Comparison of change detection techniques in Chitwan District of Nepal

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Abstract: This study explains the comparison of three change detection techniques employed for Chitwan district in Nepal by using remotely sensed images. Three change detection techniques were looked at, *viz*, Post classification comparison, image differencing and multitemporal composite and classification from the available images of Landsat TM for three different dates (1988, 1992 &2000). These techniques were analyzed independently, using the concept of well known procedures like supervised classification algorithm with maximum likelihood with additional post classification comparison, image differencing between two bands for two dates, and unsupervised classification for the multi temporal data sets as an iterative process.

The application of such standard procedures was successfully implemented for detecting change with post classification comparison. The result of the post classification comparison gave thirteen classes with change versus no change out of 80 potential changes between the two dates (1992-2000). Some of these classes are rarely found while others have occurred due to error in earlier classification. Furthermore, how these change maps could also be expressed or visualized by incorporating graphs is also presented. Image differencing was successfully implemented in identifying the areas with respect to radiance values. Out of three techniques employed this method is the most straightforward method. The change map derived from a threshold determined from the histogram can be identified with change classes as 'Change' and 'No Change'. The change map adapted from the multitemporal composite was also successfully generated. The success of such effort depends upon the number of clusters chosen to cover the spectral variation and consequently merging to meaningful change classes. The initial 25 clusters were aggregated to form 7 change classes for the two pairs of imagery (1988-1992, 1988-2000).

1 INTRODUCTION:

Remote Sensing (RS) can provide information on habitat types, vegetation structures, landscape geometry and habitat fragmentation. It also provides digital models, net primary production area, actual evaporation, and amount of biomass and leaf area indices %. Vegetation cover can be estimated by using Normalised Difference Vegetation Index (NDVI) and Transformed Soil Adjusted Vegetation Index (TSAVI) (Puredorj, 1998). The basic assumptions in RS change detection are: (a) changes in land cover result in changes in radiance values; (b) changes in radiance due to land cover changes are large with respect to radiance changes caused by other factors such as difference in atmospheric condition, difference in soil moisture and difference in sun angles (Mas, 1999).

The study has been done in Chitwan district of Nepal and will try to identify the effective tool for assessing and monitoring these change patterns by the employing three change detection techniques. Because these change pattern are usually visible in the satellite imagery.

This study was done as a part of the Individual Final Assessment (IFA) presented to the International Institute of Geo-information Science and Earth Observation for the partial fulfilment of degree Rural Land Ecology under the Natural Resources Management Programme. Source of images and content were directly form the above-mentioned IFA topic.

1.1 Objectives

The main objective of this study was to investigate the most effective classification methods for change detection in rural area of Chitwan district. The goal was accomplished by using Landsat images of the three different years (1988, 1992 & 2000), images of the same place.

2 STUDY AREA

2.1 Location

The kingdom of Nepal is a land locked country, situated in between 26^0 12' and $30^0$27' N latitude and $80^0$04' and 88^0 12' East longitude. The Tibetan Autonomous region of the Peoples Republic of China borders the country in the North and India in South, West and East. It extends to the area of 14.718 million ha. The topography of Nepal can be divided into 3 geographical zones; the snow capped high Himalayas, the mountain region with long terraced slopes leading to fertile valleys and flat sub-tropical *Terai* region. The study area is one of the low plain areas of Chitwan district, which lies in the inner part of the *Terai* region situated between the middle hills and Siwalik Mountain. Geographically, it lies in the centre of the country located at 83^0 55' to 84^0 48' East longitude and 27^0 28' to 27^0 53' North latitude. It falls under the central development region of Nepal.

Figure 1: Study area modified form http://www.tarai.com/dist/chitwan.htm

3 RESULTS AND DISCUSSION

3.1 Post classification comparison

The change map for 1992 to 2000, shown in **Figure 2** was sufficient for differentiating change areas by using a post-classification change detection method. The final classified map of 1992 and 2000 were crossed to form 80 potential types of changes. By aggregation of these 80 classes, 13 classes were formed.

