing phase in GIS interface. From this, we get flood hazard map. The sdf format from HEC-RAS is imported to the HEC-GEO RAS to get flood inundation map. This contains flood depth with flood area.

4.4.5 Flood Inundation (Hazard) Map

For hazard mapping, the flood depth was classified in 4 categories and indicated by different color as shown in table 2.

Table 2. Colour Representation of Flood Hazard

Flood depth	Coulor type	Coulor
Below 0.3 m	Light yellow	
0.3 - 1 m	Dark yellow	
1 - 2 m	Pink	
Above 2 m	Blue	

Source: Nepal Hazard Assessment, NG

5. RESULT AND ANALYSIS

5.1 Area and volume calculation of lake

Area of the Tsho-Rolpa Lake was 1.73 km^2, calculated from remote sensing image. Then we get volume using empirical formulafor three different scenariois calculated as

Table 3. Breach peak outflow equations.

Surface area (KM^2)	Height (m)	Volume (Million m^3)
1.73	55	95.1099
1.73	25	43.2318
1.73	10	17.2927

5.2 Peak discharge calculation

Themaximum peak discharge for complete dam collapse (55 m) is 27523 m^3/sec. Similarly, the peak discharge for moderate collapse (25 m) and low collapse (10 m) is calculated as 9459.2 m^3/ s and 3489.78 m^3/ s respectively.

Table 4. Peak discharge calculation

S. N.	Surface area (km^2)	Height (m)	Volume (million m3)	Kirkpatrick (m^3/sec)	SCS (m^3/sec)	Reclamation (m^3/sec)	Evans (m^3/sec)	Hagen (m^3/sec)	Costa (m^3/sec)	Average (m^3/sec)
1	1.73	55.00	95.11	28835.81	27528.28	31674.10	12184.06	55706.97	9211.53	27523.46
2	1.73	25.00	43.23	4082.45	6401.73	7365.84	8022.47	26132.67	4750.03	9459.20
3	1.73	10.00	17.29	431.73	1175.19	1352.18	4936.28	10843.30	2200.02	3489.78

Different calculation of peak discharge for different scenario using formula from different investigator are presented in table 4.

5.3 Flood inundation mapping and analysis

Flood inundation modeling and mapping three different scenario of dam breach was done. In addition to that, Peak outburst flow discharge computed by ICIMOD using GLOF simulation is also taken into consideration. Figure 2 shows

Table 5. Area covered by flood depth in different scenarios

Scenario	Area covered by Flood Depth								Total (ha)
	Below 0.3 m (ha)	%	0.3-1 m (ha)	%	1-2 m (ha)	%	above 2 m (ha)	%	
Minimum Collapse	0.94	0.49	9.06	4.76	52.68	27.67	127.73	67.08	190.40
Moderate Collapse	0.65	0.26	2.37	0.96	40.59	16.45	203.12	82.32	246.73
ICIMOD	0.53	0.25	2.73	1.28	51.30	23.99	159.29	74.49	213.85
Maximum Collapse		0.00	0.67	0.21	31.81	10.06	283.81	89.73	316.29

the flood inundation hazard map for the moderate dam collapse. Similarly, area covered by the flood in different dam breach scenario is also presented in table 5.

From the flood simulation, total area covers by minimum collapse of dam breach is 190.40 ha in which below 0.3 m flood depth covers 0.94 ha (0.49%), 9.06 ha (4.76%) by 0.3-1 m; 52.68 ha (27.67%) by 1-2 m and 127.73 (67.08%) by above 2 m. Total area covers by moderate collapse is 246.73 ha in which below 0.3 m flood depth covers 0.65 ha (0.26%), 2.37 ha (0.96%) by 0.3-1 m; 40.59 ha (16.45%) by 1-2 m and 203.12 (82.32%) by above 2 m flood depth. Total area covers by ICIMOD reference is 213.85 ha in which below 0.3 m flood depth covers 0.53 ha (0.25%), 2.73 ha (1.28%) by 0.3-1 m; 51.30 ha (23.99%) by 1-2 m and 159.29 (74.49%) by above 2 m depth. Total area covers by maximum collapse is 316.28 ha in which flood depth 0.3-1 m covers 0.67 ha (0.21%), 31.81 ha (10.06%) by 1-2 m; and 127.73 (67.08%) by above 2 m flood depth.

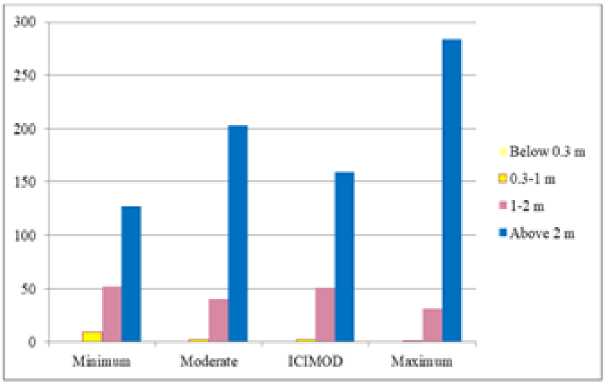

Figure 3. Area covered by flood depth according to peak dischar

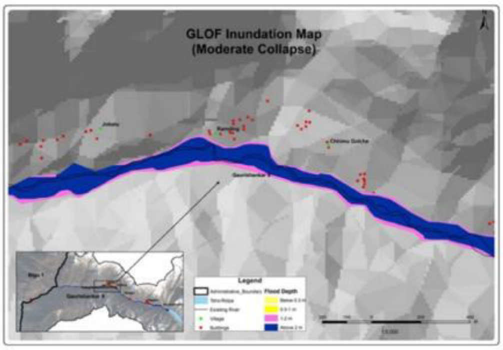

Figure 4. GLOF Inundation Map

5. GLOF EXPOSURE ASSESSMENT

GLOF exposure map is produced using flood inundation map with land use land cover map and using building and village layer. Figure 5 shows the GLOF exposure map for the moderate DAM break scenario.

Table 5 shows the statistics of landuse affected by the flood outbreak for minimum dam outbreak scenario. GLOF exposure by minimum collapse estimated 190.40 ha up to about 27.92 kilometres downstream would be exposed to

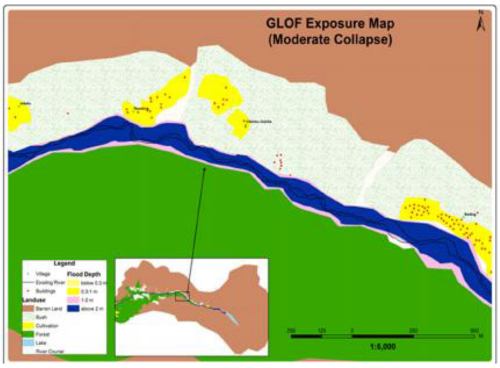

Figure 5. GLOF Exposure Map

a GLOF from Tsho-Rolpa. About 55.91% (106.46 ha) would be flooded along the course of the river, 22.23% would be barren land (42.33 ha), forests 16.99% (32.35 ha), bush 3.21% (6.11 ha), and cultivation 1.66% (3.16 ha). Among them, 0.44 ha of barren land, 0.2 ha of forest and 0.29 ha of river course will be covered by the flood of less than

Table 5. GLOF exposure area covered by Flood Depth(Minimum Collapse)

Land use	GLOF Exposure Area covered by Flood Depth (Minimum Collapse)									
	Below 0.3 m (ha)	%	0.3-1 m (ha)	%	1-2 m (ha)	%	above 2 m (ha)	%	Total	%
Barren land	0.44	47.23	3.91	43.17	10.38	19.70	27.60	21.61	42.33	22.23
Bush		0.00	0.35	3.82	1.77	3.36	3.99	3.12	6.11	3.21
Cultivation		0.00	0.67	7.42	0.80	1.52	1.69	1.32	3.16	1.66
Forest	0.20	21.27	0.95	10.49	14.08	26.73	17.12	13.40	32.35	16.99
River Course	0.29	31.50	3.18	35.11	25.65	48.69	77.33	60.54	106.46	55.91
Total	**0.94**	**100.00**	**9.06**	**100.00**	**52.68**	**100.00**	**127.73**	**100.00**	**190.40**	**100.00**

0.3m; 3.91 ha of barren land, 0.35 ha of bush, 0.67 ha pf cultivation, 0.95 ha of forest and 3.18 ha of river course will be covered by the flood of 0.3-1m depth; 10.38 ha of barren land, 1.77 ha of bush, 0.8 ha of cultivation, 14.08 ha of forest and 25.65 ha of river course will be affected by the flood of 1-2 m flood and 27.6 ha of barren land, 3.99 ha of bush, 1.69 ha of cultivation, 17.12 ha of forest and 77.33 ha of river course will be affected by the flood of depth more than 2 m after minimum dam collapse.

