Lowland Technology International 2020; 21 (4): 287-295
International Association of Lowland Technology (IALT): ISSN 1344-9656
Special Issue on: Engineering Geology and Geotechniques for Developing Countries

Research Paper

Decadal Variation in the Land Use and Land Cover Pattern of Madi, Chitwan from 1989 to 2017 with Flood Hazard Mapping

B. Adhikari [1], P. Pokhrel [2], Y. Pradhan [3] and A. Ulak [4]

ARTICLE INFORMATION

Article history:

Received: 26 October, 2019
Received in revised form: 04 January, 2020
Accepted: 31 January, 2020
Publish on: 6 March, 2020

Keywords:

GIS and remote sensing
LULC
Sinusity
Flood
Madi

ABSTRACT

Land use and Land cover changes are accelerated through anthropogenic undertakings, inviting natural calamities such as floods and landslides more frequently. Madi, covering an area of about 219 km² and being a part of Chure range of Terai, is subject to rampant exploitation by human leading to major flood events in Madi (Reu Khola) almost every year. The present study deals with land cover dynamics, flood hazard assessment of Madi along with dynamics of Reu Khola from the year 1989 to 2017. GIS and RS were used to evaluate our objectives. Decadal LANDSAT images and ALOS PALSAR DEM were classified using Interactive Supervised Classification. Subsequently, each image was classified into five class viz. water bodies, forest, bare land, cultivated land and floodplain. Throughout the span of 28 years, the change in the land features of Madi can be considered quite humble compared to that of the urbanizing areas. The flood hazard map created using multi-criteria decision analysis is one of a kind for that region showing how the geospatial techniques could be of great help in making developmental policies, identifying the areas prone to floods. The study of sinuosity of the banks of the Reu Khola showed significant meandering and winding of the river channel which, in the future, will help predict the nature and path of the flowing river.

1. Introduction

One of the most significant global challenges in this century relates to management of the transformation of earth's surface occurring through changes in land use and land cover (Mustard, et al., 2004; Daniels et al., 2008). Human use of land resources gives rise to "land use" which varies with the purposes it serves, whether be food production, provision of shelter, recreation, extraction and processing of materials, as well as the bio-physical characteristics of land itself. Hence, land use is being shaped under the influence of two broad sets of forces – human needs and environmental features and processes (Briassoulis, 2006; Gonzales, 2009; Shrestha, 2012). Land use and land cover areas are classified into nine major categories: urban or built-up land, agricultural, rangeland, forest, water areas, wetland, barren land, tundra, and perennial snow or ice (Collins, 2002).

Nepal is facing different types of disasters each year, among which Flood is one of the major in Terai region. Climate change and other activities in the mid hills and upper Himalayas is expected to result in an increase in frequency and intensity of extreme weather events in the plains of Terai region of Nepal. There will also be an

[1] Assistant Professor, Kathmandu University, 45200, Dhulikhel, NEPAL, bikashadhikari@ku.edu.np
[2] Graduate Student, Kathmandu University, 45200, Dhulikhel, NEPAL, prashila.pokhrel@gmail.com
[3] Graduate Student, Kathmandu University, 45200, Dhulikhel, NEPAL, pradhanyusha@gmail.com
[4] Graduate Student, Kathmandu University, 45200, Dhulikhel, NEPAL, ulakaarati28@gmail.com
Note: Discussion on this paper is open until September 2020

increase in frequency and intensity of extreme rainfall events (Benniston, 2009), which in turn is expected to result in more frequent occurrences of extreme flood events (Alfieri et al., 2015). This being the case, there is a need for more accurate flood risk assessment schemes, particularly in areas prone to extreme flooding. Flood hazard mapping and floodplain zoning can prove quite beneficial for mitigating the impacts of flood. It creates easily-read, rapidly accessible charts and maps which facilitate the identification of areas at risk of flooding and also help prioritize mitigation and the response efforts (Bapulu and Sinha, 2005).

1.1 Objectives

The objectives of the study are:

- Assess the decadal change in Land Use and Land Cover (LULC) pattern using GIS and remote sensing
- Asses the decadal changes in river dynamics of Reu Khola, Madi, Chitwan
- Determine the flood prone areas of Madi, Chitwan

1.2 Rationale

The Reu Khola is one of the major rivers draining Madi. Headwater tributaries originating from Churia hills directly drain into this basin. It serves as one of the major water sources for the people of Madi and also contributes to groundwater recharge.

