Research article

Monitoring of Riverbank Erosion and Shoreline Movement at Amu River Using Remote Sensing and GIS: A Case Study in Jowzjan, Afghanistan

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Abstract This study examines the quantification of riverbank erosion trend, by detecting the shoreline changes and river migration of Amu River, during the recent 14-years period in Qarqin District of Afghanistan. In this study, Landsat images (TM/ETM/OLI TRI) from 2000 to 2014 were used to categorize eroded area and identify shoreline change locations. Furthermore, the images were classified into five different classes, i.e., water, built-up, barren land, sand bank, and agriculture land. River boundaries were digitized from the shorelines on the images from 2000 to 2014. Digital Shoreline Analysis System (DSAS) was applied to calculate shoreline movement. End point Rate (EPR) and Linear Regression Rate (LRR), were used to compute long term changes for the analysis. The study found that the river movement was toward Afghanistan side, i.e., south-word. The threat of losing land of Afghanistan was estimated to be ca. 362.4 ha/year. The total eroded area was calculated to be 1,984 ha, 1,410 ha, and 1,680 ha during period of 2000-2005, 2005-2010 and 2010-2014, respectively. The shoreline was demarcated in each image and the area was categorized into three zones correspond to the erosion trend, i.e., lower as moderate eroded zone, central as high eroded zone and upper as lower eroded zone. This research work can provide the advocatory input to policy makers in war torn countries to manage riverbank erosion.

Keywords Amu River, Afghanistan DSAS, GIS, morphology, remote sensing, riverbank erosion, shoreline analysis

INTRODUCTION

Riverbank erosion and channel shifting are geomorphological phenomenon related to the bank navigation change in bed elevation, bank line change, and modification of the flow condition in the topographic reaction (Nath et al., 2013). The effects of river erosion are various, e.g., social, economic, health, education, and sometimes political. Homelessness is the most important factor, which forces people to migrate due to riverbank erosion from residential areas, and this increases poverty and involves the people into criminal activities (Lam-Dao et al., 2011). Due to the lack of proper management, hundreds of hectares of agriculture land and residential lands near the riverbank of Amu River changes to the riverbed every year. In last three decades, riverbank erosion has become a serious issue in the northern part of Afghanistan. Heavy rainfall and melting stored snow on the mountainous areas make the water flow of Amu River very fast and vast. The riverbank erosion on the left side of the Amu River occurs every year and destroys a lot of agricultural land and houses in Qarqin, Jowzjan Province and changed the riverbed drastically. In Qarqin District, 60% of the land has been washed away and consequently only four villages out of 14 villages remained over the last six decades. If the case is ignored and no serious work is done, Qarqin District people will face more serious land loss, in the near future. So far, no studies have been conducted to estimate the land lost and analyses the river shoreline migration. The overall objective of this research is to estimate riverbank erosion effect on the land use change, and to categorize the impact of shoreline movement (ADB Institute, 2009).

METHODOLOGY

Study Area

The study area is located in the northern part of Qarqin District along the Amu (Darya) River with elevation of 249 m a.s.l. and the coordinates of 37.24 46° N 66.2525° E. The Qarqin District, covers an area of around 1,275 km^2 with the population of 21,400 (2006). The Qarqin District borders with Turkmenistan to the north. It also borders Khamyab District to the west, Mardyan and Mingajik Districts to the south and Shortepa District of Balkh province to the east (Fig. 1).