The table 6 shows the statistics of GLOF exposure area by the flood with peak dam outbreak discharge taken from the ICIMOD. From the above table, we can see that, total

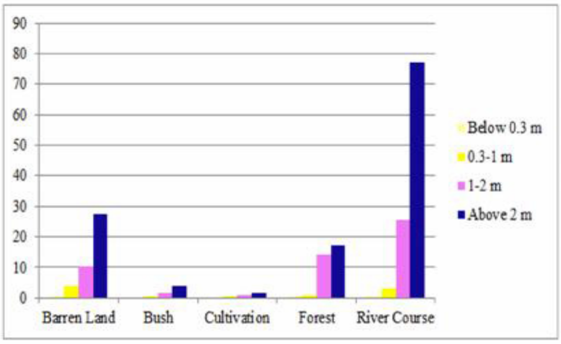

Figure 6. GLOF Exposure area covered by Flood Depth (Minimum Collapse)

Table 6. GLOF exposure area covered by Flood depth (Source: ICIMOD, 2014)

Land use	GLOF exposure area covered by Flood Depth (Source: ICIMOD)									
	Below 0.3 m (ha)	%	0.3-1 m (ha)	%	1-2 m (ha)	%	above 2 m (ha)	%	Total	%
Barren land	0.28	52.52	1.29	47.31	10.29	20.07	34.29	21.53	46.15	21.58
Bush					4.06	7.90	2.93	1.84	6.99	3.22
Cultivation					1.71	3.32	2.13	1.34	3.84	1.80
Forest			0.71	26.03	15.16	29.57	28.34	17.79	44.21	20.67
River Course	0.25	47.48	0.73	26.66	20.08	39.15	91.60	57.51	112.65	52.68
Total	**0.53**	**100.00**	**2.73**	**100.00**	**51.30**	**100.00**	**159.29**	**100.00**	**213.85**	**100**

exposure area by GLOF is 213.85 ha.Among them,0.53 ha area (0.28 ha barren land and 0.25 ha river course) will be flooded by below 0.3 m flood depth, 2.73 ha (1.29 ha barren land, 0.71 ha forest and 0.73 river course) by 0.3-1 m depth, 1-2 m depth will cover 51.30 ha (20.08 ha river course, 15.16 ha forest, 10.29 ha barren land, 4.06 ha bush andcultivation 1.71 ha) area and 159.29 ha (91.60 ha river course, 34.29 ha barren land, 28.34 ha forest, 2.93 ha bush and cultivation 2.13 ha) by above 2 m depth.

GLOF exposure by moderate collapse estimated 246.73 ha up to about 27.92 kilometres downstream would be exposed to a GLOF from Tsho-Rolpa: about 51.35% (126.69

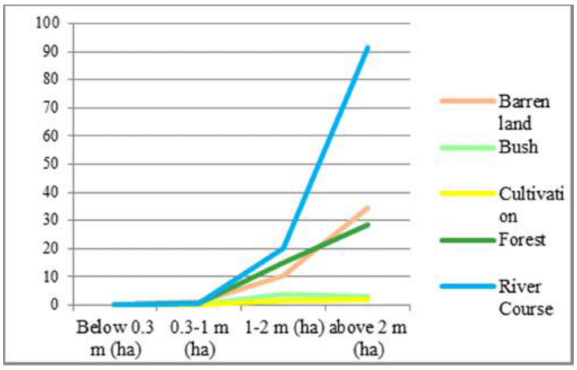

Figure 7. GLOF exposure area covered by Flood Depth (Source: ICIMOD, 2014)

ha) would be flooded along the course of the river, 24.05% would be barren land (58.55 ha), forests 15.41% (38.02 ha), bush 5.34% (13.17 ha), and cultivation 4.17% (10.30 ha).

Table 7 shows the statistics of GLOF exposure area by the flood with peak dam outbreak discharge after moderate dam collapse scenario. From the above table, it is shown

Table 7. GLOF exposure area covered by flood depth (Moderate Collapse)

Land use	GLOF exposure area covered by Flood Depth (Moderate Collapse)									
	Below 0.3 m (ha)	%	0.3-1 m (ha)	%	1-2 m (ha)	%	above 2 m (ha)	%	Total	%
Barren land	0.14	22.33	0.89	37.31	8.99	22.14	48.53	23.89	58.55	24.05
Bush					1.89	4.66	11.28	5.55	13.17	5.34
Cultivation			0.59	24.90	1.73	4.26	7.98	3.93	10.30	4.17
Forest	0.08	11.84	0.13	5.67	16.63	40.98	21.18	10.43	38.02	15.41
River Course	0.43	65.84	0.76	32.13	11.35	27.97	114.15	56.20	126.69	51.35
Total	0.65	100.00	2.37	100.00	40.59	100.00	203.12	100.00	246.73	100

that, total exposure area by GLOF is 246.73 ha.Among them 0.65 ha area (0.14 ha barren land, forest area 0.08 ha and 0.25 ha river course) will be flooded by below 0.3 m flood depth;2.37 ha area (0.89 ha barren land, 0.13 ha forest, 0.59 ha cultivation and 0.76 river course) by 0.3-1 m depth; 1-2 m depth will cover 40.59 ha (16.63 ha forest 11.35 ha river course, , 8.99 ha barren land, 1.89 ha bush and cultivation 1.89 ha) area and 203.12 ha (126.69 ha river course, 48.53 ha barren land, 21.18 ha forest, 11.28 ha bush and cultivation 7.98 ha) by above 2 m depth.

GLOF exposure by moderate collapse estimated 316.29 ha up to about 27.92 kilometres downstream would be exposed to a GLOF from Tsho-Rolpa: about 41.48% (131.20 ha) would be flooded along the course of the river, 23.22% would be barren land (73.45 ha), forests 26.67% (84.36 ha), bush 4.86% (15.37 ha), and cultivation 3.77% (11.92 ha). (Table 9) (Figure 9) (Map 9, See in annex).

Similarly, table 8 shows the statistics of GLOF exposure area by flood after the peak dam outburst discharge under

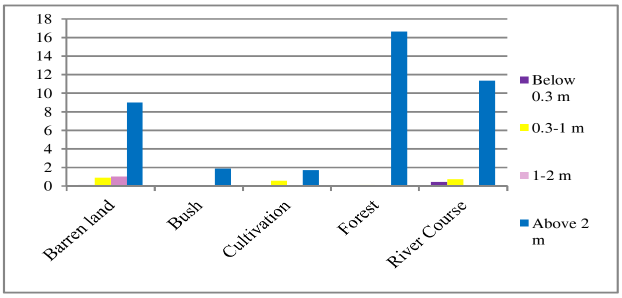

Figure 8. Figure 8.GLOF exposure area covered by flood depth (Moderate Collapse)

Table 8. GLOF exposure area covered by flood depth (Maximum Collapse)

Land use	GLOF exposure area covered by Flood Depth (Maximum Collapse)							
	0.3-1 m (ha)	%	1-2 m (ha)	%	above 2 m (ha)	%	Total	%
Barren land			9.88	31.06	63.57	22.40	73.45	23.22
Bush			2.86	8.98	12.51	4.41	15.37	4.86
Cultivation			2.47	7.75	9.45	3.33	11.92	3.77
Forest	0.67	100	13.23	41.62	70.45	24.82	84.36	26.67
River Course			3.37	10.59	127.83	45.04	131.20	41.48
Total	0.67	100	31.81	100	283.81	100	316.29	100

maximum collapse scenario. From the above table, it is demonstrated that, total exposure area affected by GLOF is 316.29 ha. Among them 0.67 ha area (forest area) will be flooded by 0.3-1 m flood depth; 1-2 m depth will cover 31.81 ha (3.37 ha river course, 13.23 ha forest, 9.88 ha barren land, 2.86 ha bush and cultivation 2.47 ha) area and 283.81 ha (127.83 ha river course, 70.45 ha forest, 63.57 ha barren land, 12.51 ha bush and cultivation 9.45 ha) by above 2 m depth.

