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Monitoring the interactions between rivers and sand dunes using remote sensing

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ABSTRACT

The performance of rivers and winds is an important factor in improving landscapes and shaping the earth's surface. Iran is located in an Arid region and the sand plain and sand dunes, have a lot of expansion and at the same time, most rivers terminate in this area. Therefore, an interaction between river process and sand dunes in 16 mining sites was studied using satellite images taken from Google Earth. Key features such as wind and river direction, type of sand dunes and river channel pattern were determined at each location. The interactions were also classified into five types, each of which determines the dominance between the river process or the wind process. The results showed that there is a significant relation between the pattern of rivers and sand dunes, so that in places where the longitudinal hills are expanded, the channel pattern is more meandering and in places where the hills are more dynamic, the river becomes arterial. Also, regarding the relation between processes and river patterns, there is a significant relation between multi-branch pattern and processes and on sites that are dominated by wind, the Alpine Channel is mostly arterial, but little connection was found between the meandering pattern and the processes studied.

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1. Introduction

The nature of geomorphology leads to a focus on the formation of landforms and the effects of various processes on them. This approach leads to regular study and segmentation of seemingly discrete processes such as river, coastal, wind, and so on. As a result, it is difficult for many regions to consider only one process to develop its landscape and explain the changes in landforms in the past and present (Bullard and Livingstone, 2002). The performance of rivers and winds is an important factor in improving landscapes and shaping the earth's surface on a regional scale; In a way, there are significant effects between river and wind processes in different places around the world (Pierre et al., 1995; Dengfeng et al., 2015). In other words, at the Earth's surface, processes rarely operate independently of each other, and in many places where there is a river and wind erosion, processes change the morphology of the environment together, which means that processes overlap (Jiansheng et al., 2006; Liu et al., 2012; Draut, 2012).

Based on this view, river and wind processes have different effects on each other in different regions, so that in some places rivers can prevent the spread of sand dunes or in some other places, they create sand dunes by carrying sand and depositing elsewhere (wen et al., 2013; Walker, 2014). In contrast, the sand dunes can divert and change the course of the river by entering the main channel of the river (Sharifikia and Malamiri, 1392) and therefore, by determining the current position of the river, they can turn it into a narrow runnel. In addition, some river systems dramatically change their pattern and behavior while encountering with sand dunes, for example, from a meandering pattern to a multi-branched pattern. Also, the balance between river and wind processes may change on a short time scale in some places, which is more related to the change of seasons, as the dominant process is windy in dry seasons and the sand dunes easily cross the river channel and cover it; and vice versa, when the river level rises in wet seasons, it prevents the movement of these hills (Liu et al., 2015; Flor et al., 2013).

The interaction between rivers and sand dunes is clearly understandable. This is despite the fact that so far few studies have been conducted in different areas (Bullard et al., 2002; Liu et al., 2015; Suzanne et al., 2005; Belnap, 2011). Only a few studies have been done on how the sea affects the formation or expansion of sand dunes. in this study, an attempt has been made to examine the interactions of rivers and sand dunes in Iran using remote sensing images.

1.1. Study area

Iran is a country in southwest Asia and in the Middle East with an area of 1,648,195 square kilometers. The land of Iran is located in a desert strip and most of its areas are considered dry due to natural conditions. In different sources, the area of sandy areas are different, so that the Soil and Water Research Institute has reported 4.5 million hectares and the Office of Sand and Desertification has reported about 5 million hectares of sandy areas, thus about 3% of the country is covered with sand. These areas are mostly in the center and east of the country. Due to the fact that most of the country's rivers originate from mountainous areas in the west of the country and their final basin is the center and east of the country, they meet with sand dunes in different places on the river. Accordingly, in this study, 16 areas that are the intersection of sand dunes and rivers were considered, which are shown in Figure 1and table 1, (Fig. 1).