It is clear from the legend that most of the change is either for cultivated field or forest. Area under forest cover has declined mostly for the open type forest. This type of change is particularly distributed in the forest of RCNP, buffer forest, and community forest. Area under cultivated field is proportionally the same. However, it has increased around the N-W side (above the agricultural land) followed by in S-E and S-W side. The areas around the N-W side are the recently carried resettlement program launched by the government from 1995. Similarly, bare land to cultivated field represented in gold yellow is the agricultural field, and distributed near the riverbank sides also. This may be because of the misclassification of the image of 1992. The bare land including sands and gravels, which almost reflect the same, should have probably been misclassified. Hence this was aggregated as one in the final change map, keeping legend bare land to cultivated field.

The other type of change is the grassland. It gives a good indication for change due to its edge distribution along the forest or in agricultural land for further expansion. Forest/to unidentified is another significant change especially concentrated in the forest of RCNP region followed by other community forest. It was strange to find out such change in park areas and community forest where there is strict form of rules and regulations. Hence, it was uncertain to relate those areas as change.

Sands, gravels and water do not show any significant change except in the riverbanks. Other changes are related to change from agriculture to sands and gravels, water, cultivated to bare land, grassland to bare land, etc are assumed to be the result of misclassification.

In comparing the classified image of 1992 and 2000, both classified image show similar pattern of change. Clear distinction could be noted on the area circled. In general, classifying the image of 1992 was more difficult with few reference data with the exception of data that could be extracted from the topographic map of 1994. On the other hand classified image of 2000 are clearer. This result may be attributed to a more accurate classification with reliable reference data of cover type eventually increasing the classification accuracy (78%).

