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Research Article

Analysis of meander evolution of Dez River in agricultural and mountainous areas by Google Earth Engine (GEE) and GIS

Ladan Khedri Gharibvand [a]*

[a]*Department of Remote Sensing, Dezful Branch, Islamic Azad University, Dezful, Iran*

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ABSTRACT

Background and objective: The rivers are vital natural resources for human activities. Knowledge of the structure and dynamics of rivers is important to understand river characteristics. Differences due to the season in river flow lead to unsteady sediment transport capacities that cause riverside erosion and the development of meandering channels. Channel migration might produce a crucial problem for water supply and hydraulic structures. Therefore, the study of a stream channel dynamical is necessary. In this research, we investigate the meander evolution of the Dez River in agricultural and mountainous areas by GEE and Geographical Information System (GIS) during 1995 - 2021.
Materials and methods: To study the meander evolution of the Dez River, the Sinuosity Index (SI) of the river in the mountainous and agricultural areas was calculated. Then the slope and The Digital Elevation Model (DEM) maps were prepared using NASA SRTM. Also, the soil texture map was derived from the U.S. Department of Agriculture (USDA) system and the monthly runoff map was prepared in GEE.
Results and conclusion: The results showed that SI in the mountainous area was constant (2.10), but it changed in agricultural areas (2.10-2.14). Also, the slope in agricultural areas was 1-4 degrees, the elevation was 30-36 meters, and the soil type was loam and clay loam. Due to the increase in runoff in recent years and the erodibility of the riverbed, it seems that the meander evolution of the Dez River is due to soil type and runoff increase.

1. Introduction

The rivers are vital as natural resources for human activities and use especially irrigation, recreation, transportation, fishing, energy, and water supply. Knowledge of the structure, energetics, and dynamics of a river is of huge value in understanding the flow characteristics of the stream and its management and protection (Ebisemiju, 1994). Disturbances created by humans, for example, changes in land use and land cover, river modification, and climate change affect the main

* *Corresponding author.* Tel.: +986142420601
E-mail address: ladan.khedri@iau.ac.ir, ORCID: 0000-0002-2414-3343

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characteristics of the flow regime in the river (Hekmatzadeh et al., 2020; Ghorbani Kalkhajeh & Jamali 2019; Pirnia et al., 2019; Mustonen et al., 2016; Yaraghi et al., 2019; Ashraf et al., 2018; Torabi Haghighi et al., 2020). The variability of main rivers is one of their innate properties and applies on an extensive range of spatial scales (Schumm, 1991, 1963; Howard, 1967; Leopold & Wolman, 1957). This variability includes variation in channel patterns and main avulsions and is influenced by parameters like river sedimentology, river hydrology, and topography (Downs & Gregory, 2014; Lang et al., 2003). The channel pattern of a river has been classified into three types braiding, meandering, and straight (Leopold & Wolman, 1957). SI is a key indicator to detect the stability of a river channel (Hooke & Redmond 1992; Toriman et al. 2006; Rosgen 1994). Sinuosity is the degree that the stream departs from a line. Straight streams possess essentially straight banks with less sinuosity; however meandering streams have larger sinuosity. (Schumm & Khan, 1972). Meandering is the most typical pattern of streams in nature (Darby & Delbono 2002; Crosato, 2008) and tends to possess an occasional gradient and therefore slow flow. Its stream bed is often composed of fine sediments, and most sediment is transported in suspension.

Differences due to the seasonality in stream flow lead to unsteady sediment transport capacities that cause riverside erosion, excessive scour of fine bed material, sedimentation and formation of bars, and development of meandering channels. Channel migration might produce a crucial problem for water supply, hydraulic structures like intakes, and bridges. Also, it can induce new trends in planimetric changes, i.e. there's a risk that the stream follows a new undesirable course, far from wherever water is required (Banda et al., 2018; Jamali & Abdolkhani, 2009). Therefore, the study of a stream channel dynamical is extremely necessary.

Meandering river bends occur in natural rivers all around the world and on all scales. Many individuals studied them, such as Leopold and Wolman 1957, 1960, Fargue 1868, O'Boyle 1981, Williams 1986, Jefferson 1902, Aswathy et al., 2008, Magdaleno and Fernández-Yusti 2011, Howett 2017, & Kyuka et al 2020. For instance, Aswathy et al., (2008) investigated the parameters influencing the sinuosity of the river of Pannagon, using IRS data and GIS techniques. Their results showed that the sinuosity changes of the river were controlled by the riparian vegetation and tectonics (Qanbari & Jamali 2015; Aswathy et al., 2008). Also, Kyuka et al. (2020) studied dominating parameters influencing the fast-changing meander caused by a flood in the Otofuke River, Japan. The results showed that the morphological processes led to strong flow deflections transversely toward the embankment which resulted in lateral channel shifting (Kyuka et al., 2020).