Madi significantly lacks sufficient examination to aware people about the condition of recurring flood events and landslides. It is crucial to know about geography, landscape, ecology, economics and biodiversity including the pattern of the natural resources to regulate land management activities. Land use and land cover go hand in hand. Land and its uses are subjected to various changes due to the changes in river dynamics and floodplain inundations. The deposition of debris, sediments and erosion degrades the agricultural land and has detrimental effect to the built up areas. Madi lies in the buffer zone of Chitwan National Park and is also a part of Terai Arc Landscape (MoSWC, 2008). It is also a major part of Chure which makes it more vulnerable to degradation by both anthropogenic and natural activities.

Additionally, flood assessment and flood hazard mapping helps us to supervise management of the flood prone areas. It also gives us the idea about riverine hazards it initiates enabling us to find out about alternative factors and reduce its adverse effects. It also serves as a platform to plan development activities and formulate reliable policies respective areas. Consequently, the findings of the project would be highly beneficial to local people of the area as well as for governmental and non-governmental agencies to advance infrastructural undertakings and to improve economic condition of the place.

2. Materials and methods

2.1 Study area

Madi municipality lies in Chitwan district of Nepal. It falls under province 3. It extends between 27.421°N latitude and 84.375°E longitude. It covers a total area of about 219 km². Madi lying entirely in the Terai region is preferred by hot and humid climate with abundance amount of rainfall (**Fig. 1**). It is surrounded by the hills of Chure lies in the buffer zone of Chitwan National Park. Madi being at the border is in contact with the forest of Valmiki National Park, India in the south and is a part of Terai Arc Landscape (TAL).

2.1.1 Climate

The municipality has a wide range of climatic seasons. October through February with an average of 25 degree offers a suitable climate. However from March to June temperatures reach as high as 44 degree Celsius. The hot humid days give away to the monsoon season that lasts late June till September resulting flooded rivers

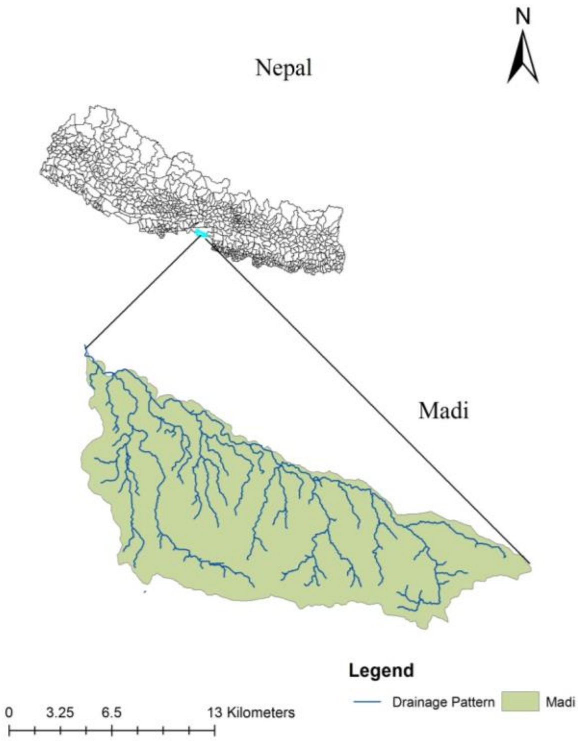

Fig. 1. Study area, Madi along with drainage patterns

(MoSWC, 2008).

2.1.2 Vegetation

The common species found in Madi Municipality are Neem (Azadirachta indica), Dudhkaraiya (Holarrhena antidycentrica), Jamun (Syzyzium cumini), Bel (Agle marmelos) and Med (Viscum album), Sal (Sorea robusta), Bakaina (Melia azedarach),Botdhairo (Lagerstromia parviflora), Sisau (Dalbergia sisoo) and Panan (Desmodium oojeinense) (Bishokarma, Kinsey, Dangol, & Chaudhary, 2014).

2.1.3 Natural hazards

The major natural hazard in this municipality is flood in the eastern and southern part of the district whereas northern part of the district is vulnerable to soil erosion. These natural hazards are mostly triggered by anthropogenic activities. Extraction is done in heavy extent due to which the municipality becomes victim of flood.

2.1.4 Socio-economic aspect

Agriculture is the core of this municipality. Due to lack of modern and professional farming techniques and technologies, farming yields only to carry on life (Adhikari, 2012). Rendering the facts collected by Dahal, 2009, almost 60% of the residents depend on agriculture for their living. The municipality hosts 80% of the country's poultry industry, and is also famous for floriculture, mushroom cultivation and bee keeping. The fertile soil of this area favors for growing various types of cash-crops and vegetable such as mustard, maize, wheat, cabbage, potato, cauliflower, radish, cucumber, pumpkins etc. Other few members are involved in trade and business. People from different ethnic group live here with harmony and cooperation. Human population consists mostly of Hindus and also includes ethnic minority groups, including the indigenous Terai Tibeto-Burmese peoples. Majority of Madi's residents are semi-subsistence farmers (Matthews et al., 2000, Gurung et al., 2009).