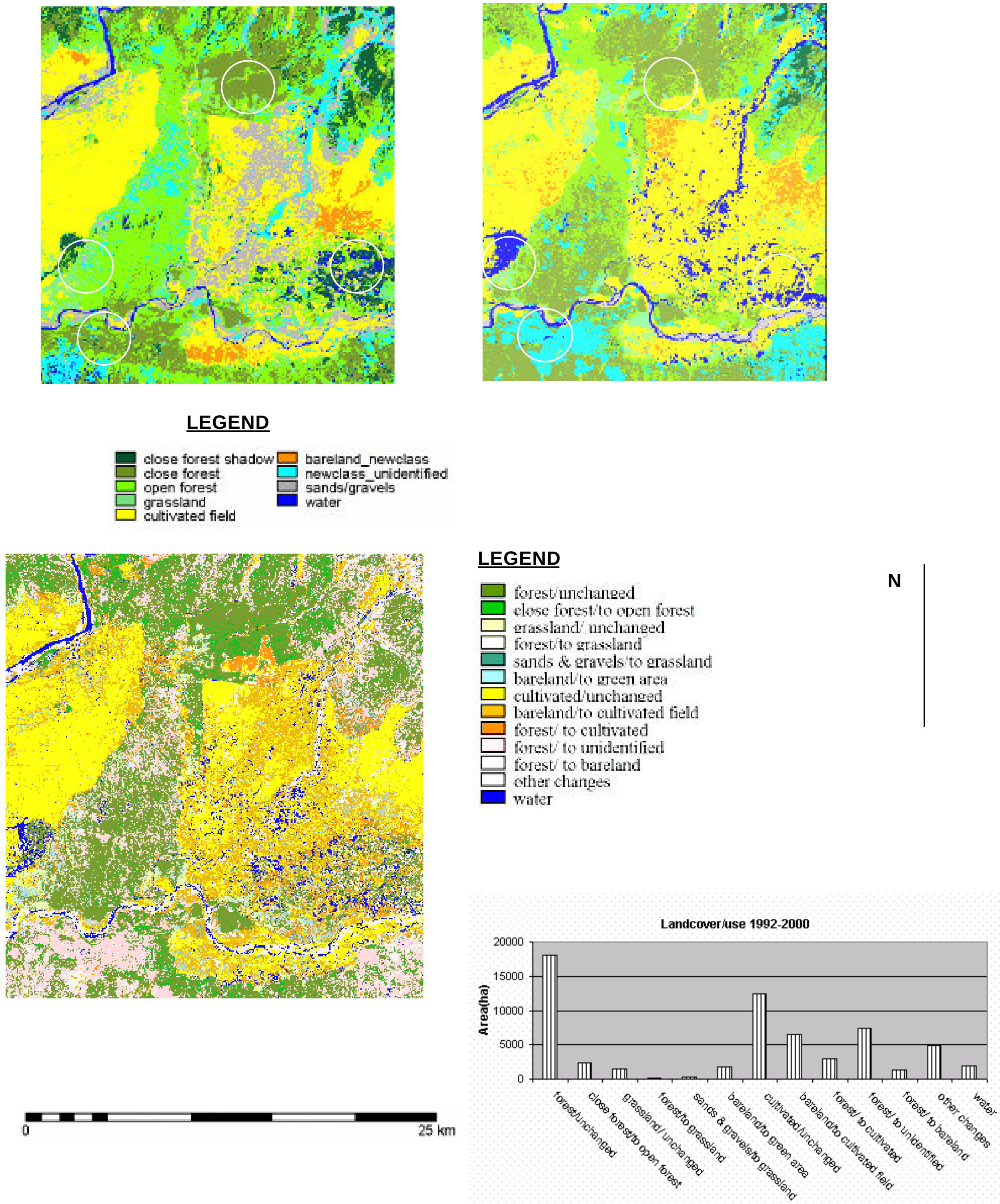
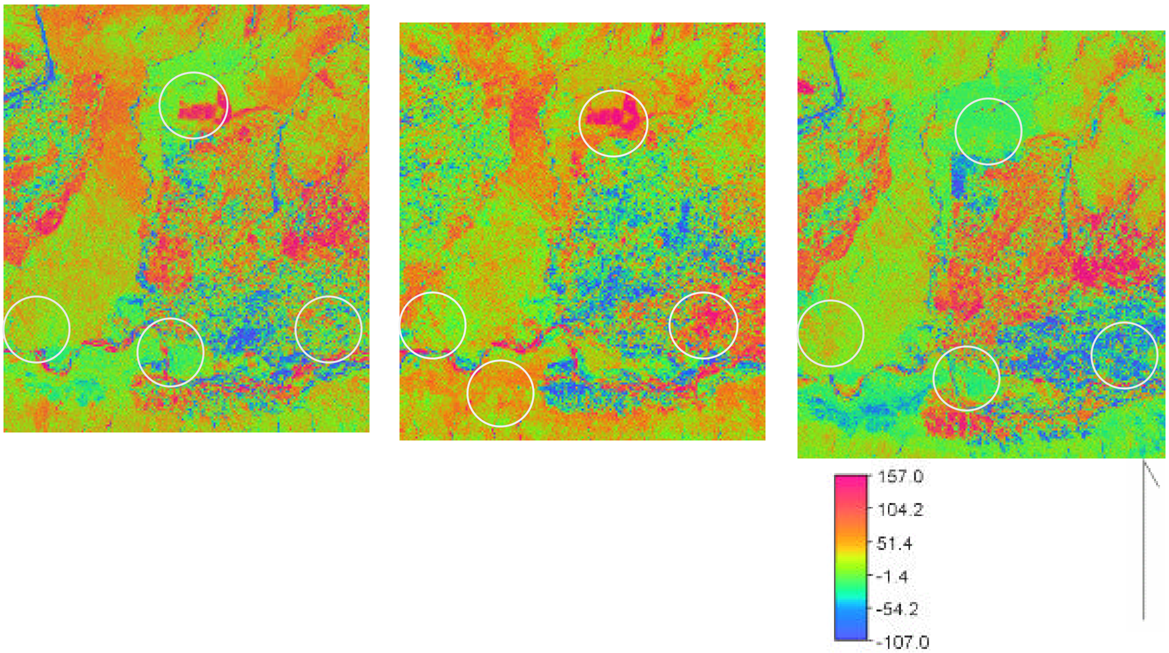


Figure 2: A (Top Left) Classified image for 1992, B (Top Right) Classified image for 2000, C (Bottom) Left) Change map for 1992-2000 and respective graph for land cover/land use