The technical advances in more recent years, most notably the development of remote sensing and GIS have enhanced the ease with which the data on channel planform and morphological changes from a variety of sources can be combined to assess the river morphology (Yang et al. 1999). The Dez River is the main tributary of the Karun River. Studies on the pattern of river channels, dynamics, and mechanics in this area are scarce. Gaps seen in the background contain no research on the Dez River by GEE and GIS. This is a unique aspect of the study. In this research, aimed to investigate the meandering evolution of the Dez River in the Karun River basin from 1995 to 2021. In the framework of this study, the factors affecting the sinusitis of the Dez River were analyzed using the GEE platform and GIS techniques. It can help the basin managers improve existing methods and strategies for better development.

2. Materials and methods

2.1. Study area

The Dez River is one of the major southwestern rivers in Iran, which originates from the Zagros Mountains (Woodbridge et al., 2016). This river connects to the Karun River and finally poured into the Persian Gulf. The Dez River's length is 400 km and its average water discharge is 230 $m^3.s^{-1}$. The river supplies water for industries, villages, and cities. The Dez River also feeds 23 water treatment plants (WTP) (Ramavandi et al., 2015). In this study, in order to investigate the changes in the route of the Dez River from 1995 to 2021, part of the river in mountainous areas and part of it in the vicinity of agricultural areas were selected and its changes were examined (Fig. 1).

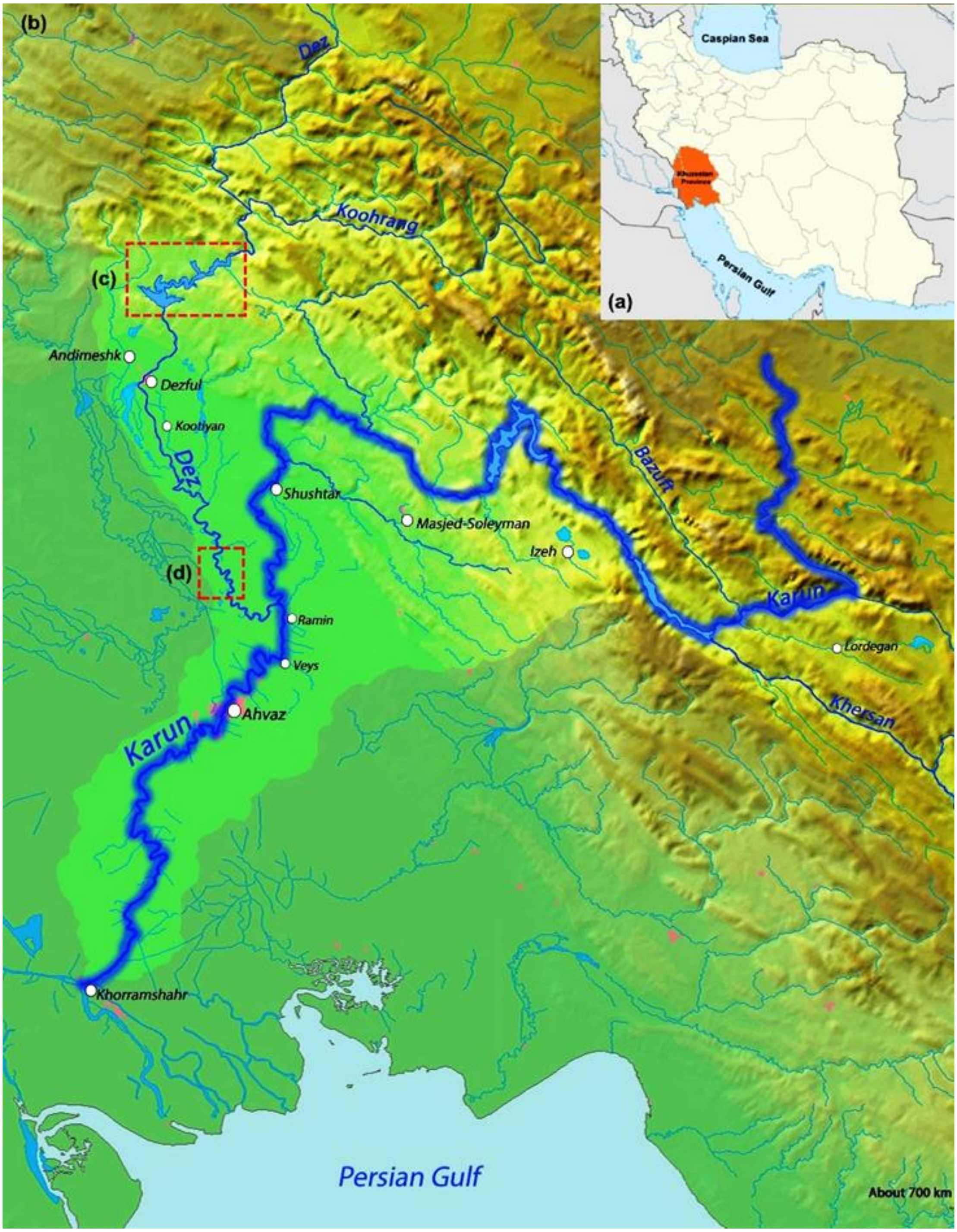

Fig. 1 - (a) The position of Khuzestan province in Iran; (b) the position of Dez River in Khuzestan province; (c) the Dez River in the vicinity of mountainous areas; (d) the Dez River in the vicinity of agricultural areas

2.2. Methods

The flowchart for studying the Dez River changes is shown in Fig. 2.