2.2 Data collection

2.2.1 Satellite images

Satellite Remote Sensing and GIS are the most common methods for quantification, mapping and detection of patterns of LULCC because of their accurate geo-referencing procedures, digital format suitable for computer processing and repetitive data acquisition (Lu et al., 2004; Chen et al., 2005; Nuñez et al., 2008; Rahman et al., 2011, cited in Hassan, et al., 2016).

Images with cloud cover less than 5% were downloaded from the official U.S. Geological Survey website. LANDSAT images of the years 1989, 1999, 2008 and 2017 were downloaded and the images extracted were from the month of October, November or December. Digital Elevation Model (DEM) file of the study area was extracted from ALOS PALSAR.

2.2.2 Collection of hydro-meteorological data

Rainfall data from nearest rainfall stations of the study site, i.e. Rampur, Bharatpur, Jhuwani, Markhu Gaun and Makwanpur Gadhi station were collected from the Department of Hydrology and Meteorology.

2.2.3 Secondary data sources

Additional information and reports were referred from the central library of Kathmandu University, Department of Hydrology and Meteorology and avidly from the internet.

2.3 Assessing land use and land cover dynamics from 1989 to 2017

For the classification and assessment of different land features of year 1989, 1999, 2008 and 2017, different remote sensing techniques were used.

2.3.1 Boundary delineation and LANDSAT image information

For the delineation of our study area i.e. Madi, one of the municipalities of Chitwan district, we used a shape file consisting official government district and municipality (Gaun Nagarpalika) boundary. Land cover map for required years were obtained using QGIS 3.0 and ArcGIS 10.3. LANDSAT images for the required years were downloaded from official site of U.S Geological survey. Different LANDSAT sensors L4-5 TM, L7 ETM+ and L8 OLI-TIRS were used for satellite images of the years 1989, 1999, 2008 and 2017 (**Table 1**). Images with minimum cloud cover were chosen. Detail information on the LANDSAT images used is given.

Satellite image pre-processing before change

Table 2. Information on LANDSAT images used

Year	Sensor	Acquisition date	Path/Row	Resolution (m)	Cloud cover (%)
1989	L4-5 TM	7th Nov	142/41	30	0.00
1999	L7 ETM+	13th Dec	142/41	30	1.00
2008	L4-5 TM	27th Nov	142/41	30	1.00
2017	L8 OLI/TIRS	19th Oct	142/41	30	4.04

detection phenomenon is very important in order to establish a more direct affiliation between the acquired data and biophysical phenomena (Abd El-Kawya et al. 2011, cited in Hassan, et al., 2016).

All images were downloaded, unzipped and opened in QGIS for preprocessing. Raw images went through Radiometric Calibration which enhanced the image quality. Images from LANDSAT L7 ETM+ and L8 OLI/TIRS were pan sharpened to increase the resolution to 15m (in case of L7ETM+ and L8 OLI/TIRS). Images were then taken to ArcGIS for further processing. Different band images of a single satellite were stacked and a composite band was made. The bands of the image were adjusted to get a false color composite (FCC) image for better visualization. All the images were geo-referenced on projected coordinate system named WGS 1984 UTM Zone 44N by default. The boundary shape file of our study area was re-projected to WGS 1984 UTM Zone 44N as well. The study area was then clipped out from the composite image and classification was carried out using Interactive Supervised Classification. Land features were divided into five classes namely water, floodplain, bare land, cultivated land and forest. After classification the images were reclassified to get total count of the pixels each class occupied and which was processed to get the area occupied by each class using Microsoft Excel.

2.3.2 Selection of training samples for classification

Suitable training samples for each class were taken from the composite image through digitization. The samples were taken based on visual identification of different land features through different band combinations.

2.3.3 Calculation of decadal variation

The classified images were then reclassified to obtain a numerical value representing the area occupied by each land class in 1989, 1999, 2008 and 2017. The change in areas of different land classes of different decades were then calculated using Microsoft Excel.

2.4 Error and accuracy assessment

The accuracy of land use and land cover (LULC) maps that are derived with digital remote sensing data is usually represented in terms of producer’s accuracy, user’s accuracy, and overall accuracy, which are commonly calculated from an error matrix (or confusion matrix (Congalton and Green, 1999)).