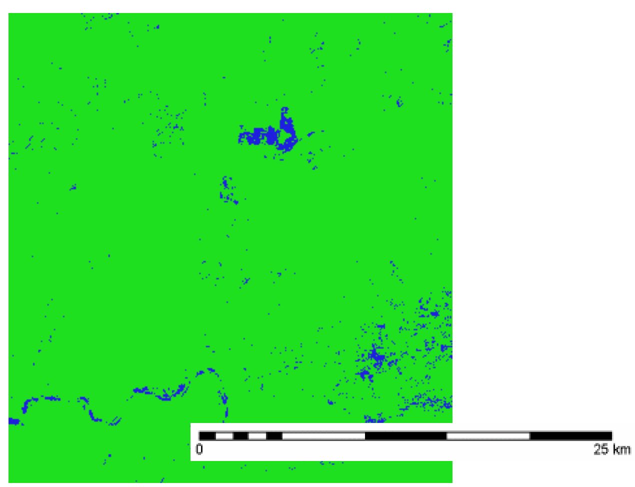
3.2 Image Differencing

Red band of 1988 and 1992 were subtracted from the 2000 images separately. The major changes can be noticed immediately in the region of the resettlement area, riverbeds and parts of agricultural field. The difference images of the two pairs show the different standard deviation within the mean. The standard deviation for the difference image of 1988-2000 is 46.84 while for 1992-2000 is 41.22. This difference in standard deviations was due to the difference in radiation and thus in illuminations, as these images were taken for during different periods. The difference map for 1992-1988 was also prepared. Here, the standard deviation was found to be 47.43, which is approximately the same as that of difference image for 1988-2000. The two difference images show a clear distinction of the change areas (**Figure 3**).

Areas mapped in pink and red show a decrease in radiance over the time periods and in general are associated with bare soil, settlements, sands and gravels, crop stubble etc. Green is generally associated with dense vegetative cover, which reduces the red radiance to a greater extent, due to strong chlorophyll absorption. This kind of change in spectral response can be used to be easily distinguished with the presence of scattered vegetation like home garden or homestead in combination with non- cover types like bare soil and settlements. This can be clearly seen in the area of agricultural fields and within the settlements area. In addition, influence of seasons responsible for change in spectral response could be seen in the difference maps shown in the **Figure 3**. In 1988-2000 difference image, there are many changes while for the change in 1992-2000 relatively few changes could be seen. This change for 1998-2000 is attributed with the change in season while for the 1992-2000 it is change in settlement areas, riversides and few in forested areas. However, in the difference maps of 1988-1992 no clear contrast in the changed area could be seen. This may be due to, firstly, shorter in time periods where change can hardly be noticed; secondly, difference in illuminations due to different seasons.



LEGEND



LEGEND

Figure 3: A (top left) Value map of the difference image for 2000 and 1988, B (top middle) Value map of the difference image for 2000 and 1992, C (top left), Value map of the difference image for 1992 and 1988, D (bottom left) Change map of 1992-2000

3.3 Multi-temporal compositing and classification

An unsupervised classification was ran for the two pairs of images, Landsat 1988-1992 and 1988-2000 images. Change clusters from the classified image as a result from the 25 clusters were merged to form 7 change clusters are shown in **Figure 4**. The results with 25 clusters contain a lot of noise in the scene and were therefore combined to form 7 classes. Green colour in Figure 7, which is distributed through out the RCNP, buffer forest, community forest represents change in forest cover either from close forest to open forest or vice versa. The pale green cluster in the scene with large form indicates the brighter values due to forest cover during the period 1988-1992. It is sensible to say that these areas were being untouched before the resettlement scheme was launched. The result of the multi-temporal composite 1988-1992 was also crosscheck with the available topographic map, 1994. The cross check does not significantly show higher variation in the result in terms of land use. The cyan and sandy brown in the classified image are associated with the change in agricultural land and other change respectivel y. This difference in change is due to variation in illumination in different periods with diffe rent cropping pattern, harvesting periods, lowland farming, and so forth.

Clusters representing the change for 1988-2000 periods are quite dissimilar from the result that was obtained from the 1988-1992 period. Clear distinction could be notable around the close forest (above agricultural field in N-W) region where there was a highly dense cluster in the classified 1988-1992 images. This large cluster apparently did not occur in the 1988 and 2000 images. In particular change in forest, agricultural land can highly be reflected in the classified images for the longer periods.

In comparing respective graph and map in **Figure 4**, it is apparent that classes for change are not significantly different. The pattern of changes is especially marked for the close forest type, which appears to be higher in the 1988-2000 period than for the 1988-1992 period.

