Analysis of river training in Qareaqaj River in Iran: Application of RiMARS

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Abstract

Erosion and sedimentation play a significant role in river morphology and are among the most important issues in river engineering. Riverbank protection is one of the common efforts in river engineering to stop or reduce the rate of side erosion in rivers. Riprap is one of the simplest and most economical river protection methods due to construction material availability, operation simplicity, flexibility, easiness to construct and repair. Anthropogenic disturbances could have several side effects in rivers and subsequently induce a change in river morphology. Hence, morphological analysis is needed to trace the history of channel formation and forecast future changes. Riprap is widely used in the Southern parts of Iran to save the rural and agricultural areas located along the river. The Qareaqaj River is one of the major rivers in the South of Iran that is affected by side erosion in many places due to its high meandering morphology. Hence, a riprap structure was constructed in 2006 to protect the Qasr Ahmad village located in the right bank of the Qareaqaj River. The objective of this study is to evaluate how the river training has affected the channel morphology for 18 years in a 10 Km stretch (5 km above and 5 km below the riprap structure). Five Landsat multispectral images captured in 1995, 1999, 2003, 2010, and 2013 were used as input in the RiMARS (River Morphodynamics Analysis method based on Remote Sensing data) for morphological analysis. The Sinuosity Index (SI) has been estimated for meanders for 18 years and the results indicated that most meanders along the stretch are classified as twisty (about 36%), meandering (22%) and winding (18%). Furthermore, the river is divided into ten sections along the flow path and temporal migration of each section is separately analyzed. The river in its halfway (where the riprap was constructed) has migrated on average by 12.5 m, 2.2 m, 5.5 m, and 9 m in 1999, 2003, 2010, 2013, respectively, when compared to the year 1995. The maximum rate of river migration was observed (6.5 m per year) during 2010-2013 at the 7th decile of the stretch, which is about 2000 m below the protected area. The results clearly indicated that the migration rates increased in the downstream of the riprap protected area after the construction date.

Introduction

The objective of the this study is to assess the impacts of anthropogenic activities on a river in Iran and to evaluate the locally documented impacts on the Qareaqaj River's morphology. At the same time, RiMARS package is utilized to employ our latest methods in satellite based remote sensing, in aiming to find the effects of human made constructions on river morphology in a certain period of time. Remote sensing data is employed from Landsat satellite in order to evaluate the channel alteration in Qareaqaj River. This enables us to identify that how much the constructions of riprap structures are impressive on channel modification. Landsat imagery provides high quality images since the early 70's until now. Although, all the images are not appropriate for this study, owing to their lack of sufficient transparency due to cloud cover, existing images can cover whole river basins efficiently. Preliminary investigations are already done to ensure suitability of existing images in the region. Historical discharge data is used for image selection procedure where the images are gathered based on the discharge value for a certain month. images are obtained during five different years 1995, 1999, 2003, 2010, and 2013, based on the preliminary assumptions which are defined before. Images have been compared morphologically to each other using RiMARS.

Methodology

The river morphological alteration framework developed in this study uses MNDWI index to generate river path from multispectral images. The index was applied to the Landsat images for delineation of the pixels representing water as:

$$MNDWI = \frac{Band_{Green} - Band_{MIR}}{Band_{Green} + Band_{MIR}}$$

where each band contains the reflectance value of each pixel in the Green and MIR bands in a Landsat image.

In three main phases, the centerline of the river was defined: MNDWI application, screening and gap-filling. Each Landsat image was arranged in m x n pixel matrix, and for each pixel, the MNDWI values were determined using the formula provided above. This leads to a gray-scale image with values from -1 to + 1. A binary-level matrix which contains pixels for water and non-water objects can be used in any threshold, as the process does not rely on threshold-segmentation methods, since the RiMARS is limited to extracting points in the buffer zone. The buffer zone is defined by placing a polygon round the river to restrict a river area, for example by defining a study region by using an external prefabricated polygon that is organized in drawing programs (for example ArcMap) by means of visual interpretation of the user. This task is not compulsory but strongly recommended, as the procedure is based on the subtraction of non-water pixels that do not exist in the region of interest. Thus the RiMARS extracts the center line of the river in an iterative process regardless of the threshold applied to the gray-scale picture.

In the screening step RiMARS is expected to represent MNDWI maximum values in each row and in the matrix column (the remainder of points are removed in this step) resulting in the centerline points of the river. In this stage the river reflects the centerline but with large gaps between the points. The screening step is followed by a gap-filling step to get a clearer river centerline. The filling of gaps regenerates new points and places them in an iterative cycle within the channel.

Later the he SI is used to evaluate quantitative and qualitative aspects of meanders to determine morphological alterations in meanders in the river.