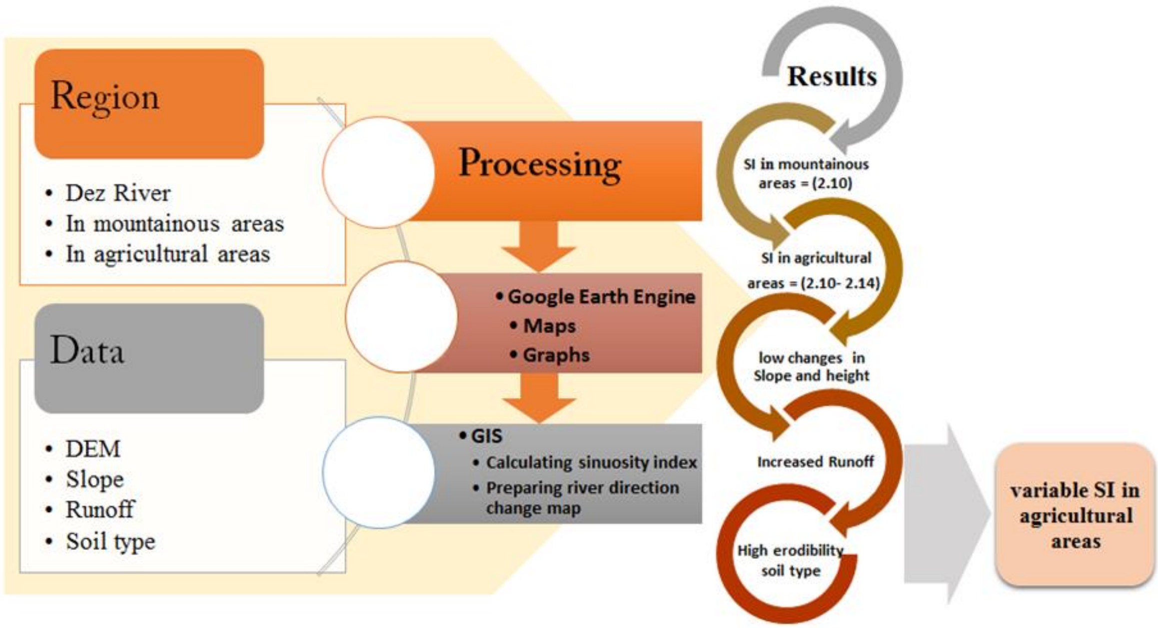

Fig. 2 - The framework for analyzing of the Dez River changes in the agricultural and mountainous areas

To study the changes in the Dez River from 1995 to 2021, first, the river SI in mountainous and agricultural areas was calculated. SI is a key indicator to identify the stability of a river channel (Hooke & Redmond 1992; Toriman et al. 2006; Rosgen 1994). Thus, the analysis was performed to determine the type of stability SI and to categorize the evolution that took place in the main alignment on the river (Table 1). The process of sinuosity measurement involved measuring the valley length as a straight line drawn from the starting point to the endpoint of each sub-reach and the channel length which was a winding line along the axis of the canal.The calculation of SI was carried out using the equation (1):

$$SinousityIndex = \frac{ChannelLength(L)}{ValleyLength(Z)} \tag{1}$$

Table 1- Type of meander evolution stability, adapted from (Rosgen & Silvey, 1996)

Sinuosity index (SI)	Stability type	Summary
<1.2	Stable	S
>1.2	Unstable	US
>1.5	Very unstable	VUS

GEE is a cloud-based platform in large-scale geospatial analysis that brings Google's great computational capabilities to bear on a variety of societal issues such as disease, water management, drought, environmental protection, climate monitoring, deforestation, disaster, and food security (Ghane Ezabadi et al., 2021; Gorelick et al., 2017). To investigate the cause of changes in river SI, factors such as slope and elevation of the area (Masoumi et al., 2014), changes in monthly runoff, and soil texture of the riverbed were examined and their maps were prepared by the GEE platform. The Shuttle Radar Topography Mission (SRTM) digital elevation data obtained digital elevation models on a near-global scale. The SRTM is provided by NASA at a resolution of approximately 30 m. In this study, the slope and elevation maps were prepared using NASA SRTM. The monthly mean runoff data also is a subset of the ERA5-Land dataset post-processed by the European Centre for Medium-Range Weather Forecasts (ECMWF). The data resolution is 11132 meters.