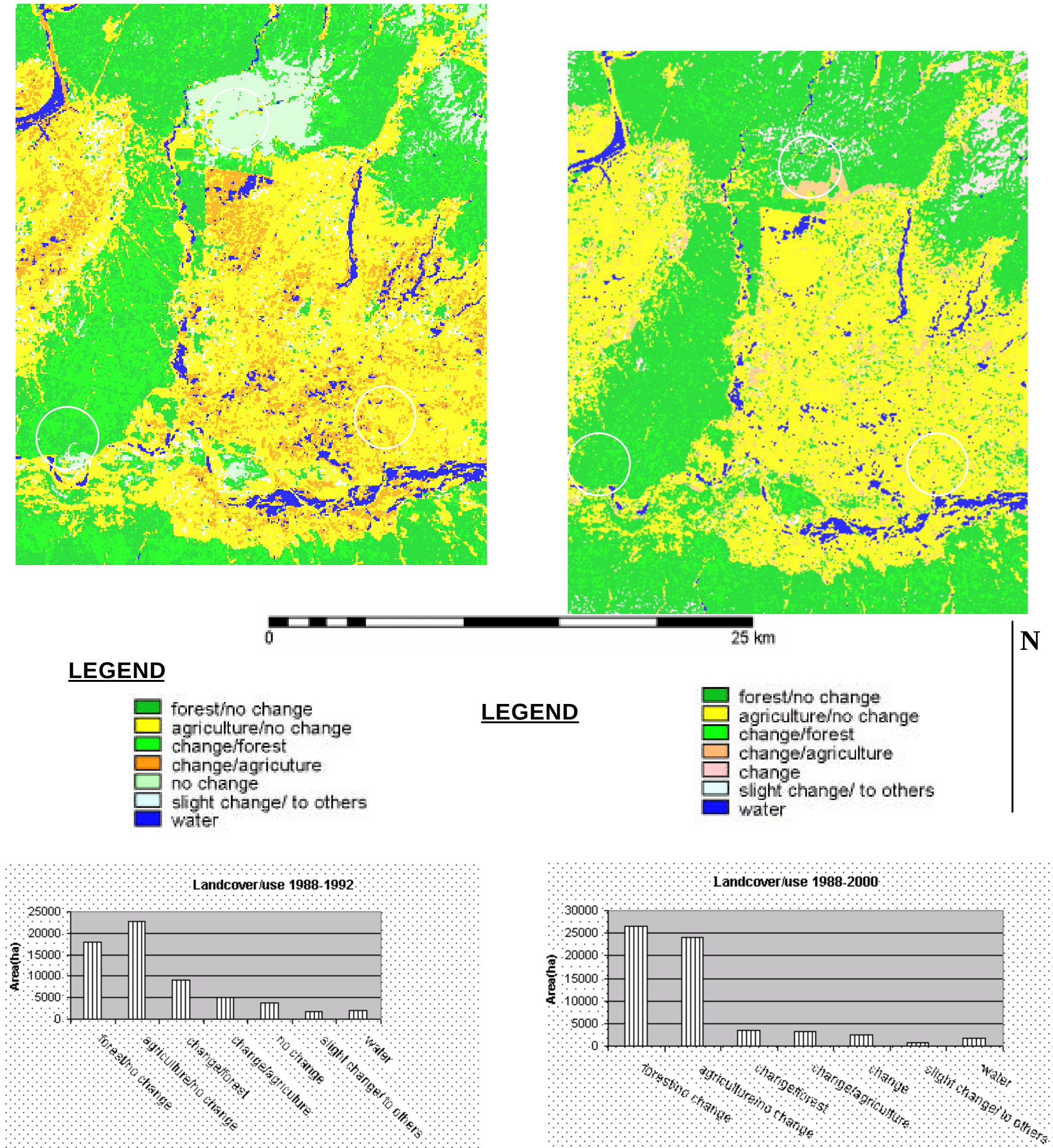


Figure 4: A (top left) Classified image for 1988-1992, B (top right) Classified image for 1988 -2000, C (bottom right) Respective graphs for land cover/use 1988-1992 and 1988-2000