5.4 Settlements affected by GLOF

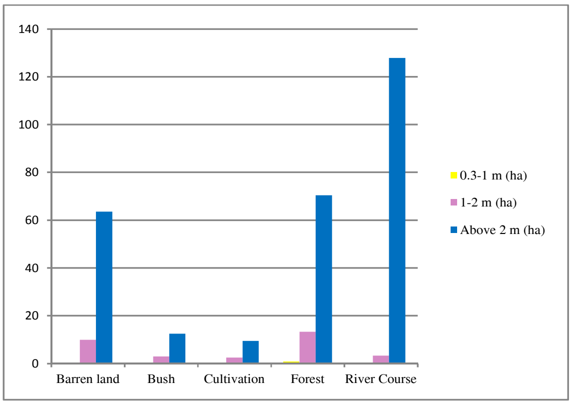

Figure 9. GLOF exposure area covered by flood depth (Maximum Collapse)

After analysis using flood map and settlement map. We draw a conclusion that the settlement in Naa and Beding village will be affected by the GLOF from Tsho-Rolpa Glacial Lake.

6. CONCLUSION AND RECOMMENDATION

Geospatial technologies such as Geographic Information System (GIS), Remote Sensing and Flood modelling tool was used to determine visualize the extent of glacial lake outburst flooding and to analyze the flood hazard and exposure mapping.

The estimated peak discharges of 55 m, 25 m and 10 m breach depths are found to be 27,523.46, 9459.20 and 3489.78 m3/srespectively. The volumes of water released from the lake in the same cases are about 95.11, 43.23 and 17.29 million m^3, respectively. The calculated flood inundation maximum depth in the river ranges mostly from 50 to 76 m. Total flooded area covered by minimum collapse is 190.40 ha, 246.73 ha by moderate collapse, 213.84 ha and 316.28 ha by dam breach of ICIMOD and maximum collapse respectively.

GLOF exposure area in minimum collapse is 190.40 ha among them river course is very high i.e. 106.46 ha and cultivation is low i.e. 3.16 ha. Likewise, from the moderate collapseis 246.73 ha among them river course is very high i.e. 126.69 ha and cultivation is low i.e. 10.30 ha. The flooded area is 213.85 ha by ICIMOD scenario; the most flooded area is high on river course (112.66) ha and low in cultivation (3.84 ha). GLOF exposure area in maximum collapse is 316.29 ha among them river course is very high (131.20 ha) and cultivation is low (3.77 ha).

A resulting flood from the outburst of the Tsho-Rolpa glacial lake can cause serious damage to downstream areas, threatening many people, hydroelectric projects and infrastructures. The simulated results of outburst flood discharge, peak flow, maximum flow depth, sediment concentrations and riverbed variations can be useful for effective preventive measures, river basin management and infrastructure planning in the river basin. Moreover, it can be also useful to raise awareness of local people and preparedness for outburst flood disasters.

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VULNERABILITY ASSESSMENT OF INDIGENOUS COMMUNITIES TO CLIMATE CHANGE IN NEPAL

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ABSTRACT

The vulnerability assessment can identify the potential threats generated by climate change to people such as indigenous. However, the vulnerability assessment of indigenous community to climate change has been a greater challenge for evaluating and determining in the developing countries. This paper intends to determine individual vulnerability and it extent due to climate change in Kailali, Chitwan, and Rautahat districts of Nepal. Three focus indigenous groups (Chepang, Tharu, and Musahar) and a total number of 180 households were interviewed by structured questionnaire during the household survey for primary data. The findings of the study showed that Musahars are more exposed and sensitive to climate change impacts than Chepangs and Tharus. However, Chepang has a higher adaptive capacity than Tharu and Musahar. This study results could be useful for preparation of effective Livelihood program and plan in this indigenous communities as well as appropriate for other indigenous communities and similar areas.

KEY WORDS

Adaptive capacity, Exposure, Vulnerability, Indigenous communities, Climate change

1. INTRODUCTION

Over the past few decades, every part of the world is suffering from climate change. The reports of Intergovernmental Panel on Climate Change, the scholarly studies of scientific society, and tangible evidence indicate that climate change effects are already being observed in every corner of the world (IPCC, 2009). An overwhelming body of scientific evidence now clearly indicates that climate change is a very serious global risk, and it demands an urgent global response (Stern, 2007). Climate change impacts are being realized globally, and Nepal with a large dependence on resources and limited development fund is among the most vulnerable under these conditions (Shrestha, 2010). Nepal's vulnerability to climate change is now universally acknowledged. In the last 30 years, the country has experienced climate-related disasters, including drought, extreme temperature, floods, and storms (Oxfam, 2011). Most of the people's livelihoods are a farm, agriculture, and forest, all of which are highly dependent on natural phenomena. Besides, the disaster-prone nature of the country due to its rugged terrain, steep topography, and fragile geological conditions have placed Nepal among the countries having a high degree of vulnerability to climate change (Joshi et al., 2011). Such high degree of vulnerability poses threats to water resources, agriculture, forestry, biodiversity, and human (Maharjan et al., 2009).

Nepal, with its fragile geography, predominantly natural resource-based livelihoods and low level of adaptive capacity due to a higher incidence of poverty are placed among the most vulnerable country to climate change (Oxfam, 2009). It is one of the 100 countries most affected by climate change, yet it has one of the lowest emissions in the world (Gum, 2009). Nepal is one of the least developing countries (LDCs) based on defined criteria for LDCs that is, low income, human resource weakness and economic vulnerability with only US$ 210 GNP/capita (Huq et al., 2003). Also, it will be amongst the most vulnerable to the adverse impacts of human-induced climate change in the future, as poor people are highly vulnerable to climate change impact and they have a lower capacity to deal with it (LI-BIRD, 2009). Climate changes impacts are also being expected to disproportionately affect the poor, young, elderly, sick, and otherwise marginalized populations (Kasperson et al., 2001). Therefore, such research assessment examines how climate change is affecting human health and the changes that may occur in the future. Similarly, It determines the present situations of these communities and could be the framework for understanding the possible risks on future. With this information, decision makers could implement effective measures to help indigenous communities and individuals to cope and adapt climate change impacts and vulnerability.

To achieve this, the general objective of this paper was to assess the vulnerability of climate change among the indigenous communities (Chepang, Tharu and Musahar) and to understand the adaptation strategies taken to mitigate climate change.

2. METHODS

2.1 Study Area

Nepal is a small landlocked country consisting of three regions. One of them is Tarai region located on the Southern part. Rautahat district is also situated in the Tarai region. The Latitude and Longitude of Rautahat is 26° 34’ to 27°04’ North and 85°31’ to 86° 31’ East respectively. It is situated in the height of 122 to 244 meters from sea level. The Musahars are agriculturist and agricultural laborers (Chaudhary, 2008). Their primary work is digging, because of this quality the Musahars play an important role in agricultural activities (Gautam et al., 1994).