Soil texture demonstrates the relative combination of clay, silt, and sand in the soil. The distribution of particle size is shown in a diagram of texture, relating the clay, silt, and sand percentages to a texture class (Jamali et al., 2018). The first texture diagram was drawn by Whitney (1911) where the silt and clay percentages were shown on a right-angled triangle. Davis and Bennett (1927) replaced it with a diagram that showed percentages of sand, silt, and clay. Then in 1945, the USDA revised the texture triangle that you can see in Fig. 3.

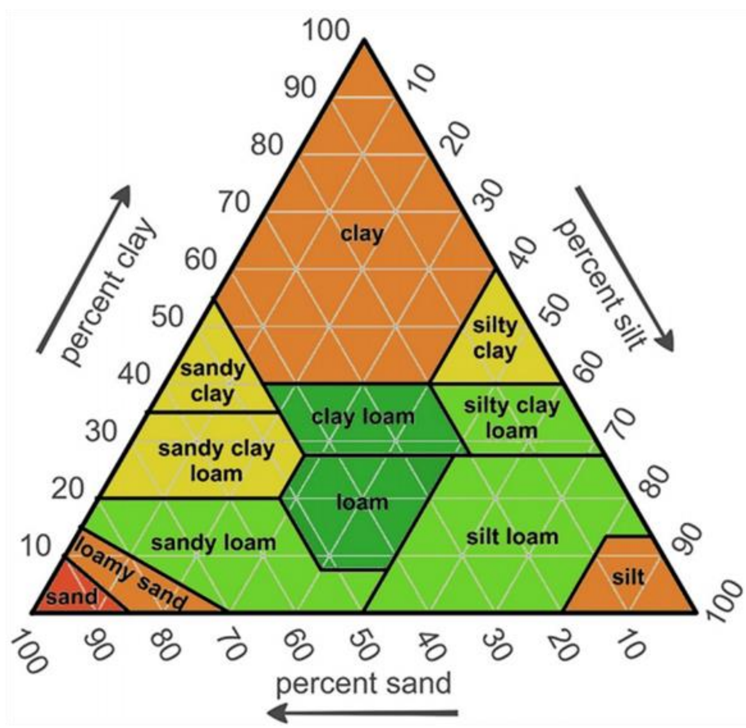

Fig. 3 - USDA textural triangle (USDA, 1945)

3. Results and discussion

3.1. River SI in mountainous areas

The river flow direction in the mountainous region and before the river reaches Dez Dam, from 1995 to 2021 is shown in Fig. 4. In this section, the SI was calculated for different years, which was equal to 2.10, and showed that the type of the river was very unstable (Jamali et al., 2021; Rosgen & Silvey, 1996). Therefore, in the study period, river sinuosity was stable in the mountainous region and did not change.

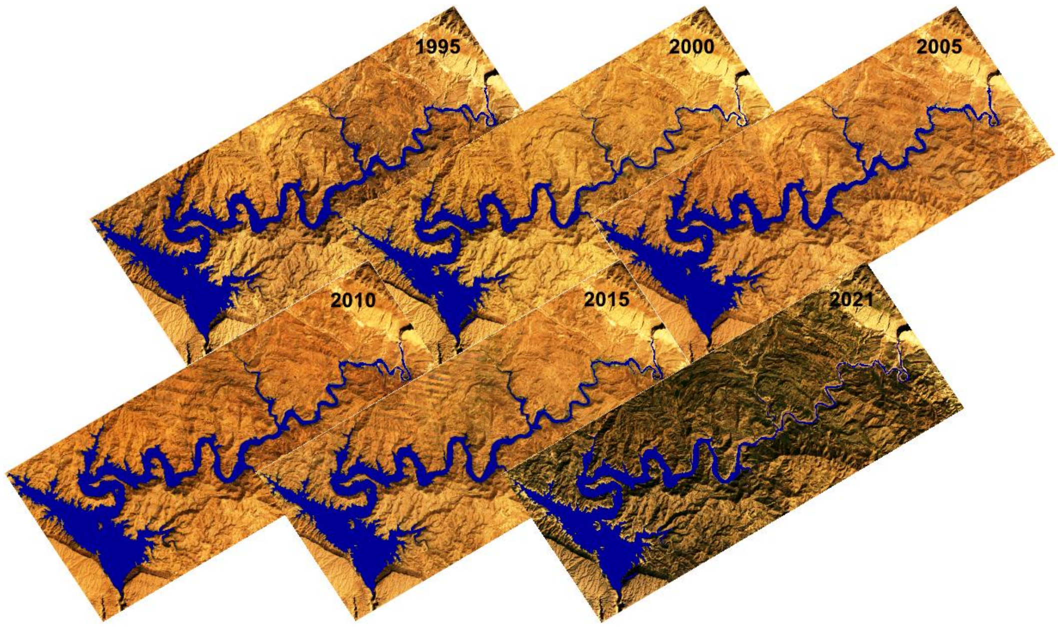

Fig. 4 - The flow direction changes of the Dez River in mountainous areas, from 1995 to 2021(images of Landsat 5, 7, and 8 satellites, resolution 30 meters)

3.2. River SI in the adjacent agricultural areas

The river flow direction maps in the adjacent urban areas from 1995 to 2021 are shown in Figure 5. For every year, SI was calculated (Table 2). The results showed that SI in agricultural areas varied (2.10 - 2.14 from 1995 to 2021, respectively), and the type of the river channel was very unstable in these areas, too.