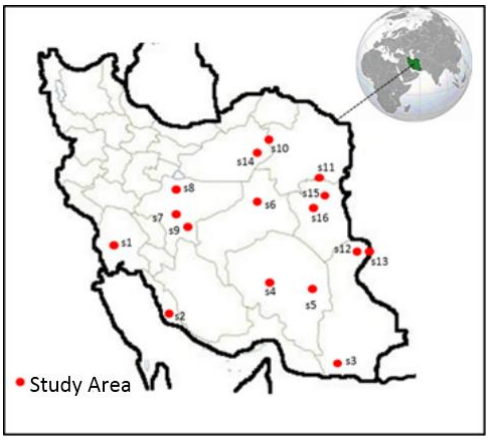

Fig. 1. Location of Studied sites (red point) in Iran

Table 1. Position of studies area

site	Region	latitude	longitude
S1	Karkheh River	31 34'22"	48 29' 8"
S2	Mond River	28°9'24"	51' 27' 31"
S3	Sistan va Balochestan	25°39'44"	58°14'32"
S4	Kerman	29°34'64"	59° 51' 25"
S5	Kerman	29°33'46"	59° 50' 40"
S6	Zarin va Ashkzhar Rig	32°37'16"	54°54'53"
S7	South of Gavkhoni wetland	31°47'48"	52°43'60"
S8	Zayandehrud river	32°22'98"	52° 45' 55"
S9	South of Gavkhoni wetland	31°29'56"	53°13'57"
S10	River near Sabzevar	35°56'51"	56° 51' 28"
S11	Gonabad Rig	34°42'80"	58°56'34"
S12	Helmand River	30°48'2"	61° 46' 41"
S13	Helmand River	30°48'2"	61° 46' 46"
S14	Sargardan Rig	33°10'20"	55°45'30"
S15	Boshrouyeh	33°46'01"	57°37'46"
S16	Sargardan Rig	33° 7'12"	55°45'37"

2. Material and Methods

The method used for this research is laboratory-analytical method. For this purpose, to provide a theoretical basis for research, documentation and library resources were examined. In the following, a laboratory method was used (Satellite image processing by Erdas), so that in this study, images related to Google Earth were used to monitor the interactions between rivers and sand dunes. Sand field images were not used in this study to reduce the error because it was not possible to distinguish them with desert and bare lands due to the Spatial resolution of the images and the possibility of errors in them (Fig. 2A). Also, the images of the hills that were covered with plants were removed due to the uncertainty about the behavior of sand dunes, which could not be interpreted with satellite images (Fig. 2B). In addition, to reduce uncertainty, wherever human activities have disrupted the environment and manipulated nature, they have been eliminated (Fig. 2C)