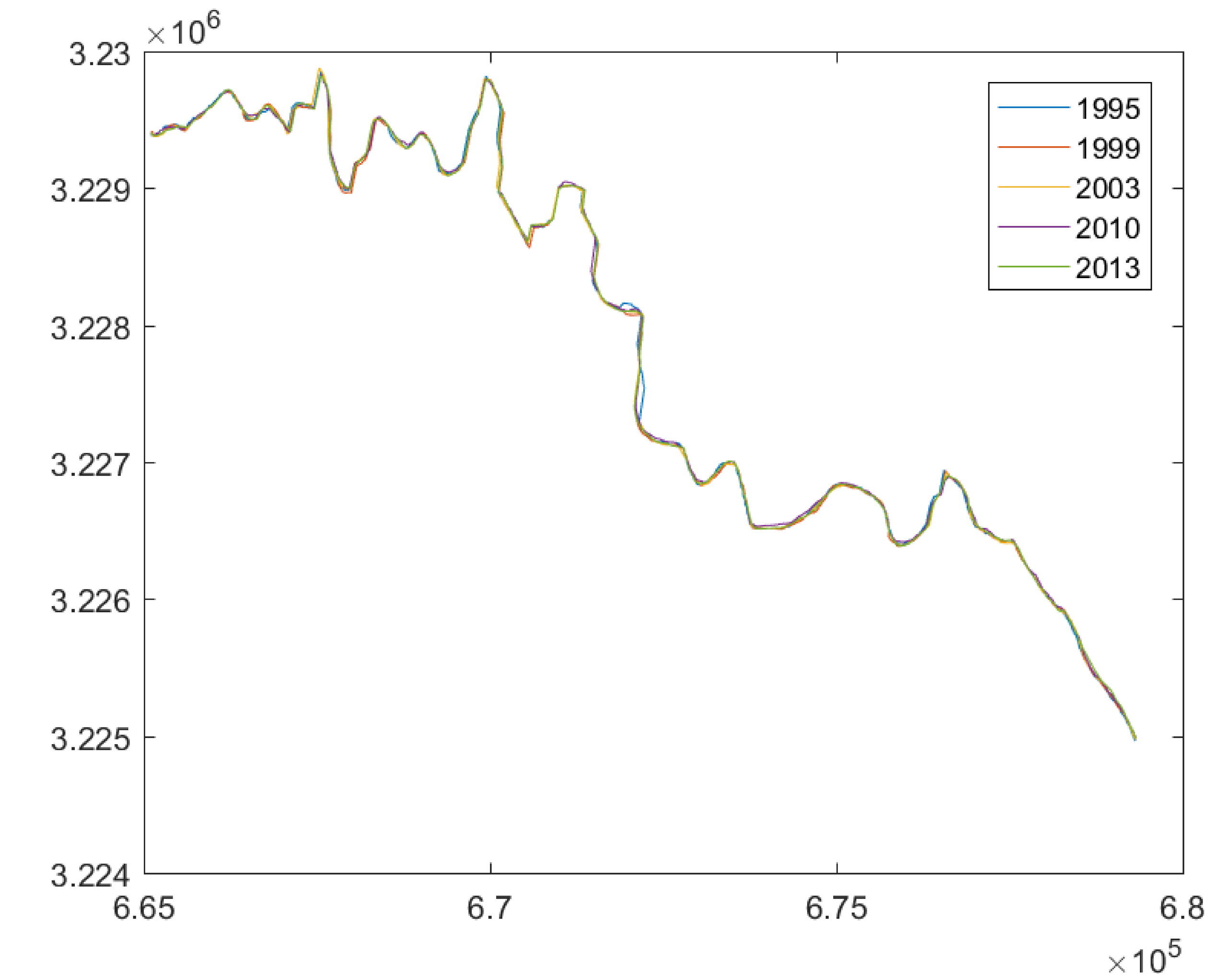
The value of the SI is: $SI = \frac{Channel\ Length}{Downvalley\ Length}$

The range of the SI values and classifications based on those ranges are provided in the following table:

Sinuosity Class	SI Range
Straight	$SI < 1.05$
Winding	$1.05 \le SI \le 1.25$
Twisty	$1.25 \le SI \le 1.5$
Meandering	$SI \ge 1.5$

Results

Using RiMARS for evaluating the river morphology enabled us to gather data at each specific point of the river while it is also possible to compare the probable modifications during different years.



The analysis of the meanders show that river is almost Winding type with about 1/3 of its meanders with SI value of greater than 1.05 and less than 1.25. Besides, 25% of the meanders have SI value greater than 1.5.