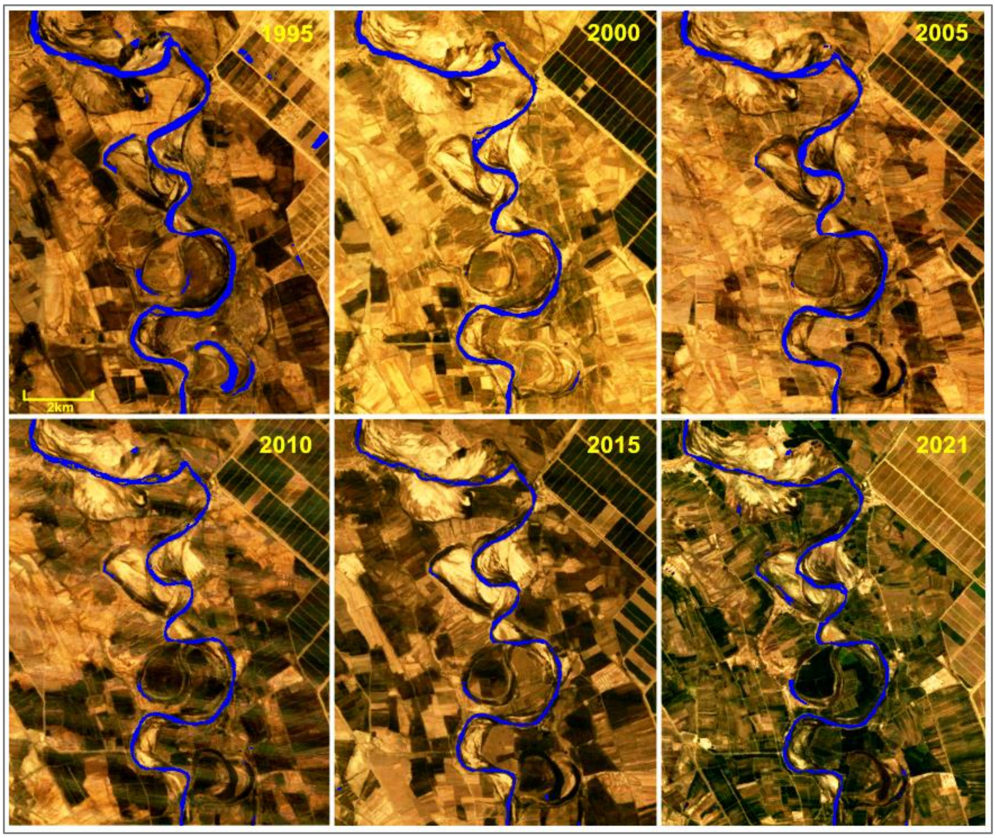

Fig. 5 - The flow direction maps of the Dez River in the adjacent agricultural areas, from 1995 to 2021(images of Landsat 5, 7, and 8 satellites, resolution 30 meters)

Table 2 -The SI of the Dez River in the adjacent agricultural areas, from 1995 to 2021

year	Channel Length(L) (m)	Valley Length(Z) (m)	Sinuosity index (SI)	Stability type
1995	18611	8974	2.10	Very unstable(VUS)
2000	18892	8974	2.11	Very unstable(VUS)
2005	18478	8974	2.10	Very unstable(VUS)
2010	18935	8974	2.11	Very unstable(VUS)
2015	18978	8974	2.11	Very unstable(VUS)
2021	19162	8974	2.14	Very unstable(VUS)

3.3. Assessment of changes in the river channel

The study of the river direction in mountainous areas and different years from 1995 to 2021 showed that the rate of changes in the direction of the river channel in the mountainous region was constant (SI=2.10) and did not change. River flow directions in the adjacent agricultural areas from 1995 to 2021 are shown in Fig. 6.