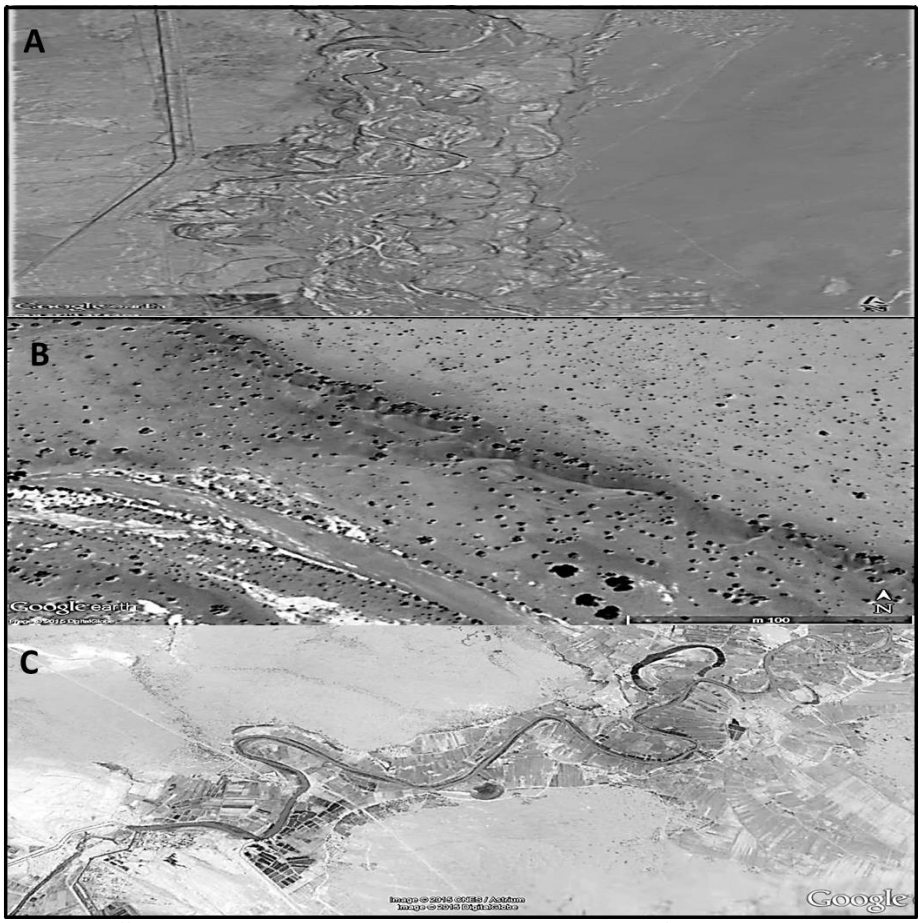

Fig. 2. Places where it was difficult to analyze monitoring between rivers and hills A) Parts of the Harirod River B) Location (25° 39′44″N 58° 14′32″E), C) Karkheh River

Then, a search was conducted to determine the desired areas on the outskirts and within the arid areas. These areas are likely to be a good place for interaction between river and wind processes. Here, the routes of the rivers were identified and then searched along the route to find places where sand dunes collided with the rivers. Where rivers flowed into a catchment area, these interactions were considered a site (Figs. 3A and B). However, in some rivers that have a long route and may cross different landscapes, due to the diversity of these landscapes, several sites were extracted from them (Fig. 3C). Also, in some places, several small streams and waterways that are connected to each other in terms of a similar process were considered as a site (Fig. 3D). In addition, several other variables were recorded in each site, by visually interpreting the patterns including river pattern, sand hill type, river flow direction, and wind direction. These factors help further analysis of interactions between rivers and sand dunes.

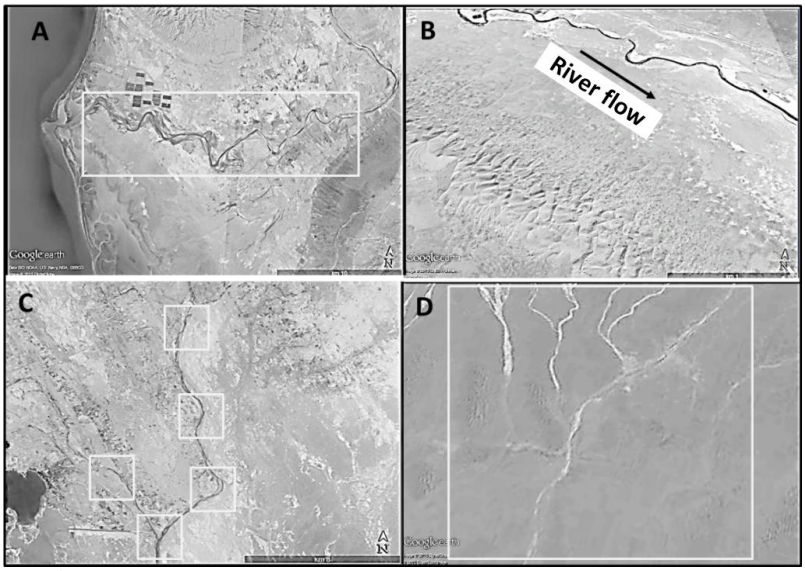

Fig. 3. Examples of sites studied A) Mond River B) Zayandehrud River near Varzaneh C) Helmand River (D) Kerman

2.1. River channel pattern

The pattern of the river in different places helps to identify the behavior and characteristics of the river. In this study, according to the characteristics of existing rivers, two types of meandering and multi-branched patterns were considered.