LANDSAT images with minimum cloud cover and of consecutive months i.e. October, November or December were chosen to minimize error. Radiometric correction was carried out for clearer and sharper image. False color composite has been incorporated for better visual interpretation and classification of land features. All the images have been re-projected to the same coordinate system i.e. WGS 1984 UTM Zone 44N. For accuracy assessment more than 400 samples from Google Earth Pro has been taken as ground truth and cross checked with the classified LULC map images of the study area of different years.

According to FCAA standard, overall accuracy of 75-99% is considered to be mostly correct, 51-74% to be correct, 24-50% to be incorrect, 1-24% to be mostly incorrect and 0% to be absolutely incorrect (Thenkabail et al., 2005).

2.5 Calculating river sinuosity

The physical appearance and operational characteristics of a modern day river is product of the adjustment of the river to the boundaries and magnitude of stream flow and the erosion debris produced from the adjacent watershed (Rosgen, 1996, cited in Shrestha, 2010).

The classified images of different decades showed us significant change in the main river course draining Madi, i.e. Reu khola. So in order to calculate the change in sinuosity of Reu Khola, firstly, we delineated the left bank and right bank using polyline feature in ArcGIS up to the extent of 23 km from 27°30’N 84°15’E to 27°24’N 84°27’ E. Then using the Stream Gradient and sinuosity toolbox, we calculated the sinuosity of left and right bank of Reu khola from the years 1989, 1999, 2008 and 2017, which is generally the actual path length divided by the shortest path length (Leopold, Wolman, & Miller, 1964) given as,

Sinuosity = (Actual path length of the river)/(Shortest distance between two points)

2.6 Development of flood hazard map

Flood hazard mapping was performed by using ArcGIS 10.2 software tools. Multi-criteria decision analysis (MCDA) has been recognized as an important tool for analyzing complex decision problems, which often involve incommensurable data or criteria (Hwang and Lin 1987; Malczewski, 2006, cited in Rahmati et al., 2016). MCDA methods could be employed to integrate technical, environmental and socio-economic objectives to achieve an optimal decision (Ghanbarpour et al., 2013, cited in Rahmati et al., 2016). The map was prepared by considering slope, rainfall distribution, LULC pattern and the distance away from river (Acharya, 2016). Digital Elevation Model obtained from ALOS PALSAR and the rainfall data obtained from Department of Hydrology and Meteorology were used to prepare the maps for each individual factor.

Slope weightage map was created with the help of DEM file of the study area. Slope of the entire study area was divided into three classes: 0-10°(high), 10-20° (moderate), >20° (low).

According to the previous studies (Fernandez and Lutz, 2010), the most affected areas during floods are those near these rivers, as a consequence of overflow. Weightage map for distance away from the river parameter were created by using multiple buffer ring operation that helped in classification of the study area. The distance intervals used were 0-200 m (high), 200-800 m (moderate), 800-1500 m (low), >1500 m (very low).

Interactive supervised classification was adopted for the classification process of the land features. The whole study area was divided into 4 classes (bare land, cultivated land, water body/floodplain, forest).

Rainfall data from five meteorological stations (Bharatpur, Rampur, Jhuwani, Makwanpur gadhi and Markhu gaun) from the year 1989 to 2017 were collected from the Department of Hydrology and Meteorology. The rainfall data were then used to create a rainfall distribution map of the study area.

Rainfall distribution of the study area was classified into two classes 1500 - 2000 mm and > 2000 mm. The rainfall data was then opened in ArcGIS and interpolated using Inverse Distance Weighted (IDW) method (Acharya, 2016).

2.6.1 Flood hazard zone

The flood hazard zone map was prepared by reclassifying the maps and giving appropriate weight to each of the factors considered depending on the extent of effect individual classes have on flood development. Then, the maps were overlaid using Weighted Overlay tool in ArcGIS and then the weighted sum of each of the factors were calculated and the maps were compiled using Raster calculator from ArcGIS toolbox.

3. Results and discussions

3.1 Land cover dynamics from 1989 to 2017

When LANDSAT images of the study area (Madi) were attributed to Interactive Supervised classification, the area covered by different land features showed significant variation with time (**Fig. 2**). Water bodies which covered 7.1 km^2 in 1989 have increased to 10.26 km^2 in 2017. Floodplain which covered 4.7 km^2 in 1989 has increased to 6.44 km^2. Bare land which covered 42.7 km2 in 1989 has decreased to 22.6 km^2 in 2017. Cultivated land which covered 30.1 km^2 in 1989 has increased to 54.08 km^2 in 2017. Forest area which covered 134.4 km^2 in 1997 has decreased to 125.62 km^2 in 2017. Changes in area of each class for every decade are shown in **Table 2**.