4 DISCUSSION

Post classification methods gives an accurate result for change detection where the user can independently classify the two images in question. However, some sort of misclassification can easily occur during the process and thus cause a decrease in the classification accuracy. Hence errors compounded in the original classification/operation will tend to be cumulative in the final post classification comparison(Skidmore, 1999). These types of error in classification can attributed due to the same spectral signatures of the different classes or error occur in GIS overlay. In this study also some misclassification occurred during classifying for water and forest under shadow condition. Numerous studies show that inadequate selection of signatures for classification decreases accuracy and thus leads to a poor result (Li & Yeh, 1998). The decrease in classification accuracy is also is related to the scale on which one is working. Scale plays an important role in the land cover mapping. On the other hand classification accuracy can increase even to a greater extent whenever consistent reference data are readily available. In this study reference points and ground truth points were taken for checking the accuracy. The reference points taken from the topographic map of 1994 do not give accurate cover type since the area identified forest in land use may not fall cover type forest in an image. This often decreases the overall accuracy. For this reason care was taken for improving the classification accuracy. Similarly, improvement in accuracy of 2001 was also found by merging the classes like maize, paddy field, home garden, etc.

Post classification comparison can be effective method when it has to express the specific nature of changes compiled with statistics in terms of tables, graphs or change maps. In the above study both images of 1992 and 2000 were classified successfully are comparable and could easily identify the areas where the changes have occurred with respect to maps as well as from graph.

Results obtained form image differencing allow immediately the observer to locate where change has occurred. Generally, image differencing is a straightforward approach to identify the area covering in larger scale. Normally, this technique shows through an increase in the reflectance of the red band where a clearing has occurred or through decrease in red reflectance where there is an increase in lush green vegetative cover. Sunar (1998) found image differencing extremely straightforward when using a single band, and slightly more complicated when using multiple bands due to having to interpret the colours for a false colour composite. In addition, other studies suggested that image differencing does not adequately deal with all types of change that are occurring in an area (Sohl, 1999).

In this study red band was used for the image differencing. Soarse & Hoffer(1996), concluded band 5 and 7 of Landsat were found to be effective for evaluating the changes in Eucalyptus forest plantation and for other type of changes. The most critical and subjective aspect of image differencing is identification of threshold values and this depends upon the users preference. In the above change detection method, several attempt were made to identify the threshold to find where the changes has occurred. After several attempt the difference images with changes could be produced with determined threshold.

Worthwhile, to discuss here is the critical observation that could be made from the difference map the change around the riverside. If we look carefully at the two rivers in the image Figure 1, one can see two types of river, i.e., one is meandering (River Rapti) while the other is fairly straight (River Narayani). The one which is meandering is in a flat area with relatively less slope at an elevation of approximately 160 amsl, while the other passes through Churia range (rock outcrops) with steeper slope and about 190-200 amsl. Thus, it is more likely to get fresh sediment deposits in the flat areas. This became apparent while comparing difference images (1992-2000) for change in river sediments due to instability in riverside. In this context image differencing can be a useful technique for detecting change near the riverbank and could possibly be valuable for predicting hazard zone. This is supported by earlier studies about the use of satellite imagery for monitoring changes in the hydrological regime to provide complimentary approach to field monitoring (Al Khudhairy et al., 2001).

Multi-temporal compositing results are quite satisfactory. The major problem with the unsupervised classification system for change detection is determination of clusters. The success of such effort depends upon whether the change classes have significantly different spectral signatures compared to classes with no change. After determining the required number of clusters, grouping/merging the clusters that show the same informational classes is a very tedious and subjective aspect. Herbin et al., (2001), found that estimating the number of clusters is directly involved in unsupervised classification and hence difficult.

In the above results both the images show a noticeable change especially in the area of resettlements, buffer area and some parts in agricultural field. Most of the merged clusters give similar results as that from the supervised classification. In addition finer result was obtained by applying the 3*3 majority filter. Earlier studies suggest that most accurate classification maps could be obtained by applying the majority filter in unsupervised classification (Jensen et al., (1993). Change in terms of area represented by graph is also possible from this method. Most of the studies related to unsupervised classification are being done for monitoring purposes which indeed demand for the images taken every few days or couple of weeks or other regular time intervals. It gives better result and training classes if water, road, and bare land are excluded because they have a similar reflectance (Bourne & Graves, 2001). In addition, better results were achieved by merging the images from the different sensor type (Grignetti, Salvatori, Casacchia, & Manes, 1997). However, the limitation of this study was only to use one type of sensor.