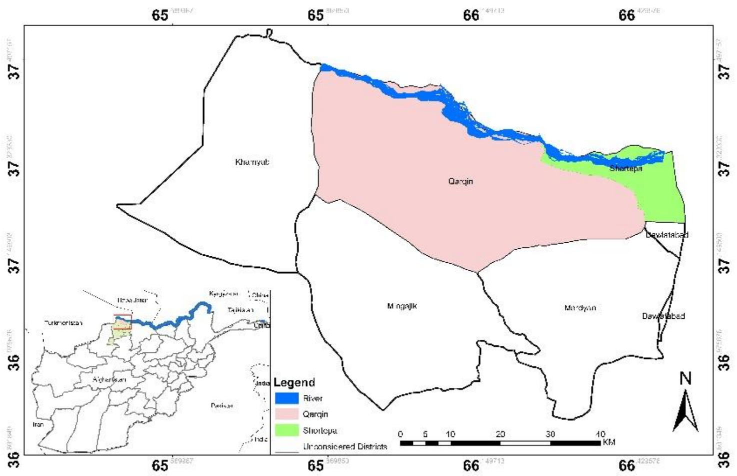

Fig. 1 Study Area in Qarqin District, Jowzjan, Afghanistan

General Methodology

To evaluate the river migration of Amu River during the 14 years (Fig. 3), Landsat images (TM/ETM/OLI TRI) from 2000 to 2014 have been considered for the analysis. Pre-processing, including atmospheric noise correction, contains data process which usually precedes most of the manipulation and analysis of the image data to extract exact information. Scan line corrector (SLC) and geometric corrections were performed. Most of images in the study area were required to fill the gaps by SLC. The gaps were removed from those images by SLC implemented in ENVI software. Geometric correction was applied for each year's image and taken 2014 image as a base image to adjust all 14 yeas images into exact the same location with the sufficient RMS error (RMS < 1 pixel). Finally, The Landsat imagery was set as 185 km X 185 km, i.e., 34,225 km^2. However, in order to avoid a large data set and save analysis time duration image was subsided into 1,258 km^2 subset imagery, adjacent to the banks of the Amu River in the study area (Aher et al., 2012).

Remote sensing and GIS application is very powerful tools to study river geomorphology and channel shifting studies in the different time. In this research supervised classification was performed and all areas was classified into classes, i.e., water, Built-up, Barren land Agriculture and Sand Bank. Furthermore, the classified area was verified with very high resolution IKONAS images (Table 1).

Table 1 Overall accuracy of image classification based on the very high resolution

Landuse	Built-up	Water	Barren Land	Agriculture	Sand	Row Total	Producers Accuracy
Built-up	11	0	0	0	0	11	100.00%
Water	0	5	0	0	0	5	100.00%
Barren Land	0	0	1	0	2	3	33.33%
Agriculture	0	0	0	4	2	6	66.67%
Sand	0	1	0	0	4	5	800.00%
Users Accuracy	100.00%	100.00%	33.33%	66.67%	50.00%	30	
Overall Classification Accuracy = 83.33%							

Vector overlay, and human interpolation were done to identify the shoreline change. The river shoreline was extracted from the available satellite imagery in different period, based on spatial overlays techniques (Rahman, 2013). Digitization was performed to collect shoreline or bank line layers from individual year basis. Digital shoreline analysis system (DSAS), developed by USGS, was used for baseline measurement and calculation of the statistical change rate from the time series of shorelines. DSAS (ver. 4.4) is a computer software which can calculate morphological and statistical change from the historical shoreline positions under ArcGIS system. The baseline is considered as a starting point for all the transects opened by the DSAS program. DSAS creates transect lines that are perpendicular to the reference line, i.e., baseline, at a user-specified distance interval. The distance between the baseline and each point of the intersection of the shoreline with the DSAS transect can be used to calculate the distance measurements such as shoreline change envelope and net shoreline movement (Thieler et al, 2016). Thus, to calculate the rate of change statistics based on DSAS, 123 transects were generated. All the transects were oriented perpendicular to the baseline at 300 m spacing and ca. 65 km along the Amu River in Qarqin District, with some part of Shortapa District. In this research, linear Rogation Rate (LRR) and End Point Rate (EPR) approaches were used to calculate long term change rate.