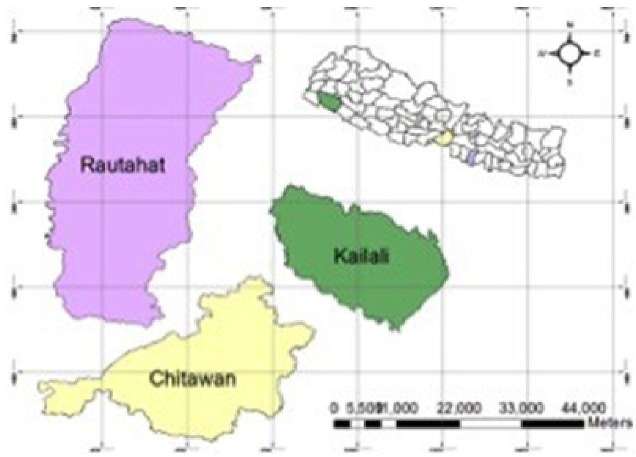

Figure 1. Map of Nepal showing three study districts in three different colors.

Chitwan district is positioned in the latitude of 27◦21’ to 27◦52’ North and the longitude of 83◦55’ to 84◦48’ East. The altitude of the district ranges from 144 m to 1945 m. More than 95% of the Chepangs live in the hilly villages of Chitawan, Makwanpur, Dhading and Gorkha districts (CBS, 2011). These communities have very low literacy rate, therefore they suffer most by climate change and its impact (Piya et al., 2012). Chepangs also depend upon livestock, wage laboring, collection and sale of forest products, handicrafts, skilled non-farm jobs, salaried jobs, and remittance for cash income (Piya, Maharjan, & Joshi, 2011).

Kailali is the terai region and situated in far western region of the country. Total three VDCs were taken as the study area, ChaumalaMasuriya, and Urma. Kailali District is one of the most backward districts of Nepal with little infrastructure base and a poor state of educational facilities (Bakhundole et al., 2007). The population of Kailali District largely comprises native Tharus and migrated people from different districts of Far Western Region and other parts of Nepal (Karna, 2008).

These three districts three indigenous communities (Chepang, Musahar, Tharu) were selected for vulnerability assessment of indigenous communities to climate change

Table 1. Indigenous group population in the three districts, Nepal, 2011 Census.

Indigenous group	Population	Percent of Total	Percent of literate	Dependence
Tharu	1,737,470	6.6 %	30 %	2.5 %
Musahar	234,490	0.89%	21.67%	3.8%
Chepang	52,237	0.23%	26.67%	3.5%

in Table 1. Among them, Tharus are one of the major, whereas Musahar minor indigenous communities of Tarai, Nepal according to the National Census of 2011.

2.2 Methodology

Descriptive cross sectional research design was used to explore knowledge on the vulnerability of Indigenous communities to climate change.

2.2.1 Sampling Techniques

Descriptive cross sectional research design was used to explore knowledge on the vulnerability of Indigenous communities to climate change.

2.2.2 Data Sources

From each of the three selected districts as shown in Figure 1 three-village development committees (VDCs) were selected for the household survey (9 VDCs total). These VDCs were selected based on socio-demographics, livelihoods, social networks, health, food and water security, natural disasters and climate variability for household survey. The VDCs name, the average household of the VDCs and the total number of sampled in each district are given in Table 0.2. According to the national census 2011 data from each VDCs and the average of households were used to calculate the sampling frame.

Table 2. Sampling VDCs and Sample size taken for household survey from each districts.

District	VDCs selected	Average household of VDCs	Sample Size
Chitwan	Kabilas, Dahakhani, Shaktikhor	589-1570 (Chepang)	60
Kailali	Chaumala, Masuriya, Urma	569- 2080 (Tharu)	60
Rautahat	Brishrampur, Dharampur, Rangapur	390-760 (Musahar)	60
Total	9 VDCs	390-2080	180

2.2.3 Data Collection Procedure

Verbal and written permission was obtained from VDCs authority before data collection. After that at start of the household survey, the researcher first introduced him to the respondents who participated in the study. Then researcher clearly explained the purpose of the study to each respondent. Verbal informed consent was taken from each respondent. A structured and semi- structured both English and Nepali version of the literate participant questionnaire was distributed to the respondent. The researcher himself collected data with 30 responded each day. Data was check for the completion during collection of questionnaires.

The household survey technique had been applied to get personal identification, population, structure of family size, religion, education, past and present occupation, landholding, family income, age, sex composition, socio-demographics, livelihoods, social networks, health, food and water security, natural disasters and climate variability among the communities Chepangs, Tharus and Musahars of Chitwan, Kailali, and Rautahat districts respectively of Nepal. During the study, structured questionnaire was used as a major tool for collecting data as well as information of the indigenous community. For reliable information, an unstructured questionnaire was used.

2.2.4 Observation

Participant observation has been one of the main sources of obtaining primary Data. The researcher visited the Chepang, Tharu and Mushar communities to collect the data. Studies relying on secondary data have to structure their analytical framework around available data, contend with inconsistent or missing data, and sometimes must combine data collected at different temporal or spatial scales (Sullivan et al., 2002; Vincent, 2004; Sullivan and Meigh, 2005). Information on sources of measurement error in secondary data sets is often lacking making sensitivity analysis difficult. Methods relying on sophisticated climate projections and multiple international and national databases may be impractical for health and development planners working at the community level (Hahn et al., 2009). Therefore, the primary data collection is chosen for the household survey among the indigenous communities of Tharu, Chepang and Mushar.

2.2.5 Data Analysis Procedure

All the data was kept in order for coding and editing. Simple descriptive statistics was used for data analysis example frequency, percentage, means score, standard deviation. Inferential statistic was used such as: ANOVA test for hypothesis and variable testing, using Microsoft Excel and SPSS. The data was presented in table, bar diagrams, graphs, and maps for the analysis.

Calculating the Livelihood Vulnerability: IPCC Framework Approach

The method developed by Hahn et al. (2009) for calculating the LVI based on the IPCC vulnerability definition, which highlights exposure, adaptive capacity and sensitivity. Natural disasters and climate variability were framed under 'exposure'; water, food and health sectors under 'sensitivity'; and socio-demographic profile, livelihood strategy and social network under 'adaptive capacity' were applied. The reasoning behind this categorization is that exposure of the study population is measured by the number of natural disasters in the last 5 years by the survey questionnaire as well as climate variability in the last 30 years using meteorological data from stations located in the selected districts. Adaptive capacity is quantified by the demographic profile of a district (e.g., percentage of female- headed households), the types of livelihood strategies employed (e.g., percentage of household working outside for income) and the strength of social networks (e.g., borrow/lend money). The sensitivity is measured by assessing the current state of a district's food and water security and health status. The same subcomponents outlined in survey questionnaire as well as Equations 1, 2 and 3 were used to calculate the VI-IPCC.

$$CFd=(\sum^{8}_{(i=1)}WmiMdi)/(\sum^{n}_{(i=1)}Wmi) \quad (1)$$

Here, CFd is one of the contributing factors to VI-IPCC (exposure, sensitivity and adaptive capacity) for district d, Wmi is the weightage of one of the major contributing factors and Mdi is the major component for district d indexed by i. In this work, equal weight was given to all the components as insufficient information for assigning different weights. After calculating the contributing factors, the vulnerability is calculated using the following formula:

$$\text{VI-IPCC} = (\text{Exposure - Adaptive capacity})*\text{sensitivity} \quad (2)$$

The VI-IPCC index ranges from -1 (least vulnerable) to 1 (most vulnerable).

Hahn et al. (2009) approach has several advantages over past efforts. Some of them are such as for constructing the livelihood vulnerability index, uses primary data from household surveys, which avoid the pitfalls, associated with using secondary data. At regional scale provides a framework for grouping and aggregating indicators. Also, it does not depend on climate models and misses livelihoods complexity at the local level (Toufique, et.al. 2013).