Concluding, of the three-change detection methods that were studied, all showed satisfactory result. Post classification comparison gives an effective result if reliable ground truth data are readily available. Image differencing seems to be an effective method to identify the area immediately where the change has occurred. The disadvantage of this method remains the data acquisition of the same period possibly the same season. Multi-temporal compositing seems to be promising when the analyses is need to be done for a regular time interval.

5 CONCLUSION

The results reveal are consistent with the change detection techniques studied for Chitwan district of Nepal. These techniques were studied independently with available images of the Landsat for three dates. This has been done to understand, analyse and evaluate the different change detection methods.

Initially it was assumed that detecting change with three methods would be significantly different. It has been found, however, that three change techniques give almost similar results. Post classification comparison and image differencing has been found to be superior to some extent, excluding for the multi-temporal composite and classification.

Post classification comparison gives detailed information of a probable change between two years. It gives multiplication of two classes than from originally classified images. Some of these classes are rarely found or probably occur due to an error in earlier classification or imperfect geo-referencing.

Image differencing is a rather straightforward and simple approach. Though this study only used red band, it successfully differentiates the area namely in change and no change. The limitation of this technique is based on immediate identification of the change area, instead classifying the whole image.

Multi-temporal composite and classification produces partly inconsistent results. These inconsistencies may be due to the large spectral variability within classes. These changes in spectral variability make a difficulty in merging them into same informational classes. Finally, merging to same informational classes was successful in certain extent, giving the areas where change has occurred.

Concluding, there will still remain the uncertainties for the best technique to be taken into account for the different studies. Studies regarding change techniques have been carried for a long time, and have had developed many useful techniques. As these studies do not provide uniform methods, hence, further investigation is needed with the scale of application for different studies. Further, an integration of other aspects as slope, Digital Elevation Model (DEM), socio-economic attributes etc by the aid of GIS layer seems to be a promising for change detection analysis.

References

Al Khudhairy, D. H. A., Leemhuis, C., Hoffmann, V., Calaon, R., Shepherd, I. M., Thompson, J. R., Gavin, H., & Gasca Tucker, D. L. (2001). Monitoring wetland ditch water levels in the North Kent Marshes, UK, using Landsat TM imagery and ground-based measurements. *Hydrological Sciences Journal, 46*(4), 585-597.

Amatya, D. M. (1991). *Forest development, utilisation and management.* Paper presented at the In Background papaer to the National Conservation Strategy for Nepal.

Bourne, S. G., & Graves, M. R. (2001). *Classification of Land- Cover Types for the Fort Benning Ecoregion Using Enhanced Thematic Mapper Data* [world wide web]. SERDP. Retrieved 2002,1 August, 2001, from the World Wide Web: http://www.wes.army.mil/el/ecmi/pdfs/ecmi0101.pdf

CBS. (2001). Statistical Year Book of Nepal (pp. 74-80).

CMS. (2001). *Initial Environment Examination for Chitwan Distict*. Kathmandu.

FAO. (1997). *Forests in global context* .

Grignetti, A., Salvatori, R., Casacchia, R., & Manes, F. (1997). Mediterranean vegetation analysis by multi-temporal satellite sensor data. *International Journal of Remote Sensing, 18*(6), 1307-1318.

Herbin, M., Bonnet, N., & Vautrot, P. (2001). Estimation of the number of clusters and influence zones. *Pattern Recognition Letters, 22*(14), 1557-1568.

HMGN. (1998). *The Ninth Five Year Plan(1997-2002)*: National Planning Commission.

HMGN. (1999). Forest Resources of Nepal: Department of forest resereearch and survey,MoFSC.

Jensen, J. R. (1981). Urban change detection mapping using Landsat digital data. *American Cartographer, 8* (2), 127-147.

Jensen, J. R., & other. (1993). An evaluation of the coastwatch change detection protocol in South Carolina. *Photogrammetric Engineering and Remote Sensing, 59*(6), 1039-1046.