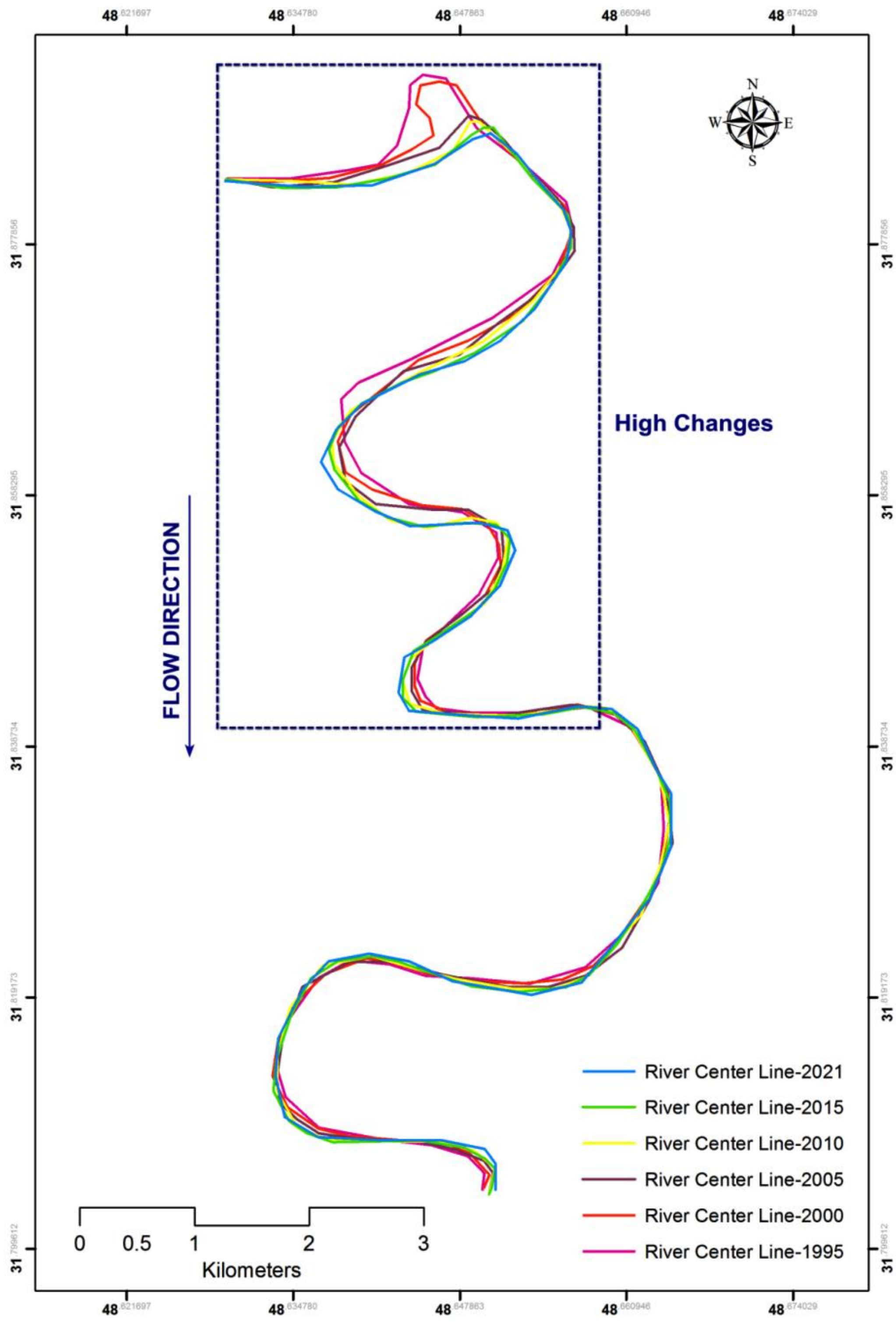

Fig. 6 - Map of changes in the river channel direction from 1995 to 2021

The study of changes in river flow directions adjacent to agricultural areas showed that in the upstream parts, the intensity of changes in the river channel was more than in the downstream part of the river. The reason for this may be due to the difference in soil type in this area compared to other areas, which has led to more erosion and changes in this area than in other areas.

3.4. Elevation and slope

The Digital Elevation Model (DEM) and slope maps around the Dez River in the agricultural areas are shown in Figures 7 and 8. Examination of the DEM map showed that the height in the north of the region is higher than the height in the south and its amount varies from 36 to 30 meters from upstream to downstream, respectively (Fig. 7). But this difference of 6 meters along 19 kilometers will not have much effect.