3. RESULTS AND DISCUSSION

This deals with the analysis of Vulnerability assessment of Indigenous Communities (Chepang, Tharu, and Musahar) to Climate change in the Chitwan, Rautahat, and Kailali. Data analysis and interpretation was done in relation to the objectives of the study. The results were analyzed through Microsoft Excel and SPSS were used to perform analysis of the data. The obtained data are presented using tables and graphical presentation. The main findings of the study on socio-demographics, livelihoods, social networks, health, food and water security, natural disasters and extreme events were presented in below parts:

The overall, Musahar (0.59746) had a higher LVI than Chepang (0.5484), and Tharu (0.52762), indicating relatively greater vulnerability of socio-demographics, livelihood strategies, social networks, health, food and water security, natural disasters and extreme events of these districts to

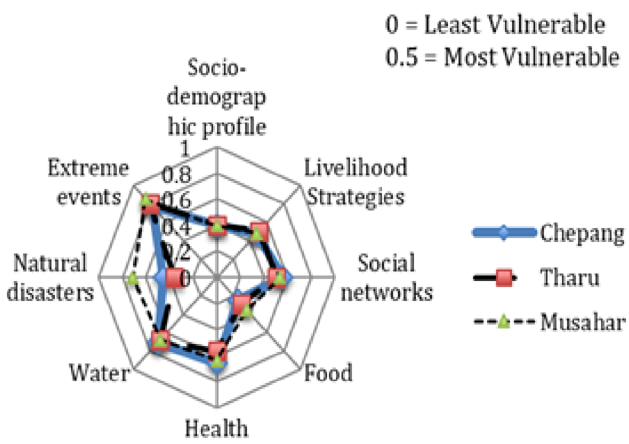

Figure 2. Vulnerability spider diagram for the major componenets of the livelihood vulnerability index (LVI) for Chitwan, Kailali and Rautahat districts of Nepal.

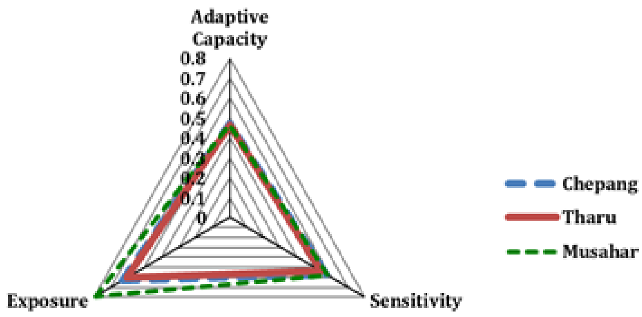

Figure 3. Vulnerability triangle diagram of the contributing factors of the livelihood vulnerability index-IPCC (VI-IPCC) for Chitwan, Rautahat, and Kailali Districts, Nepal.

climate change. The results for major components are presented in a spider diagram (Figure 2). Musahar were rated more vulnerable in the food, natural disasters (such as flood, landslide) and extreme events (such as droughts, heavy precipitation) sub-components. Meanwhile, Tharu showed more vulnerability in socio-demographics, and livelihood strategies sub-components. Social networks, health, and water had the highest value for Chepang.

The overall VI-IPCC scores, on a scale of -1 to 1, indicate that livelihood-vulnerability of Musahar (0.19024) are most vulnerable which is followed by Tharu (0.077012) and Chepang (0.09201). Musahar (0.7906) is more exposed to climate change impacts than Chepang (0.6305) and Tharu (0.6048). However, Musahar (0.5824) is more sensitive to climate change impacts than Chepang (0.5735) and Tharu (0.5393). Chepang has a higher adaptive capacity than the Tharu and Musahar. The scores for exposure, adaptive capacity and sensitivity are illustrates on the vulnerability triangle diagram (Table 2; Figure 2).

Table 2. VI-IPCC contribution factors in the three districts.

Contributing factors	Chitwan	Kailali	Rautahat
Adaptive Capacity	0.47007	0.4620	0.4640
Sensitivity	0.5735	0.5393	0.5824
Exposure	0.6305	0.6048	0.7906
Overall VI-IPCC	0.09201	0.077012	0.19024

Musahars of Rautahat district were found to be more vulnerable to climate change than Chepangs and Tharus those of the Chitwan and Kailali districts respectively as measured by LVI. The overall LVI was slightly higher for Musahars than Chepangs and Tharus. The Musahars are more exposed to the natural disasters like floods, droughts, landslides. In general, three districts are very highly affected by flood (UN, 2016; GON, 2016). Along with these three communities are also listed as the most flood-prone by the National Adaptation Programme of Action (MOEST, 2010). Musahars people are rated more vulnerable in the food. Because of landless and poverty that they don't have sufficient food to eat whole year in their home (Chaudhary, 2008). Though some of them have their own land and the majority had occupied a small piece of common land, this is not sufficient to feed them for even for 2-3 months of the year (Paudel, 2007). Hence, they are compelled to work in others land and depend on natural resources for their livelihood (Deo, 2013). The extreme events such as consecutive heavy rainfall had affecting these Musahars communities. As, they don't have shelter to live in, more than 7-12 persons live in a small hut (Chaudhary, 2008; Deo, 2013).

Chitwan district, although nearer to Kathmandu, the capital city of Nepal, is underdeveloped in many infrastructures in the hilly areas, and even today many Chepang people living in high hills have to walk for an hour to fetch drinking water and that the availability of water in the source is also inconsistent. It has also been reported that natural springs, wells and water sources of the Chitwan district have dried up (DDC, 2014) as in other hilly districts of Nepal such as Dhading, Lamjung (Sagun, 2009; Gentle et al., 2014). Water vulnerability of rural house- holds is caused particularly when there is a high dependency of agriculture on water and the existing infrastructure is poor (Pandey et al., 2014). Due to this water quality and availability, they are exposed to health threats resulting from water contamination by sewage, and industry. Owing to the impact of sewage, typhoid, dysentery, and cholera is endemic every summer (Khadka, 1993). This makes Chepang community vulnerable to water-borne diseases in future and its ramifications would be seen in other livelihood outcomes (Koirala, 2015). The limited access to sufficient water was seen as the key reason for poor sanitation in the first place (Sullivan et al., 2002).

Meanwhile, Tharu showed more vulnerability in socio-demographics, and livelihood strategies sub-components. The 30% of heads of total households had education and only around six percentages had good employment. The average household size was approximately 8 and about 35% of households had more than 9 members in their household (Sunit, 2008; Gyawali, 2008). Tharu ethnic people were found to be agricultural-based with bare subsistence livelihood in which more than 90 percentages depended on agriculture (Gachhadar, 2012; Gyawali, 2008). Crops and livestock are both important components of Tharu farming communities, which are used for both consumption and cash income (Gyawali, 2008). Tharu male people are outside their place to urban areas in Nepal, the rest go to other countries including India, middle-east countries, Malaysia, and others. The migration is mainly for employment (UNESCO, 2010).

Musahar is most vulnerable, which is followed by Tharu and Chepang. They are the most vulnerable group in the whole country and depend on more than any group on natural resources (UNDP, 2012; Murdiyarso, 2006). In recent years natural resources such as forest have been deteriorated in many parts of the country by unusual floods, invasion of unwanted vegetation (Chapagain et al., 2009). This situation had created decrease in grazing land, lack of feed availability prevails and other demographic factors were causing the decline in livestock population was disclosed by the study (CareNepal, 2009). Similarly, like the forest, other livelihood resources like food, water, and public health are plagued by climate change (Sharma, 2010). These scenarios lead them to the more exposure and sensitive to climate change impacts than Chepang and Tharu.

Chepang has a higher adaptive capacity than the Tharu and Musahar. These two groups have limited livelihood options due to the direct impact caused by lack of capital assets, institutional barriers and the increase in the frequency, suddenness, and magnitude of flooding in these areas (CareNepal, 2009). Limited livelihood options also mean limited strategies, which can lead to reduce adaptive capacity and increased vulnerability (Dulal et al., 2010).