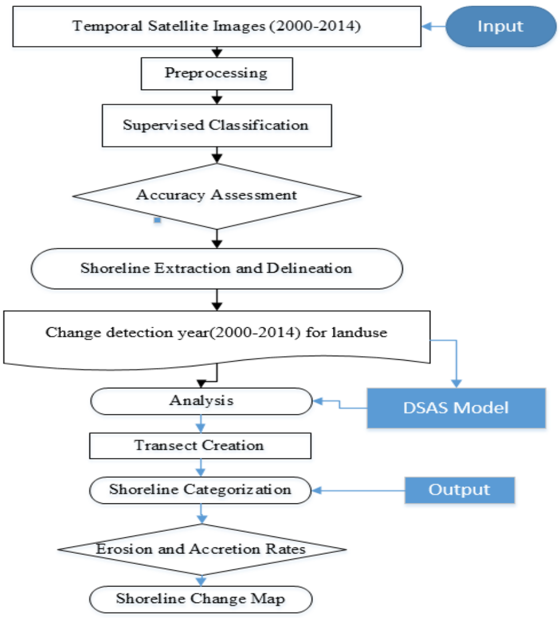

Fig. 2 General Methodology

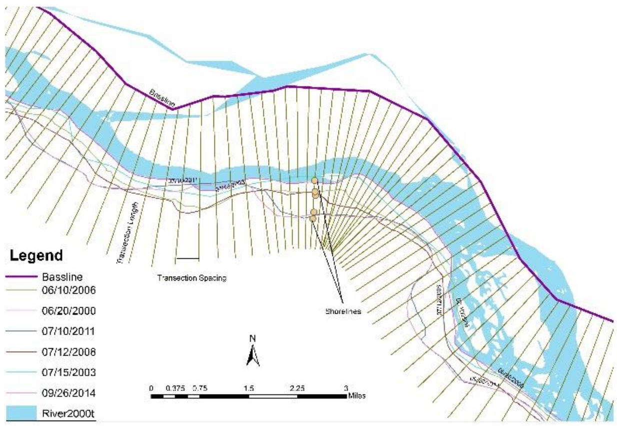

Fig. 3 Shoreline with transect line

RESULTS AND DISCUSSION

The riverbank line change rate was calculated as shown in Table 2. Shoreline changes are present with an emphasis on shoreline erosion, because it is an important natural disaster for Qarqin District. Shoreline movements from different locations and period were demarcated. The eroded area was calculated based on the most recent and oldest shorelines from 2000-2014 in Qarqin and part of Shortapa Districts. The riverbank erosion had occurred differently in the erosion rate and can be classified into 3 zones, i.e., Moderate, Low, and High eroded zones, from downstream, towards upstream (Fig. 4). The overall migration trend of the present right bank was south-eastward. Similarly, the upper and center part of the riverbank shoreline shifting to the south-eastward. In the different parts of the study area, it was different rate of shoreline change and erosion activity (Fig. 5).

Table 2 Long term shoreline change from EPR for 14 years using different interval of shorelines

Years	Mean Erosion (m/yr)	Maximum Erosion (m/yr)	Minimum Erosion (m/yr)	S.D (m/yr)	Mean Accretion (m/yr)	Maximum Accretion (m/yr)	Minimum Accretion (m/yr)	S.D (m/yr)
2000-2003	14.7	125.8	0.22	34.8	5.43	68.6	0.45	29.0
2003-2006	15.4	143.8	0.08	36.0	5.97	68.6	0.21	26.7
2006-2008	21.8	127.6	1.77	36.1	7.56	68.6	0.58	23.8
2008-2011	17.9	149.5	0.02	38.4	4.22	40.9	1.05	13.7
2011-2014	11.3	111.1	0.06	32.3	4.89	53.8	0.08	20.9

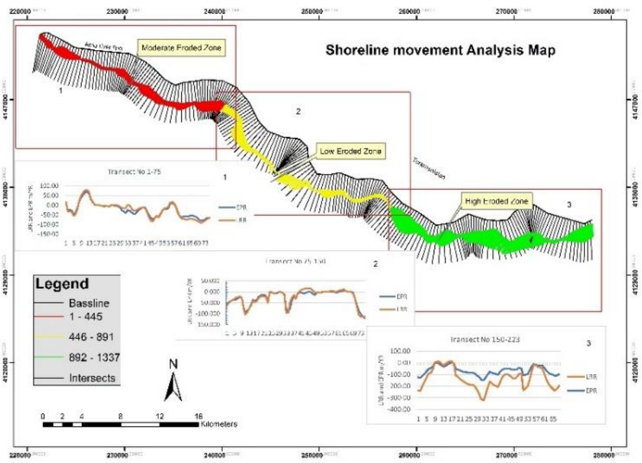

Fig. 4 Shoreline change demarcation (EPR and LRR in meters per year) for year 2000-2014