2.2. Sand dunes pattern

High resolution satellite images can clearly identify the pattern of hills, so in this study, with the help of spot satellite images taken from Google Earth, three types of sand dunes identified, including Barchan, transverse sand dunes and longitudinal sand dunes. Longitudinal patterns were considered to be the most abundant in the study area. Hills' patterns helped us to identify the prevailing wind direction in the area (Fig. 4).

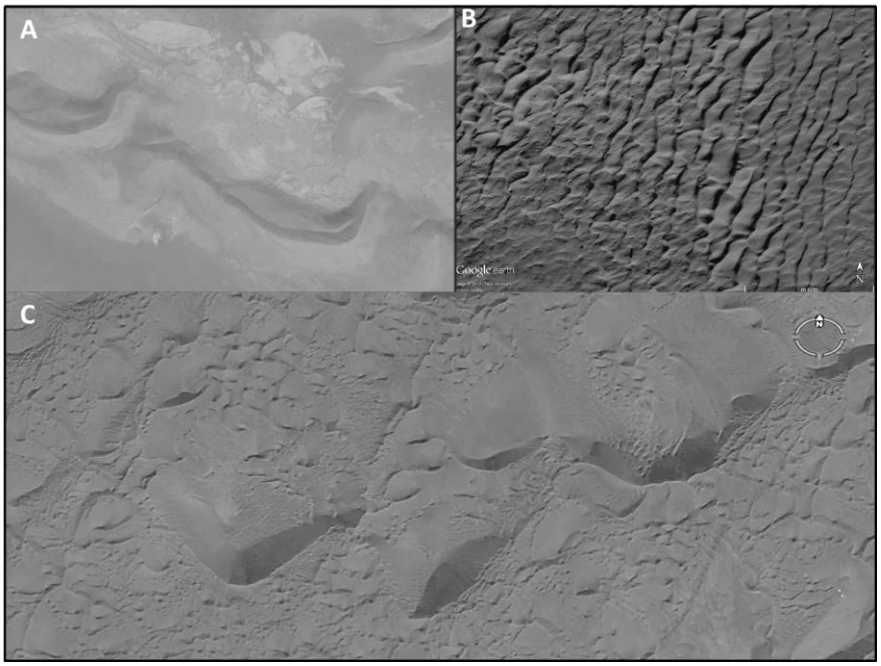

Fig. 4. Sand dunes patterns A) Barchan B) Longitudinal sand dunes C) Transverse sand dunes

2.3. Classification of interaction types

In this study, the type of interactions in different places were divided into five different categories, and in the following, the location of sites in each of them was examined:

A) Completely fluvial process: This class is taken into account when river processes

have complete control over the development of the landscape in the region and the river flow has enough power to carry sediment from sand dunes. In these areas, the sand dunes have stopped along the rivers, and the power of the river does not allow the hill to move to the other side of the channel, and the sand dunes are clearly not expandable. In fact, the river is like a dam in front of a sand dune. (Figure 5A).

B) Mostly fluvial process: In this class, the power of river processes is reduced and interactions are more balanced. Here the river is able to pass through the sand dunes, but it is not able to carry all the sediment from the sand dunes, thus allowing limited movement to them. There are hills on both sides of the channel in this class, but on one side of the river the size of the hills is smaller or the type of hill changes due to the decrease in sediment supply, for example, it turns from transverse sand dunes to Barchan (Fig. 5B).

C) Balanced Process: In this class, the power of the river and wind process has become close to each other, no process is dominant, and both processes are operating without interruption. Here the river passes through a sand dune field while the hills develop on both sides of the river and the size and type of the hill does not change (Figure 5C).

D) Completely windy process: In this class, the wind process is predominant and the river ends in a sand dune field (Fig. 5D).