4. CONCLUSIONS AND RECOMMENDATIONS

A study is about Vulnerability Assessment of Indigenous Communities To Climate Change In Nepal. The sample size of the study was 180. Among three communities, Musahar (0.7906) is more exposed to climate change impacts than Chepang (0.6305) and Tharu (0.6048). However, Musahar (0.5824) is more sensitive to climate change impacts than Chepang (0.5735) and Tharu (0.5393). Chepang has a higher adaptive capacity than the Tharu and Musahar districts. The overall VI-IPCC scores Musahars (0.19024) are most vulnerable which is followed by Tharus (0.077012) and Chepangs (0.09201).

The challenges of climate change could be mitigate by implementing different risk reduction steps and adaptation strategies at local/community level. Vulnerability assessment could be the framework for the decision makers for developing plan policies to reduce and cope with the climate change and its impacts.

5. ACKNOWLEDGEMENTS

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GUIDELINES FOR AUTHORS PREPARING MANUSCRIPTS FOR PUBLICATION IN THE JOURNAL OF LAND MANAGEMENT AND GEOMATICS EDUCATION

Author Name,[1] Author Name[2]

[1]Author Affilation & Email Address
[2]Author Affilation & Email Address

ABSTRACT

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

KEY WORDS

Manuscripts, Journals, LMTC, Guidelines for Authors, StyleGuide

1. MANUSCRIPT

1.1 General Instructions

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

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

1.2 Page Layout, Spacing and Margins

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

1.3 Length and Font

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

Table 1. Margin settings for A4 size paper

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

2. TITLE AND ABSTRACT BLOCK

2.1 Title

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

2.2 Key Words

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

2.3 Abstract

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

3. MAIN BODY OF TEXT

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

3.1 Headings

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

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

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

Use decimal numbering for headings and subheadings

3.2 Footnotes

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

3.3 Illustrations and Tables

3.3.1 Placement Figures must be placed in the appropriate location in the document, as close as practicable to the reference of the figure in the text. While figures and tables are usually aligned horizontally on the page, large figures and tables some-

times need to be turned on their sides. If you must turn a figure or table sideways, please be sure that the top is always on the left-hand side of the page.

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

3.4 Equations, Symbols and Units

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

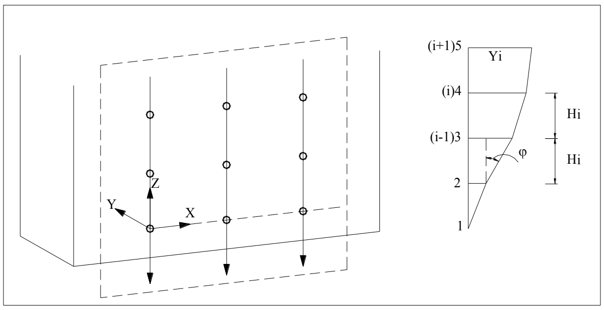

Figure 3. Figure placement and numbering

$$x=x_0 -c(X-X_0)/(Z-Z_0);\ y=y_0 -c(X-X_0)/(Z-Z_0) \qquad (1)$$

where c = focal length

x, y = image coordinates

X_0, Y_0, Z_0 = coordinates of projection center

X, Y, Z = object coordinates

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

3.5 References

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

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

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

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

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

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

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

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

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

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

4. ACKNOWLEDGEMENTS (OPTIONAL)

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

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APPENDIX (OPTIONAL)

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

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

AN INTRODUCTION TO LAND MANAGEMENT TRAINING CENTER

1. INTRODUCTION

Land Management Training Center (LMTC), under the Ministry of Land Management, Cooperatives and Poverty Alleviation (MoLMCPA) of Government of Nepal (GoN) is the oldest and the only governmental institution continually and significantly producing human resources and conducting research activities in the field of geo-information science since its establishment in 1968 A.D. It was initially named Napi Talim Kendra (Survey Training Centre). Later, by the decision of the then Ministry of Land Reform and Management, Napi Talim Kendra was renamed as LMTC on July 10, 2000, since then the training centre has broadened its scope of work. In one hand, LMTC has continued conducting long-term training programmes namely—Senior Survey Training and Junior Survey Training. In the other hand, to transform long term trainings into academic courses, a Memorandum of Understanding (MOU) was signed between the Center and Kathmandu University (KU) in 2007 A.D. Accordingly, as per the MOU, Bachelor of Engineering in Geomatics Engineering course commenced in August 2007. Till date, eight batches of qualified Geomatics Engineers have graduated and are serving in several sectors, predominantly as Survey Officer under the several ministries of GoN. From September 2013 A.D., Masters in Land Administration course has been running by LMTC in collaboration with Kathmandu University. Similarly, KU, Council for Technical Education and Vocational Training (CTEVT) and LMTC signed a trilateral MOU to run three years Diploma in Geomatics Engineering course in September 2015 A.D. Master of Engineering in Geoinformatics is the most recent approved academic course pioneered by LMTC to be commenced in collaboration with KU from August, 2019. Moreover, Center has been running short term flexible professional training courses in Geographic Information System (GIS), Land Information System (LIS), Remote Sensing, Land Administration and many more as per governmental needs. These short-term training courses are designed and provided to governmental employees for their continuous capacity development.

The center is located at 85^{0}20'11" E and 27^{0}42'59"N about 30 kilometers east of Kathmandu, in Dhulikhel Municipality ward number 4 of Kavrepalanchok district. LMTC spreads over an area of 2.86 hector. The educational environment is enhanced by the greenery, moderate climate and its proximity to Kathmandu University.

Overall, LMTC is mandated to produce highly skilled manpower and to conduct research and development in the Geo-information sector.

2. VISION, MISSION AND OBJECTIVES

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

The mission of LMTC is to conduct academic courses, professional trainings, refresher courses and research in Land Management and Geomatics sector for the production of qualified and skilled human resources.

The objectives of LMTC are enlisted below:

• To produce qualified and skilled human resources in the field of Surveying & Mapping, Geo-information and Land Management.

• To conduct and promote research and development activities in the field of Surveying & Mapping, Geo-information and Land Management.

• To establish collaborative relationship with national/ international institutions for mutual benefit by knowledge sharing, professional trainings and technology transfer.

3. ORGANIZATIONAL STRUCTURE

Land Management Training Center (LMTC), under Ministry of Land Management, Cooperatives and Poverty Alleviation has in total 39 permanent employees of different level. There are four sections. The respective sub-sections under each section are shown in the organization structure of Figure 1.

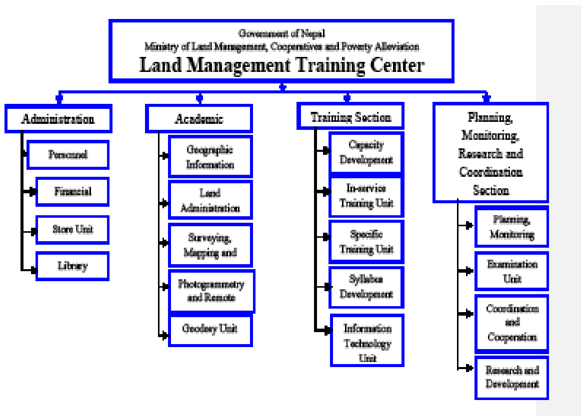

Figure 1: Organization Structure of Land Management Training Center

Table 1. Position and Number of Employee

S.N.	Position	Number of employee	Remarks
1	Executive Director	1	
2	Directors	4	
3	Officers	16	
4	Other Staff	18	

4. COURSES OFFERED AT THE CENTER

4.1 Training Courses

LMTC has been continually organizing various short and long term training courses to develop the knowledge and to build the capacity in surveying and mapping, geo-information and Land Administration. The short term professional trainings are focused for skill development of departmental staffs whereas long term trainings are designed for producing professionals in sector of surveying and mapping, geo-information and land administration.

