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An Assessment of Lake Area Shrinkage through Geospatial Approach: Case study of Phewa Lake of Kaski District, Nepal

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Abstract

Lake area shrinkage has been severe throughout all ecological regions in Nepal. Sedimentation of lakes reduces both effective depth and surface area of lake, which ultimately reduce the effective life of the lake. Phewa Lake covering an area of about 439 hectares has been one of the prominent tourist attractions of Nepal. Remotely sensed data sets are emerging as better choice for managers to observe spatially explicit changes over the time period where a high repeat frequency is required. This study aims to determine the spatio-temporal change and assess the shrinkage rate of Phewa Lake area. Six temporal (November 1988 to October 2012) Landsat TM and ETM satellite images were used as primary data to detect change and calculate dimensions of the lake. ERDAS IMAGINE 9.2 and ESRI ArcGIS 9.3 were used for digital image processing such as projecting in common coordinate system, digitizing the lake boundary and calculating the area. Standard formula used to calculate annual shrinkage rate of the lake reveals this rate as 0.46% and the lake area as 410.5 ha. respectively. The mean annual decrease of the lake was about 2 ha. Shrinkage in the lake area has indicated that it could create potential threat of eliminating the lake in future. Thus, a detailed study and regular monitoring is recommended for controlling sedimentation problem in the lake.

Keywords*: Spatio-temporal change, Sedimentation, Phewa Lake, Lake Area shrinkage*

Introduction

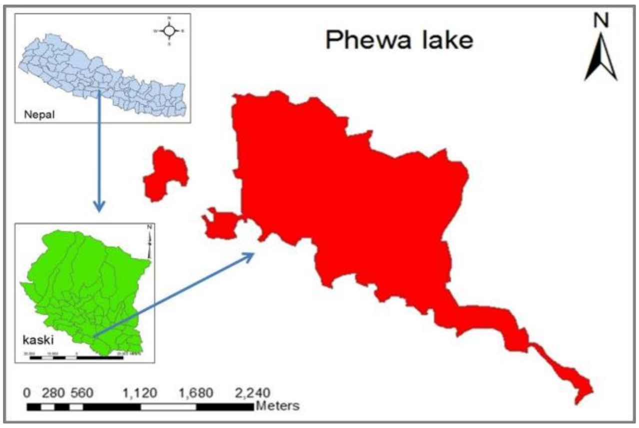
Lake holds 3% of available water of Nepal. Lake area shrinkage has been severe in Nepal throughout all ecological regions. Most lakes are geologically young and shrinking since the natural results of erosion will tend to wear away the sides and fill the basin. Lake and river are the sources of irrigation, drinking water and most importantly they are sources for poor people. Sedimentation of lakes reduces both effective depth and surface area of the lake, which ultimately reduces the effective life of the lake (Awasthi et al. 2007, Sthapit and Balla, 1998*).*

Phewa Lake, one of the lakes having national significance, covers an area of about 439 hectares and has been one of the prominent tourist attractions of Pokhara. Beside recreational service, Phewa Lake also supplies water to generate 1 megawatt of hydropower and to irrigate approximately 320 hectares agriculture land (Sthapit and Balla, 1998).A physical collapse of Phewa dam occurred in 1974 that drained out much of lake water causing lake area shrinking to a smaller area (Pokharel S, 2008) resulting encroachment of 138 hectares of land of Phewa lake area surveyed illegally during survey in 1977 (The Kathmandu Post, Aug 4, 2012.). An average delta formation is continued at the rate of about 2 hectares annually since 1973 so that silt trap area, depending upon the situation of Harpan khola, main feeder of the lake, will completely filled up in between 24 to 33 years reducing 16% of the lake area (Sthapit and Balla 1998). Despite different conservation program, (Heyojoo et.al, 2009) has estimated that annual siltation rate has a range of about 175,000-225,000 m3. At this rate the terminal silt trap portion will be separated from the main lake by next 20-25 years and the lake will be proper "dead" by next 135-175 years, assuming loss of 80% water volume (Sthapit and Balla, 1998).

Interpretation of aerial photographs or satellite imageries taken at various intervals provides valuable information of physical features such as land use, soil, vegetation, stream networks and land forms at different time intervals (Burrough and McDonnell, 1998).Remote sensing for land cover mapping and change detection, particularly in areas where due to accessibility, spatial extension or other factors, the conventional means of ground survey are not sufficient, is considered by several authors as having great potential and as extremely valuable tools (Xiuwan, C et al., 1999). Due to the spatial nature of watershed parameters, remote sensing combined with GIS has proved effective for analyzing, storing, retrieving such biophysical and socio-economic data (Awasthi et al. 2002).