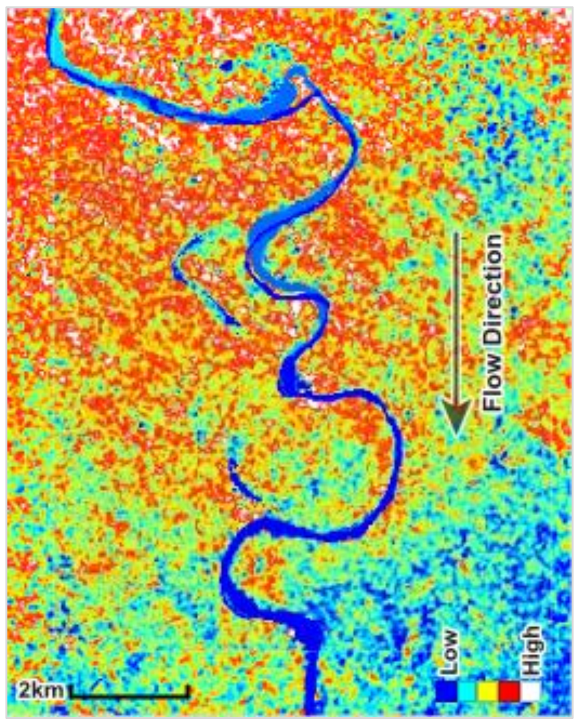

Fig. 7 - The DEM map around the Dez River adjacent agricultural areas

Also, the study of the slope map of the region showed that the slope changes in the region are very small and vary from 4 to 1 degree from north to south (Fig. 8). Since the slope and altitude of the area did not change much, it seems that these parameters did not have much effect on increasing the sinuosity of the river in this area.

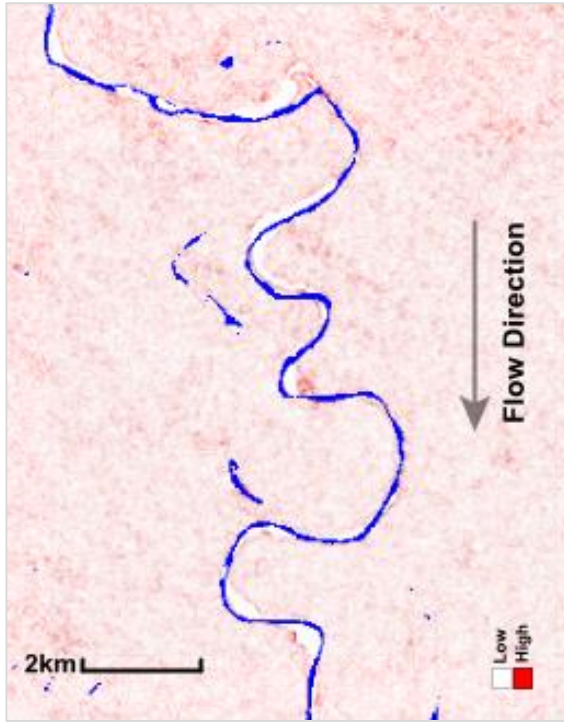

Fig. 8 - The slope map of the Dez River adjacent agricultural areas

3.5. Monthly runoff

The monthly runoff maps in the vicinity of the agricultural areas are shown in Fig. 9. The charts analysis showed that the trend of monthly runoff changes from 1995 to 2021 is generally declining. But as you can see in Figure 9, from 2018 to 2020, the amount of runoff increased compared to previous years.

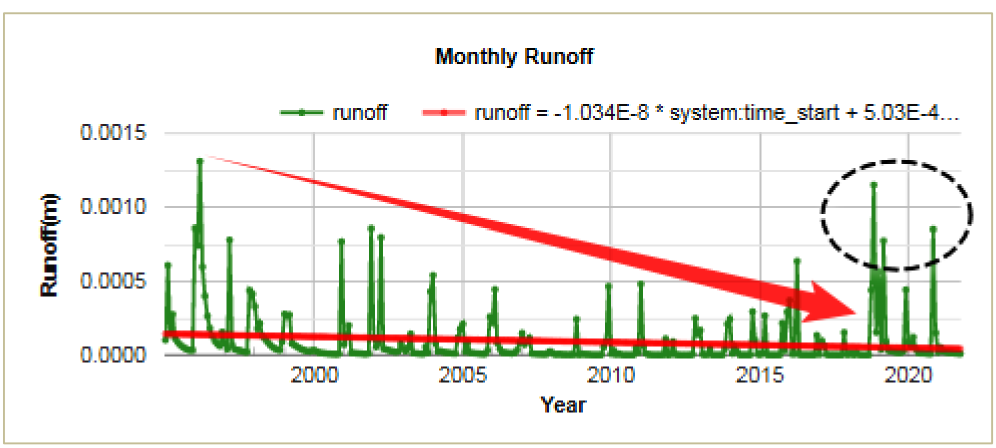

Fig. 9 – The monthly runoff chart in the agricultural areas from 1995 to 2021

3.6. Soil texture

The Soil texture maps at different depths around the Dez River adjacent agricultural areas are shown in Fig. 10. Examination of the maps showed that the Dez riverbed soils in these areas are loam (Lo) and clay loam (ClLo) types that the amount of loamy soil from the surface to a depth of 2 meters has increased. Loam is a mixture of clay, silt, and sand, and Clay loam is the soil with a fine texture (USDA, 1998).