4.1.1 Short Term Training

Short term trainings are designed to meet specific needs in the fields of geo-information science. Short trainings, generally of 2 to 5 weeks span, are conducted at its own compound or at provincial levels.

The main trainings organized are Digital Cadastre training, Land Administration training, Basic GIS training, Advanced GIS training, WebGIS training, Photogrammetry training, remote sensing training, Real estate valuation trainings and Landuse/land zoning training.

Table 1. Details of short term training courses provided by LMTC till fiscal year 2075/76.

S. N.	Course Title	Total Number of Trainees
1	GIS Training (Including Basic GIS, Advance GIS and Web GIS)	376
2	Digital Cadastre Training	650
3	Land Administration and Management Training	431
4	Real Estate Valuation Training	40
5	Integrated Training	26
6	Geodetic Observation Training	68
7	Photogrammetry Training	46
8	Map Reproduction Training	45
9	Cartography Training	71
10	Survey computation Training	28
11	GPS Training	12
12	Remote Sensing and Digital Image Processing	23
13	Land Management (for in-service) and Refresher Training	253
14	Precise Observation related 30 working days Training	6
15	Land Administration in Computerized System	15
16	Basic related 1 week Training	51
17	Total Station related Training	38
18	Map making and reading Training	12
19	Special Training on Climate Change	13
20	Digital Cadastre and Office Management Training	101
21	Cadastral survey, Digital Cadastre and GIS related Training (Using the resources of the court)	46
22	3 months long pre-service training course for Survey Officers	27
23	Professional course on Geomatics and Land Administration	11
	Total	2379

Digital Cadastre training is aimed at training surveyors of the District Survey Offices to acquaint them with the digital technology in cadastral survey. This training is conducted at provincial level while prioritizing employees working in offices where digital cadastral mapping is on-going.

Training on Land Administration is also provided in provinces for the capacity enhancement of the professionals working on various Land Revenue Offices of Nepal. This training is mainly focused on the basics of mapping and organization of land resources and overall administration of the land.

Basic GIS training is provided to the GIS enthusiasts from various government offices for providing basic knowledge of the geo-information science. This training provides basic knowledge on working with GIS. Another GIS training on Advanced GIS is organized to increase the analytical and mapping capabilities of the professionals working on various government institutions who are acquainted with basic GIS knowledge. The participants in GIS trainings come from the Survey Department, Ministry of Land Management, Cooperatives and Poverty Alleviation, different Survey Offices, Department of Hydrology and Meteorology, Department of Geology, Department of Urban Development and Building Construction, Nepal Army, Nepal Police, Nepal Armed Police Force etc.

With the advent of World Wide Web, the paradigm of GIS has shifted to web. In this context, Web GIS training is delivered to Survey Officers to provide knowledge of the current Web GIS technologies.

The training on Photogrammetry and remote sensing is provided to enhance the working capacity on photogrammetry and remote sensing techniques.

LMTC has also been organizing the trainings on Real Estate Valuation and Landuse/Land zoning which focuses on the valuation of the land and management of land resources for sustainable development of nation.

With time, LMTC has been continually introducing new short term training courses. The recent mentionable trainings are: in-service training on Digital Cadastre and Office Management spanning 30 days for non-gazetted I and II class employees of Engineering service Survey group, and in-service Professional course on Geomatics and Land Administration spanning 30 working days for gazetted III class employees of Engineering service Survey group. After the successful completion of these two courses, the participants are awarded two points for their promotion based on evaluation of competency. Other remarkable training course is 3 months long pre-service training course for newly appointed Survey Officers.

4.1.2 Long-Term Training

The short course trainings are only focused on specific subject matter, so for in-depth knowledge of surveying, mapping, geo-information and land administration, long term trainings are conducted. LMTC has been conducting long-term trainings of 1 year duration for producing the skilled manpower in the sector of Surveying and Mapping, Geo-information and Land Administration. The long term trainings are also helpful for the up gradation of survey professionals. At present, the center has been providing Junior Survey Training Course and Senior Survey Training Course as long term training courses. The long term training courses are conducted on the Module basis in which each subject are dealt with in a time span of 3 to 4 weeks. These courses are delivered providing theoretical concepts, practical classes and labs, and field exercises which creates manpower with both theoretical knowledge and practicalities.

The theoretical modules comprises of Introduction to Surveying & Geo-informatics, Mathematics & Physics, Computer Application & DBMS, Geodesy and Astronomy, Photogrammetry, Remote Sensing, Geographic Information System, Cartography, Cadastral Survey & Land Administration and Topographical and Engineering Survey. There are three to four field survey modules consisting of Conventional Survey, Geodetic Control and Cadastral Survey, and Engineering and Construction Survey Methods.

Trainees are encouraged to perform project work and research activities on various geo-information techniques and land administration in the final independent project module. The projects and research are supervised and motivated by the instructors to encourage research practices.

4.1.2.1 Junior Survey Training Course

Junior Training Course is provided to both in-service and fresh candidates. For the in-service candidates, the training is for their knowledge enhancement as well as the upgradation of their professional career from Amin to Surveyor. Fresh candidates are also enrolled in Junior Training course for creating the skilled junior surveyor for Surveying and mapping, who are generally consumed in government survey offices as well as private consultancies and other government institutions. The Junior Survey Training is mainly focused on producing operational level manpower in the surveying and mapping sector in Nepal.

4.1.2.2 Senior Survey Training Course

Similarly, the Senior Survey Training course is provided only to the government employees working as gazetted and non-gazetted officials working in survey sector on the different government offices. Senior Survey training has been mainly developed with the objective to create the advanced skilled manpower to work in Survey sector. The training graduates are knowledgeable with the different perspectives of Surveying, mapping, Geo-information, Land Administration and new technologies in this sector. Presently, Training center has graduated the 29th batch of Senior Survey Training group to be competitive for Survey officer in case of having the required other qualification. The training groups are selected either on the written examination competitive basis amongst the in-service government employees working in survey sector of Engineering Group or are selected on the seniority. The Senior Survey training is one of the steps to fulfil the criteria for the officer level post in government services.

Table 3: Details of long term training courses provide by LMTC till fiscal year 2075/76.

S. No.	Course Title	Total Number of Trainees Graduated
1	Senior Survey Training	609
2	Junior Survey Training	1898
3	Basic Survey Training	2614
	Total	5121

4.2 Academic Courses

LMTC has been working in collaboration with KU and CTEVT to produce academic manpower in the sector of surveying, mapping, geo-information science and land administration. The academic courses are Diploma in Geomatics Engineering, Bachelor of Engineering in Geomatics Engineering and Masters in Land Administration.

4.2.1 Diploma in Geomatics Engineering

The most recent program launched at LMTC is Diploma in Geomatics Engineering run in trilateral collaboration between LMTC with KU and CTEVT. The three years long Diploma program can be enrolled by SEE graduates. This course is focused on producing the academic professionals to work as surveyor—equivalent to the Junior Survey Training graduates. Diploma graduates can appear in an open competition of Public Service Commission examination for the position of non-gazetted class I Level of Engineering service Survey group of GoN. Additionally, the products from Diploma course can directly work in private firms and organization working in Geo-information sector.

The intake each year for this course is a total of 48 students. Till date, LMTC has enrolled four batches from the year 2015 to 2018. The students of the year 2015 have completed their course.

Two selection criteria are used to enroll students in this course. First selection criteria is based on open competition in which highest scoring SEE graduates in the entrance examination taken by CTEVT are selected. Second selection criteria is for in-service candidates in which highest scoring non-gazetted class II government employees of Engineering service Survey group are selected. The first batch of the year 2015 comprised of 44 students selected from open competition and 3 were in-service candidates. Batch 2016 has 43 students selected from open competition and 3 are in-service candidates. Following batch of the year 2017 includes 45 students coming from open competition while 3 are in-service candidates. The last batch of the year 2018 consists of 44 students from open competition and 3 from in-service.