Study area

The lake is about 2 km North West from Pokhara airport and is more or less leaf-shaped (Figure 1) that lies on the narrow space between the Seti Valley. The lake is extended from latitude of 83^{0}55'44"E to 83^{0}58'10"E and from longitude of 28^{0}11'44"N to 28^{0}13'40"N with average altitude of 794m from mean sea level. Water is collected from the watershed of about 123 sq.km. area through the different river and tributaries to the Phewa Lake such as Bhumdi, Marse, Budhimul, Singare, Hadi, Sidhane, Orlang, Andheri, Pokhre byase, Harpan. The Phewa Lake is formed by complex and rugged ridges and spurs and valley bottoms. The hilly terrain and valley bottoms stand out as distinct natural features in the landscape crisscrossed by a number of irregular ridges and spurs. The climate falls under tropical to sub-tropical monsoon type with mean annual rainfall of 4160mm and annual temperature ranging from 29.7^0 C to 32^0 C maximum temperatures from April to June in comparison to mean temperature from 23^0 C to 24^{0}C.



Materials and method

Landsat satellite images freely downloaded from www.earthexplorer.usgs.gov and as listed in Table 1 were used as the main data in the study. The overall processes followed in research is presented in Fig. 2.

$$\text{Rate of change (\%)} = \left\{\left(\frac{b}{a}\right)^{\frac{1}{n}} - 1\right\} X100 \text{(UNDP, RFDTh and FAO, cited by Lamichhane, 2008)}$$

$$PAI = \frac{(A_{i+n} - A_i)}{n}$$

Where,

a = base year data,
b = end time data,
n = number of year,
A_{i+n} = Area of (i+n)th year
A_i = Area of ith year

Flow Chart Diagram, in which Erdas Imagine 9.2 was used for digital image processing such as layer stacking, resolution merge, image reprojection, image enhancement particularly, edge enhancement. The boundary of the lake in each images were digitized and converted into shape files and corresponding area were computed using Arc GIS 9.3. The rate of lake area shrunk was estimated by standard formula referred by UNDP and FAO cited by Lamichhane, 2008.

The analysis and interpretation of different aspects of the numeric data of Lake area change were done on Microsoft Excel. The results are presented in the forms of maps, tables, graphs and charts.

Table 1 : Details of Landsat imagery used in the study

Sl N	Satellite	Sensor	No of Band	Pixel size (m)	Observation date
1	Landsat-V	TM	7	30X30	Nov.20, 1988
2	Landsat-VII	ETM+	8	15X15	Dec.22, 1999
3	Landsat-VII	ETM+	8	15X15	Dec.13, 2003
4	Landsat-VII	ETM+	8	15X15	Nov. 3, 2008
5	Landsat-VII	ETM+	8	15X15	Nov.28, 2011
6	Landsat-VII	ETM+	8	15X15	Oct.29, 2012

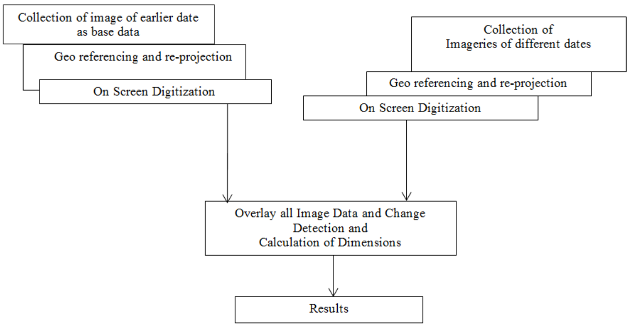


Figure 1: Flow Chart of Data Analysis by GIS Method for Change Detection

Results and discussion

Spatial and temporal changes of the lake

Sedimentation and siltation has significantly contributed the shrinkage of Phewa Lake. Not surprisingly, area of the delta in western side has increased which is main evidence for the shrinkage of the lake. This supports the findings of many studies on estimation of sedimentation to the lake from watershed, including one from the author himself (Heyojoo et. al, 2009) In the past, Phewa lake was giant covering large area in comparison to present as shown in Figure 3 and part of the Phewa lake in western side has been isolated from the main lake as detected from the image from 2003 (Figure 4). Figure 4