Jensen, J. R., & Toll, D. L. (1982). Detecting residential land-use development at the urban fringe. *Photogrammetric Engineering and Remote Sensing, 48*(4), 629-643.

Kiefer., T. M. L. a. R. W. (2000). *Remote sensing and image interpretation* (Fourth edition ed. Vol. 24 cm). New York: Wiley & Sons.

Lallianthanga, R. K., Goswami, D. C., & Sarma, C. M. (1999). Satellite monitoring of secondary succession subsequent to shifting cultivation: A case study of Aizawl district, Mizoram. *Ecology Environment and Conservation, 5* (1), 29-33.

Li, X., & Yeh, A. G. O. (1998). Principal component analysis of stacked multi-temporal images for the monitoring of rapid urban expansion in the Pearl River Delta. *International Journal of Remote Sensing, 19* (8), 1501-1518.

Macleod, R. D., & Congalton, R. G. (1998). A quantitative comparison of change-detection algorithms for monitoring eelgrass from remotely sensed data. *Photogrammetric Engineering and Remote Sensing, 64*(3), 207-216.
Martin, L. (1989). An Evaluation of Lanndsat-based chnage dtection methods applied to the Rural-Urban Fringe. (Remote Sensing and methodlogies of land use analysis, (Waterloo: University of Waterloo)), 101-116.
Mas, J. F. (1999). Monitoring land-cover changes: A comparison of change detection techniques. *International Journal of Remote Sensing, 20* (1), 139-152.
Nepal, S. M. (1999). *Analysis of forest cover change using multi temporal remote sensing and ancillary data : the case of Chitwan district, Nepal.* Unpublished MSc-thesis, ITC, Enschede.
Pilon, P. G., Howarth, P. J., Bullock, R. A., & Adeniyi, P. O. (1988). An enhanced classification approach to change detection in semi-arid environments. *Photogrammetric Engineering and Remote Sensing, 54*(12), 1709-1716.
Puredorj, T., Tateishi, R., Ishiyama, T., and Honda, Y.,. (1998). Relationship between Percent Vegetataion Cover and Vegetation Indices. *19*(International Journal of Remote Sensing), 3519-3535.
Rajesh Acharya, 2002, Comparison of change detection techniques in Chitwan district of Nepal, IFA, International Institute of Geo-information Science and Earth Observation.
Schweik, C. M., Adhikari, K. Pandit, K.N. (1997). *Land cover change and forest institutions: A comparision of two sub-basins in the southern Siwalik hills of Nepal*.
Singh. (1984). *Change detection techniques*. Retrieved August 5, 2002, from the World Wide Web: http://www.cast.uark.edu/local/brandon_thesis/Chapter_IV_change.htm
Singh, A., & Ashbindu, S. (1984). Detecting changes in tropical forest cover due to shifting cultivation using Landsat MSS data. *Satellite remote sensing: Review and preview Remote Sensing Society, 103-110; 2 fig.*, 2 tab.
Skidmore, A. K. (1999). Accuracy assessment of spatial information. In B. Gorte (Ed.), *Spatial statistics for remote sensing* (pp. pp. 197-209): Kluwer Academic Publishers.
Soares, V. P., & Hoffer, R. M. (1996). Detection of change in Eucalyptus spp. stands and other cover types using Landsat TM data in Vale do Rio Doce-MG, Brazil. *Revista Arvore, 20*(1), 117-127.
Sohl, T. L. (1999). Change analysis in the United Arab Emirates: an investigation of techniques. *PE and RS, Photogrammetric Engineering and Remote Sensing, 65*(4), 475-484.
Sunar, F. (1998). An analysis of changes in a multi-date data set: a case study in the Ikitelli area, Istanbul, Turkey. *International Journal of Remote Sensing, 19*(2), 225 -- 235.
Tokola, T., Lofman, S., & Erkkila, A. (1999). Relative calibration of multitemporal Landsat data for forest cover change detection. *Remote Sensing of Environment, 68*(1), 1-11.
Wang, F. (1993). A Knowledge-Based Vission System for Detecting land changes At Urban Fringes. *31*, 136-145.
Weismiller, R. A. (1977). Change detection in Coastal Zone Environment. *Photogrammetric Engineering and Remote Sensing, 43*, 1533-1539.