Full scholarship was granted to the in-service candidates. 100 % scholarship was awarded to 14 entrance examination toppers from 7 provinces—2 from each province. Partial scholarship of 50% was provided to top scoring 6 female, 5 indigenous, 4 madhesi, 1 dalit and 1 student from remote area of Nepal till the intake of 2018.

The table 4 enlists the number of students in each batch.

Table 4: Details of Diploma of Geomatics Engineering course run at LMTC till fiscal year 2075/76.

	Intake of the year 2015	Intake of the year 2016	Intake of the year 2017	Intake of the year 2018
Female	15	14	9	17
Male	32	31	37	30
Total	47	46	46	47

4.2.2 Bachelor in Geomatics Engineering

LMTC, in collaboration with the Kathmandu University School of Engineering, established a four years BE course in Geomatics Engineering within the framework of Memorandum of understanding (MOU) conceived in 2007.

Under the first MOU signed between KU and LMTC, the then Ministry of Land Reform and Management had provided financial support for 7 years for four batches. This governmental fellowship covered 75% of the total fees of 24 students.

After the completion of 7 years tenure of first MOU, the second MOU was signed on May 04, 2012 with new terms. A 100% tuition fee was waived for two students from government employees working in the engineering services under survey group category, a 50% fee was waived for eight students from four Development Regions except the Central regions of Nepal and 33% of tuition fee was waived for 10 students passing the Kathmandu University Common Admission Test (KU-CAT) entrance exam on merit basis The thirs MOU was signed between KU and LMTC in August 2015 which had the provision of providing 35% of the fee off to total of 20 students on the merit basis of Kathmandu University Common Admission Test entrance exam. This MOU's term ended in the year 2018.

The most recent MOU was signed on June 24, 2019 between KU and LMTC offering scholarships to total 25 students. Full scholarship is awarded to 4 employees of GoN. Under inclusive quota, 21 cadidates, 3 from each province, is awarded 35% scholarship. From 3 quota allocated to each province, 1 is granted to Female, 1 to Adibasi Janjati/Dalit/ Madhesi and 1 to Backward region/Economically deprived.

4.2.3 Masters in Land Administration

According to the MOU signed between LMTC and KU on 2013, a 2 years Masters degree course in Land Administration (MLA) was launched with the objective of producing academic human resources in the sector of Land Management and Administration. This course is aimed at producing highly skilled manpower for planning the effective utilization of land resources.

In this joint collaborative master course, there was provision of 100% scholarship for 10 departmental students. The departmental students could come from any governmental institution working in the sector of Land Administration and Management. The first batch of MLA in the year 2013 consisted of 10 departmental candidates—2 female and 8 male. In 2014, second batch of MLA course comprised of 5 departmental candidates—1 female and 4 male. The latest batch of MLA of the year 2016 has 6 departmental candidates—all male, yet to graduate.

The recent MOU of this course signed on June 24, 2019, has provisioned full scholarship for 5 candidates out of 10 intakes working for government.

4.2.4 Master of Engineering in Geoinformatics

Despite the production of large number of geomatics engineer graduates from universities of Nepal, till date there is no master programme in Geoinformatics. Looking at the demand of those graduates to pursue higher degree and production of managerial level human resource; on June 24, 2019, MOU was signed between KU and LMTC, to launch Master of Engineering in Geoinformatics course to be commenced from August, 2019. Out of 10 intakes, 5 seats are reserved for government employees. They shall be granted 100% scholarship.

5. PHYSICAL FACILITIES

The training center has training blocks with classrooms and labs under its premises of about 29000 square meters area. The training center is equipped with the surveying and mapping equipments. The equipments available in center are traditional analog equipments like theodolite, levels, plane table, telescopic alidade, etc. and the modern equipments like total stations, digital levels, hand held GPS, DGPS, UAVs etc. The class rooms are facilitated by multimedia system and projector. And different labs are set for Computer, GIS, remote sensing and digital photogrammetry. The training center has recently developed the digital library system from its analog library. The library is equipped with more than 5000 books relating to survey and mapping, geo-informatics, land administration, laws, general sciences, information technologies, etc and various newspaper and journals.

6. RESEARCHES

Each year research is carried out by the training center. The research works performed at the training center are enlisted below:

1. Year 2014: Technology comparison for Cadastral Mapping of Plane Table, Total Station and DGPS.

2. Year 2015: Shift due to Nepal Earthquake 2015 on Land Management Training Center surrounding.

3. Year 2015: Computation of transformation parameter from WGS84 to Everest 1830 for small area.

4. Year 2017: 3D Modeling of Land Management Training Center.

5. Year 2018: UAV-based photogrammetric approach for cadastral Mapping.

6. Year 2019: Validation of freely available high resolution DEM of hilly region.

7. MEMBERSHIP

LMTC is an academic member of FIG from the year 2002. A team of delegates led by Kalyan Gopal Shrestha, the then Executive Director, from LMTC attended XXV INTERNATIONAL FEDERATION OF SURVEYORS CONGRESS held at Kuala Lumpur, Malaysia, 16–21 June 2014.

8. MAJOR STAKEHOLDERS

List of the major stakeholders of LMTC are:

• Survey Department; the National Mapping Organization of Nepal

• Department of Land Management and Archive

• Nepal Army/Nepal Police

• Other Government agencies having surveying professionals engaged in their regular business

9. CHALLENGES AND WAY FORWARD

Although the training center is equipped with surveying and mapping instruments along with the instructors, there have been some challenges such as insufficiency of the modern equipment. The experts in some of the courses are insufficient. In present context, the training center has been challenged with the balance of existing and new modern technologies.

The state restructuring of Nepal has provided ample scope for geomatics professionals. It is a major challenge for the institution to fulfil this humongous demand of geomatics professionals in the local, provincial and state governments.

Geomatics domain has the characteristics of rapid development and adoption of newer technologies. This has led to a large number of human resources skilled in traditional technology but new to modern technology. It is a challenge for LMTC to timely provide training to such a large number of professionals.

10. FUTURE PLAN

The future plans of LMTC are enlisted hereafter:

• Enhancing the quality of the academic/training/refresher courses

• Widening its scope, especially to contribute in the capacity development of the local government, as the local government has important responsibility in the sector of land management

• Contributing to materialize the spirit of the Civil Service Act / Regulation that every civil personnel should have at least a training in three years time.

• Collaborating with Universities, academic institutions, industries, and development partners (national and international) for academic courses, research activities and technology transfer

11. CONCLUSION

Land Administration is one of the critical and always a rising issues in Nepal and all round the world. The service delivery on land has mostly so much difficulties. The Surveying and mapping along with the Geo-information sector is the major part of management of land and other resources. Therefore, the qualified and skilled human resources are necessary in these fields with the acquaintance with the modern technologies. LMTC has trained more than 5000 survey professional who have been carrying the surveying, mapping and land administration in various places and sectors. But with development of technologies, the need of capacity building of those professionals to the new upgraded technologies as well as the new energetic professionals are also required. Therefore, LMTC have been now instructing with the new and digital technologies which can be helpful for the advancement of the whole geo-information sector of Nepal.

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PHOTOS GALLERY

Staff of Land Management Training Center

Junior Survey Training In-service Group, Batch 2075/076

Senior Survey Training In-service Group, Batch 2076/077

Junior Survey Training Fresh Group, Batch 2075/076

Diploma in Geomatics Engineering, Batch 2016

Diploma in Geomatics Engineering, Batch 2017

Diploma in Geomatics Engineering, Batch 2018

Golden Jubilee Ceremony of Land Management Training Center, 2075-03-25


Field Survey Camp, Lele-05, Lalitpur, 2075


Trainees at field, Junior In-service 2075


Field Camp Visit by Honorable Minister and Other Delegates


Trainees Preparing for UAV survey


Cultural Performance by Diploma in Geomatics Engineering Students


Classroom Lectures