E) Intermittent process: In this class, the river process and wind process are moved alternately, for example, when the river's water flow decreases or dries in the dry season, the wind process transfers the sand dunes to the channel and fills the channel with robots. However, in wet seasons, the flooding of the river causes the erosion of these sediments and as a result, the route of the river channel changes. (Fig. 5D).

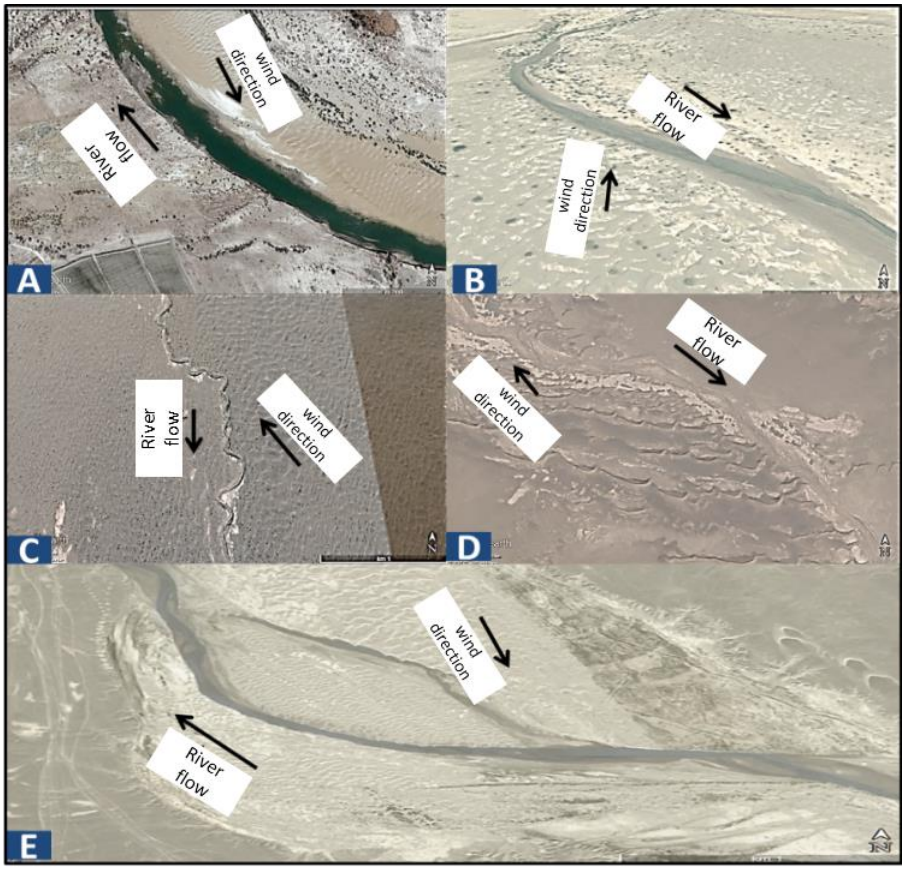

Fig. 5. Types of interaction A) Mand river B) Zayandehrud river near Varzaneh C) river near Sabzevar D) Waterways in Kerman E) Helmand River

3. Results and discussion

As mentioned above, in this study, sixteen sites were extracted from satellite images for analyzing the interactions; In all these sites, first by extracting the river pattern and the type of sand dunes and then by classifying the type of interactions, the necessary analyzes were

performed. The results showed that the highest pattern of river channel (11 sites) is related to meandering pattern and then multi-branch (arterial) pattern with 5 sites with distribution (Figure 6A). The abundance of these patterns is directly related to the supply of sediments, so that wherever the amount of sand in the region is higher due to the instability of sediments, the river can easily erode sediments from sinusoidal to melancholy or develop an artery. Extracting the pattern of sand dunes also makes it clear that longitudinal sand dunes with 43.8% have the highest prominence in the range and then transverse sand dunes with 37.5% and Barkhan with 18.7% have the lowest frequency. (Fig. 6B).