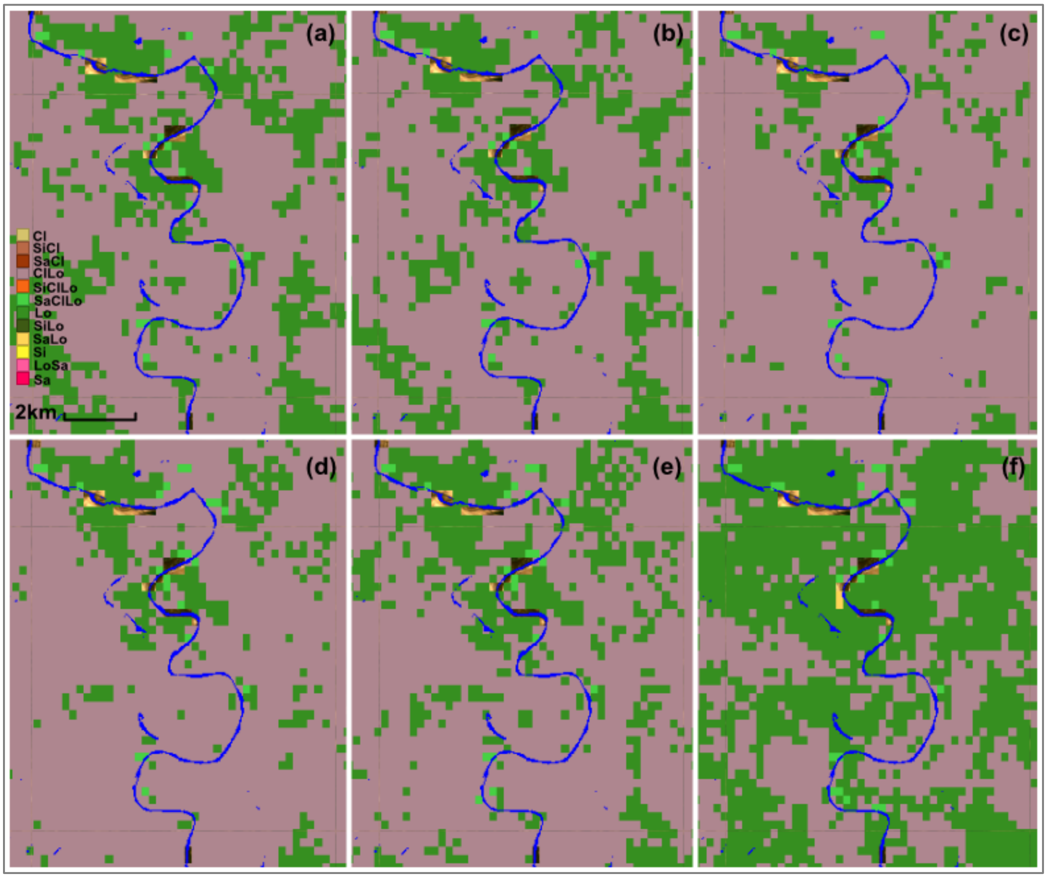

Fig. 10 - The soil type maps in different depths of the Dez riverbed the adjacent agricultural areas (a) surface (b0); (b) the depth of 10 cm (b10); (c) the depth of 30 cm (b30); (d) the depth of 60 cm (b60); (e) the depth of 100 cm (b100); (f) the depth of 200 cm (b200).

Since the amount of runoff has increased in recent years compared to previous years and the type of soil in the riverbed is erodible soils, it can be effective in increasing the river sinuosity in 2021 compared to previous years. Studies have also shown that river sinuosity increase with decreasing particle size and increasing the amount of silt and clay in the soil (He et al., 2021; Rosgen, 1994; Schumm, 1963). Therefore, the main reason for the change of river direction in agricultural areas during the study period (1995-2021) could be the increase in surface runoff and erodible soil of the riverbed (Parsasyrat & Jamali 2015).

4. Conclusion

Studying morphological changes in river systems can help river management. In this study, the meandering evolution of the Dez River in mountainous and agricultural areas from 1995 to 2021 was investigated. For this purpose, the river SI in these areas was calculated at the time of the study. The results showed that the SI was constant in mountainous areas (2.10) and it changed in agricultural areas (2.10-2.14), but the river was very unstable in both areas. To investigate the reasons for river change in agricultural areas, the parameters of height, slope, monthly runoff changes, and riverbed soil type were examined. Variations in altitude and slope were small and probably did not have much effect on river changes. But, the riverbed soil was loam and clay loam that have high erodibility. Also, the study of monthly runoff during this period showed that from 2018 to 2020, its amount has increased compared to the previous year. Therefore, it is likely that the increase in runoff and the high erodibility of riverbed soil can be a reason for changes in river direction during this period. It is suggested that for future studies, the impact of human activities on changes in river course be examined, too.

Declarations

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Conflict of Interest /Competing interests (None)

Availability of Data and Material (Data are available when requested)

Consent to Publish (Author consent to publishing)

Authors Contributions (All co-authors contributed to the manuscript)

Code availability (Not applicable, or for e.g. GEE code…)

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