Table 2: Change in parameter of Phewa Lake

Dates	Area (ha)	Perimeter (m)	PAI (ha)	Rate of change (%)	Data source
1988	458	18301			Imagery
1998	439.5	NA	-1.85	-0.41147	Sthapit &Balla
3/19/1999	437.8	19392	-1.7	-0.3868	Imagery
12/23/2003	429.9	18981	-1.98	-0.4542	Imagery
11-03-08	419.1	18903	-2.16	-0.50757	Imagery
11/28/2011	412.7	18416	-2.13	-0.51164	Imagery
10/29/2012	410.5	18205	-2.2	-0.53307	Imagery

shows that shrinkage of the lake area is prominent towards the western part of the lake. However, very little change in area and shape has been observed on other side of the lake because of well-defined shoreline and little sediment deposits.

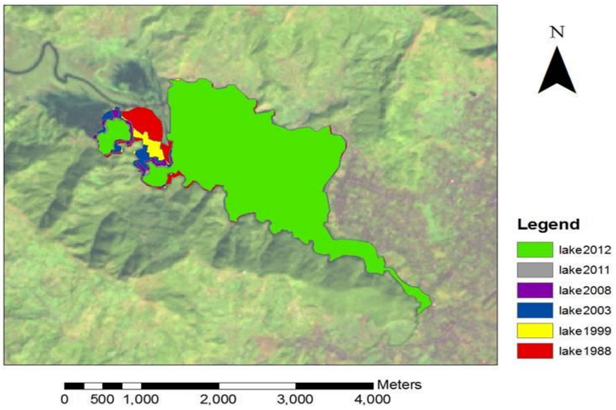


Figure 3: Change of lake between an1988and 2012

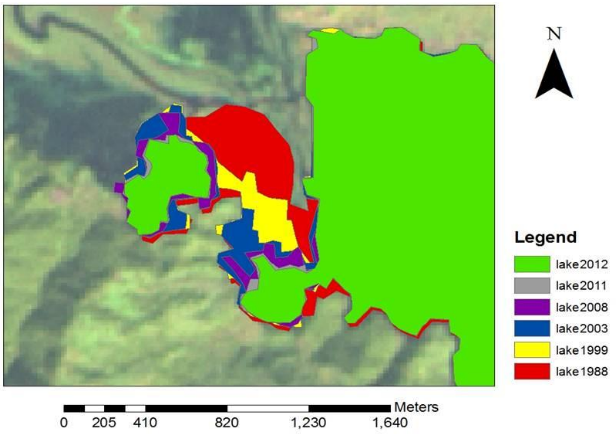


Figure 4: Change in western part of the lake

Trend of negative Periodic Annual Increment (PAI) and Percentage Rate of Change are found to be accelerated from 1999 (-1.70 ha/year & -0.38680) to 2003 (-1.98 ha/year & -0.45420) and 2008 (-2.16 ha/year & -0.50757) and followed by nominal difference in 2011 (-2.133 ha/year & -0.51164). The continuous shrinkage of lake is likely to take place over the coming days as no integrated effective conservation program is visible in the site.

Lake area verification

The lake area estimated from the image of 1999, i.e. 437.8 Ha and that Sthapit and Balla (1998) had calculated 439.5 ha are very near. Similarly the area estimated from imageries in 2011 was 412.7ha and the same calculated from Google Earth image of higher resolution of same year was 410.9ha. This apparent disparity in result can be attributed to low resolution of imageries. Advantages of RS & GIS technology in assessing earth's feature area changes over short time has been valuable gift. This technology has immense potential hence, should be fully harnessed in the field of natural resource management

Conclusion

The net reduction of lake area by 47.5 ha over the period from 1988 to 2012 can be attributed to sediment deposits due to anthropogenic activities such as rural road construction, improper and inappropriate land use pattern both in upstream and downstream. Considering Mean Area Increment (MAI) equal to about 2 ha/year negative and average rate of change as 0.467 % negative from the study, the lake will be dead over 209 years. Shrinkage is seen prominent in the western part of the lake resulting isolation of a part of the lake from main body. The shrinkage area has potential to be encroached as encroachment of lake area has been reported repeatedly

Consequences brought by lake area shrinkage are not only an environmental phenomenon rather it is a social, political and economic issue. Country like Nepal needs special attention to mitigate impacts of such phenomenon as it may bring negative consequences in economy, environment and bio-diversity in both upstream and downstream

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