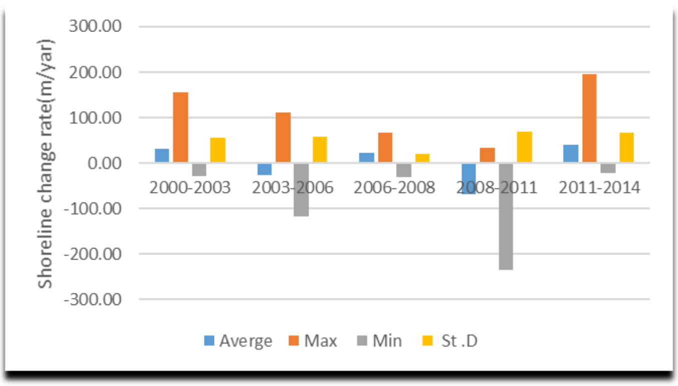

Fig. 5 Average shoreline change rate

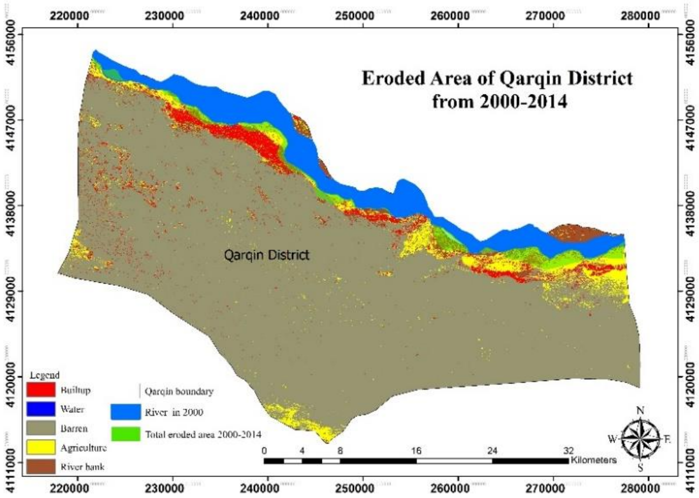

Fig. 6 Total eroded map from in Qarqin District 2000-2014

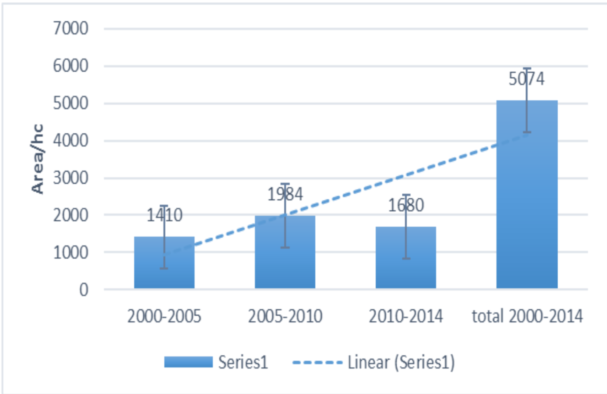

Fig. 7 Total eroded scenarios of Amu River in Qarqin District

The erosion and accretion activity were calculated at 14.7 m/yr and 5.43 m/yr, respectively, remarked at all the 65 km length within the study area of Amu river. In the period between 2006 and 2008, it had severe erosion in all along the Amu river with the average erosion of 21.8 m/yr and accretion rate of 5.97 m/yr. The calculated eroded area was 1,984 ha, 1,410 ha and 1,680 ha during period of 2000-2005, 2005-2010 and 2010-2014, respectively (Fig. 7). Visual comparison of the three-time period of land use maps reveals that illustrates the significant changes in land use between 2005 and 2000, that most changes included the incising the water and sandbank and similarly decreasing the agriculture, buildup and barren land (Fig. 6). According to the land use change map analysis, the water and sandbank area extent increased in the most of time. However, agriculture, buildup and barren land are decreased, it shows that river is expanded, which means the houses and agricultural land which are near to the river had to be changed into the riverbed and sand bank. Therefore, large amount of land loss accounts for a significant loss of income marginal farmers and their livelihood. A progressive river migration of the bank line of the Amu river toward in Afghanistan side and continue channel shifting which is resulted in obvious land loss in the region.

CONCLUSION

In the last three decades' riverbank erosion became a serious issue in Afghanistan, due to rainfall and snow with high flowing water velocity. Every year, a large amount of soil erosion occurs in the right side of Amu River and large area of agricultural lands and houses are destroyed. In this research, image classification and Digital shoreline analysis (DSAS) were used to compute the shoreline change location and land loss due to the Amu riverbank erosion in Qarqin District. Remote sensing and GIS applications and statistical technique indicate a suitable method for riverbank erosion management with geographical approach were applied. According to the classified images and landuse change detection results, large area of land has changed from the agriculture and buildup to river bed. By calculating classified area, the result was found that the water value had increased more than other classes which mean the land loss and river has migrated every year in Afghanistan side. Another outcome which is explored from the calculation of the area from the three-year time period shows that total amount of land loss during the 14 years' period was 5,074 hectares of land in the Qarqin District. Finally, using DSAS approaches End Point Rate (EPR) and Linear Regression Rate (LRR), were computed long term changes. The study found that the river movement was toward Afghanistan side i.e., south. The estimated threat of losing land was about 362.42 ha/year. The calculated eroded area was 1,984 ha, 1,410 ha and 1,680 ha during period of 2000-2005, 2005-2010, and 2010- 2014, respectively. The shoreline was demarcated and categorized into three zones i.e., lower as moderate eroded zone, central as high eroded zone and upper as lower eroded zone. This research work can give input to policy makers in war torn country to manage Riverbank erosion.

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