Among all the land features, cultivated land is increasing at higher rate than other land features. However, there is a decrease in bare land and forest area with higher decreasing values for bare land. There is only slight area increase in case of water bodies and floodplain through the years 1989 to 2017.

3.2 Land cover dynamics from 1989 to 2017

After comparing the ground truth points taken from Google Earth Pro, the accuracy for each of the land feature was calculated by the given formula and the result is present in **Table 3**.

Overall accuracy (%) = (Total correct values)/(Total number of sample taken)×100%

Overall accuracy of the entire study and classification was found to be 82.02% (**Fig. 3**) which is considered to be mostly correct and highly reliable (Thenkabail et al., 2005).

3.3 River Dynamics

Sinuosity for both the banks of the Reu Khola, up to an extent of 23 km, was calculated to assess the impact of changing river course to the adjacent surrounding. High sinuosity (>1.50) suggests meandering of the channel, whereas 1.05 - 1.25 suggests the channel is winding. Sediment transports, bed load together with

Table 2. Decadal variation in the area of each land feature from 1989 to 2017

	Area in km²				Change in km²			
Class	1989	1999	2008	2017	1989-1999	1999 - 2008	2008 - 2017	Total change
Water body	7.1	3.19	8.22	10.2	-3.91	5.03	2.04	3.16
Bare land	42.7	29.15	25.8	22.6	-13.55	- 3.35	-3.2	-20.1
Cultivated land	30.1	46.93	50.42	54.0	16.83	3.49	3.66	23.98

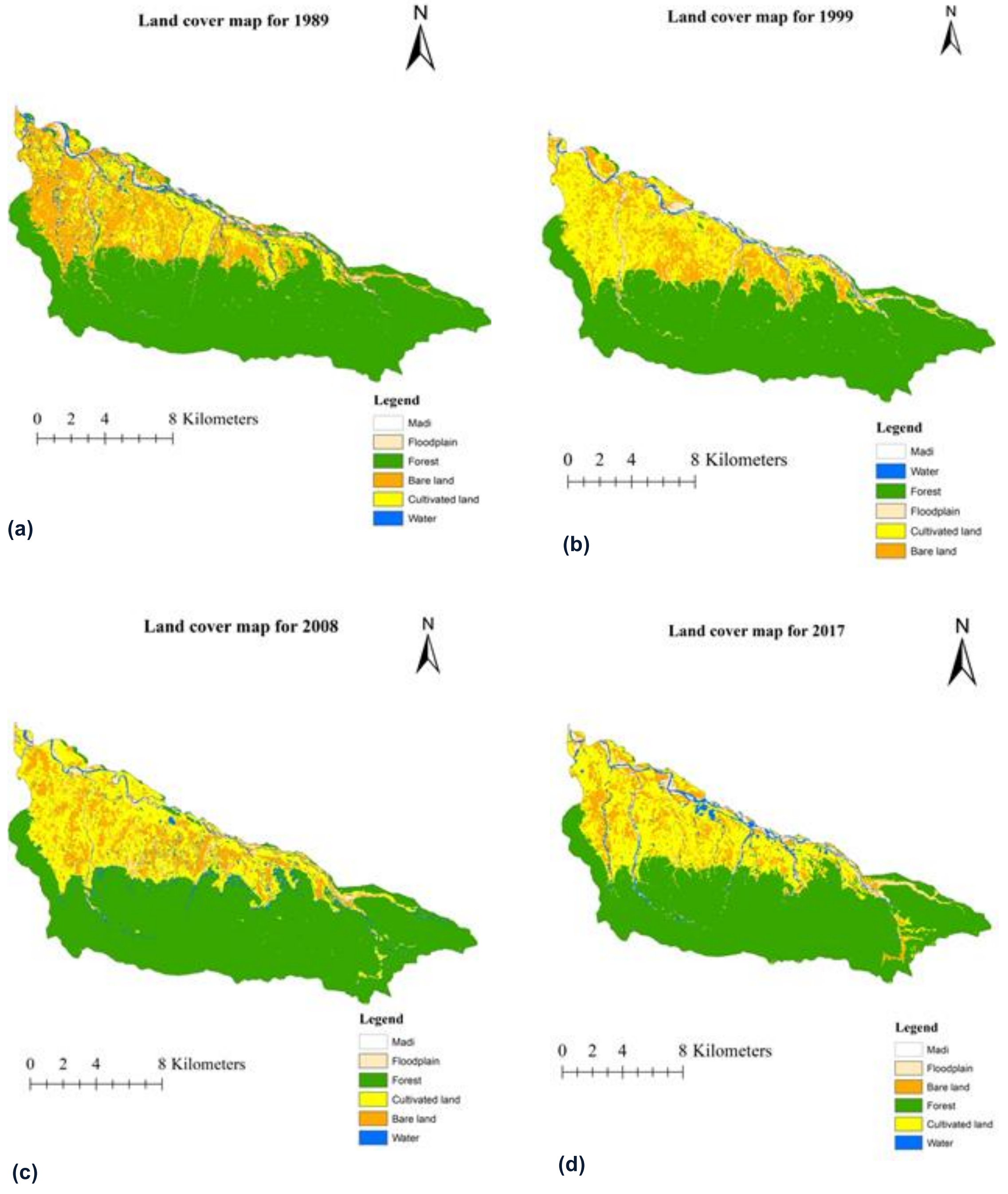

Fig. 2. Land use and Land cover maps for the year (a) 1989, (b) 1999, (c) 2008 and (d) 2017

Table 3. Accuracy assessment of all land features from 1989 to 2017

Land features	1989 (%)	1999 (%)	2008 (%)	2017 (%)	Overall Accuracy for each land feature (%)	Overall Accuracy (%)
Water	88.2	94.2	68.5	88.89	84.94	
Floodplain	95	98.9	55.5	77.78	81.8	
Cultivated land	65.1	78.9	70	85	74.75	
Bare land	90	75.7	75	57.89	74.64	82.02
Forest	98.9	97.1	94.2	85.71	93.97	
Overall Accuracy for each year (%)	87.44	88.96	72.64	79.054	-	-

slope of the floodplain are the basic factors that influence sinuosity (Smith, 1998). Anthropogenic modifications can also influence the change in sinuosity of a river.

The sinuosity of the Reu Khola has increased from 1989 where the sinuosity seems to be the lowest for both banks of the river. The sinuosity is highest at 2008 for both the left bank (1.36) and the right bank (1.66). It however decreases as we reach 2017, which could indicate the cutoff of the extreme meandering of river course.

3.4 Flood hazard zone

Flood hazard zone map was created by overlaying all the contributing factors mentioned before. Flood hazard zone map for Madi is shown in **Fig. 4** which is classified into five classes: very high, high, moderate, low and very low. The flat areas i.e. the areas occupied by bare land, cultivated land and the water body and its vicinity for Madi is particularly seen in risk of flood hazard.

4. Conclusions and recommendations

GIS application has practically revolutionized the planning process in Nepal, and more and more productive results have been developed as per its usefulness and efficiency. RS and GIS is a powerful tool for mapping, evaluating and monitoring. This information is congregated in the project which presents a systematic approach in the preparation of LULC map, flood hazard map as well as in obtaining the sinuosity of Reu Khola in Madi municipality. The techniques and analysis part can also be used in the variety of applications in disaster management at various levels and scales.

During the study of LULCC over four decades, it is found that forest and bare land in the study area has been notably decreased. Other three classes water bodies, cultivated land and floodplain have also changed but considering the study period their changes are almost persistent. After analysis, it was found that water bodies which occupied 7.1 km^2 in 1989 has increased to 10.26 km^2 in 2017, cultivated land which occupied 30.1 km^2 in 1989 has increased to 54.08 km^2 in 2017, floodplain which occupied 4.77 km^2 in 1989 has increased to 6.44 km2 in 2017, bare land that covered 42.7 km^2 in 1989 has decreased to 22.6 km^2 in 2017 and finally, the forest that covered 134.4km^2 in 1989 has been decreased to 125.62km^2 in 2017. Both the anthropogenic (deforestation, urbanization, migration) and natural activities (floods, landslides, earthquakes) are the contributing factors for the changes in geographical features of the study area.

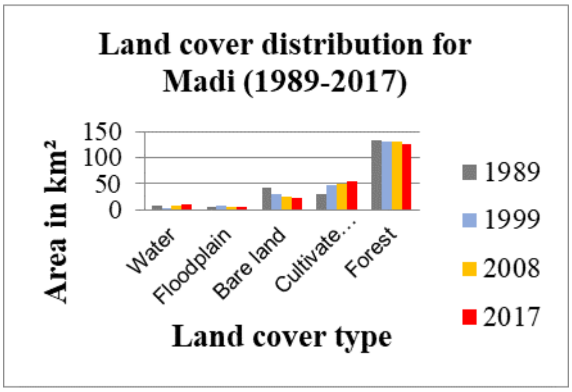

Fig. 3. Bar graph showing the area covered by each land feature from 1989 to 2017

Table 4. Decadal sinuosity of the Reu Khola

S.N.	Year	Left bank	Right bank
1	1989	1.21	1.22
2	1999	1.37	1.29
3	2008	1.36	1.66
4	2017	1.24	1.23

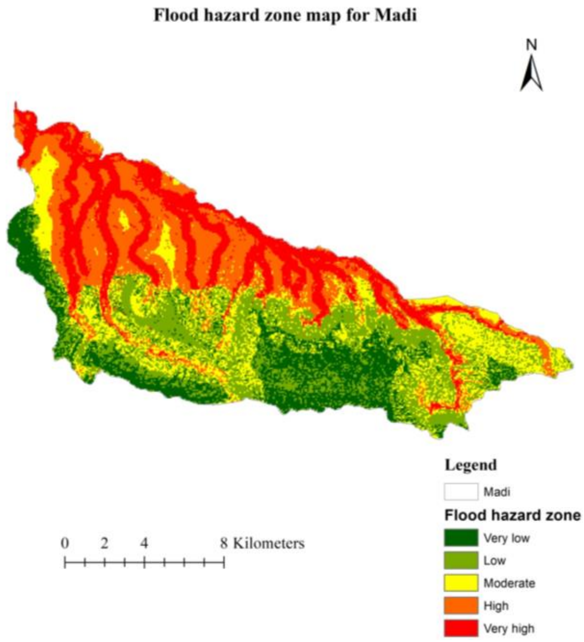

Fig. 4. Flood hazard zone map for Madi

The study of river dynamics of the Reu Khola from 1989 - 2017, representing four decades, shows variation in the path followed by the river. The calculation of sinuosity in both the banks of the Reu Khola indicated meandering of the river course in 2008 with the highest value of 1.66 (for the right bank) and 1.36(for the left bank). However, the sinuosity of other decades showed significant winding of the river course.

Multi criteria evaluation method is adopted to develop flood hazard zone map with five zones visualize very high, high, moderate, low and very low. Factors like slope, rainfall distribution, distance away from river and LULC of the study area are being considered. Floods are natural phenomena which can't be prevented but mitigating measures can be incorporated to reduce the risk. Flood hazard in Madi Municipality of Chitwan district is related with both natural and anthropogenic activities. Besides natural factors, the anthropogenic factors like extraction of sand and sediments from the Chure region are responsible for the floods. Occurrence of floods is increasing due to climate change issues, improper watershed management, increasing number of assets and people in flood hazard zone.

The constructive and efficient GIS and RS tools provide assistance in the development of flood hazard zone map which is simple, cost effective and reliable. Using the flood hazard map, flood prone areas can be identified which can further be considered for planning the developmental works in well-mannered and sustainable way.

However, due to unavailability of past flood hazard zone data for Madi and also data for other parameters which could affect the flood development, our study was limited as we couldn't increase the reliability of our data and validate it.

4.1 Recommendation for future works

Study was conducted under constraint of limited data availability. Results would be more reliable and enhanced if study could be conducted with adequate amount of data and required information. Some of the recommendations are made for further studies in the future.

4.1.1 High resolution LANDSAT images

For classification, LANDSAT images of high resolution will be better so that the land features of the study area can be properly represented and delineated with minimum cloud coverage.

4.1.2 Study area visit

The project we conducted was based on the desk review, however, the visit to study area would have been more informative and reliable.

4.1.3 Consideration of additional factors to develop flood hazard map

Inclusion of factors like soil type, infiltration rate, drainage density, number of watershed, discharge rate and flow velocity can provide more accurate and reliable flood hazard map.

References

Acharya, A., 2016. Land cover dynamics and flood hazard assessment along the rivers of Nawalparasi District from 1991 to 2015 (unpublished).

Adhikari, D. R., 2012. An introduction to Madi.

Alfieri, L., Burek, P., Feyen, L., and Forzieri, G., 2015. Global warming increases the frequency of river floods in Europe. 2247-2260.

Attanasi, E.D. and Karlinger, M.R., 1979. Risk preferences and flood insurance. American Journal of Agricultural Economics, **61**: 490–95.

Bapulu, G.V. and Sinha, R., 2005. GIS in Flood Hazard Mapping: A case study of Kosi River Basin, India. Noida.

Benniston, M., 2009. Trends in joint quantiles of temperature and precipitation in Europe since 1901 and projected for 2100.

Benz, U.C., Hofmann, P., Willhauck, G., Lingenfelder, I., and Heynen, M., 2003. Photogrammetry & Remote Sensing. Multi-resolution, object-oriented fuzzy analysis of.

Bishokarma, B.K., Kinsey, C.K., Dangol, D.R. and Chaudhary, P., 2014. Folk use of plant resource at Madi valley of Chitwan District, Nepal.

Chrisman, N.R., 1999. What does 'GIS' mean? Transactions in GIS: 175-186.

Collins, G.B., 2002. Land Use Land Cover (LULC). US Geological Survey.

Congalton, R. and Green, K., 1999. Assessing the accuracy of Remotely Sensed data principles and practices.

Dufour, S., Rinaldi, M., Piegay, H. and Michalon, A., 2015. How do river dynamics and human influences affect the lanscape pattern of fluvial corridors? Lessons fron the Magra River,Central-Northern Italy. Landscape and Urban Planning: 107-118.

DWER. (n.d.). Erosion and Sedimentation. Retrieved from Department of Water and Environmental Regulation, Government of Western Australia: http://www.water.wa.gov.au/water-topics/waterways/threats-to-our-waterways/erosion-and-sedimentation.

FAO, 2000. The Global Forest Resources Assessment 2010, Rome, Italy. Food and Agriculture Organization of the United States.

Fernandez, D. and Lutz, M., 2010. Urban Flood Hazard Zoning in Tucuman Province, Argentina, using GIS and Multi-Criteria Decision Analysis. Engineering Geology, **111**: 90-98.

Hassan, Z., Rabia, S., Sheikh, S. A., Malik, A. H., Aziz, N., Butt, A., et al., 2016. Dynamics of Land Use and Land Cover Change(LULCC) using geospatial techniques:

A case of Islamabad Pakistan. Springerplus, **5** (1): 812.

Heidari, A., 2009. Structural master plan of flood mitigation measures.

Leopold, L.B., Wolman, M.G. and Miller, J.P., 1964. Fluvial Processes in Geomorphology. San Fransico: W.H. Freeman and Co.

MoSWC, 2008. Report on Climate Assesment of Lower Terai Region. Ministry of Soil and Water Conservation.

Mustard, J.F., Defries, R. S., Fisher, T. and Moran, E.F., 2004. Land Use and Land cover change pathways and impacts. In Land Change Science: Observing, Monitoring and Understanding Trajectories of Change on the Earth's Surface, Springer: 411 - 429.

Rahmati, O., Zeinivand, H. and Besharati, M., 2016. Flood hazard zoning in Yasooj region,Iran, using GIS and mulit-criteria decision analysis. Geomatics, Natural Hazards and Risk, **7** (3): 1000-1017.

Rawat, J. S. and Kumar, M., 2015. Montoring Land use/ cover change using remote sensing and GIS techniques. A case study of Hawalbagh block, district Almora, Uttarkhand, India.

Shrestha, P., 2010. Climate Change Impact on River Dynamics of the Bagmati Basin, Kathmandu Nepal. National Adaptation Progaram of Action(NAPA) to Climate Change Project, Government of Nepal.

Shrestha, S., 2012. Drivers of Land Use Change: A Study of Sundarijal Catchment, Shivapuri, Nagarjun National Park.

Smith, C., 1998. Modelling high sinuosity meanders in a small flume. Geomorphology, **25** (1): 19 - 30.

Thenkabail, P. S., Schull, M. and Turral, H., 2005. Ganges and Indus river basin land use/land cover (LULC) and irrigated area mapping using continuous stream of MODIS data. Remote Sensing of Environment: 317-341.

Wu, G.S., 2008. On the accuracy of landscape pattern analysis using remote. Landscape Ecol.: 505-511.

Yu, Q., Gong, P., Clinton, N., Biging, G., Kelly, M. and Schirokaver, D., 2006. Object-based Detailed Vegetaion. Photogrammetric Engineering & Remote Sensing: 799 - 811.

Symbols and abbreviations

%	Percentage
mm	millimeter
km	kilometer
km^2	Kilometer square
°	Degree
N	North
E	East
ALOS	Advanced Land Observing Satellite-1
DEM	Digital Elevation Model
ETM	Enhanced Thematic Mapper
FCC	False Color Composite
GIS	Geographical Information System
IDW	Inverse Distance Weighted
LANDSAT	Land Observation Resource Satellite
LULC	Land Use Land Cover
LULCC	Land Use And Land Cover Change
OLI/TIRS	Operational Land Imager/ Thermal Infrared Sensor
PALSAR	Phased Array type L-band Synthetic Aperture Radar
RS	Remote Sensing
TAL	Terai Arc Landscape
TM	Thematic Mapper
UTM	Universal Transverse Mercator
WGS	World Geographic System