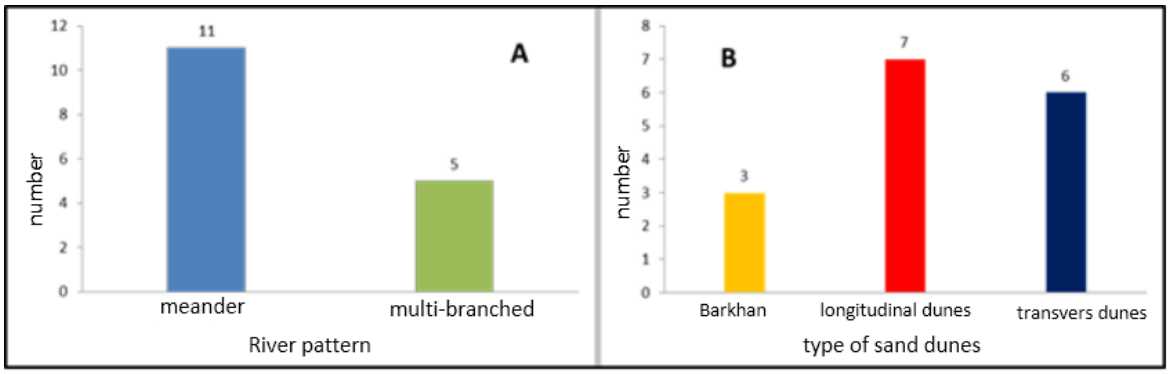

Fig. 6. Diagrams for viewing patterns in the study areas A) River pattern B) Sand hill pattern

Based on these issues, the results of the interaction between the river pattern and sand dunes made it clear that there is a significant relationship between them, so wherever the amount of sediment supply increases but the dynamism of the hills are less (longitudinal hills), the river pattern is more meandering.so that wherever the supply of sediments increases, but the dynamics of the hills are less. In this study, among the sites that had longitudinal sand dunes (7 sites), 6 of them had rivers with meandering pattern and only one of them had multi-branched pattern, while in areas where the hill was more dynamic, the incidence of meandering and arterial pattern in rivers has become closer so that in places where there is a transverse sand dune, both patterns are equal (3 each) and places in which Barkhan has been active have been updated with very close values (arterial pattern 1 and meandering pattern 2) (Fig. 7) Accordingly, it can be said that increasing the input of sediment from wind sources to the river channel can be considered as an effective stimulus to change the pattern of rivers.

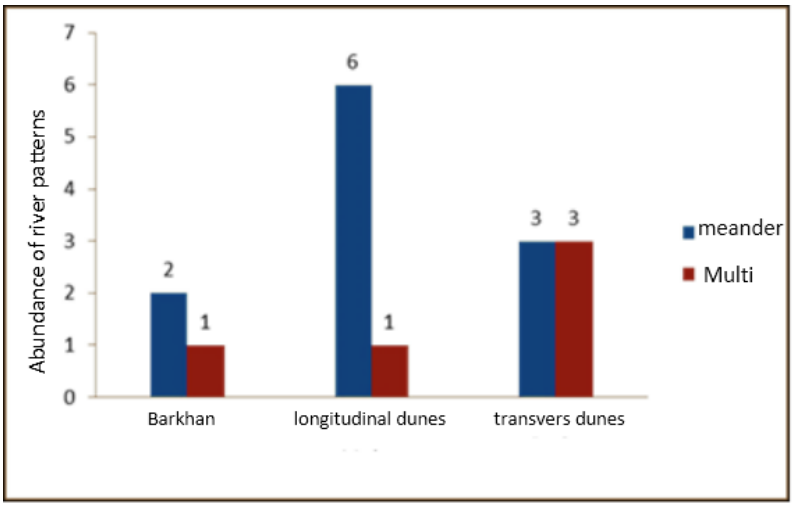

Fig. 7. The abundance of river patterns and their interaction with the pattern of sand dunes

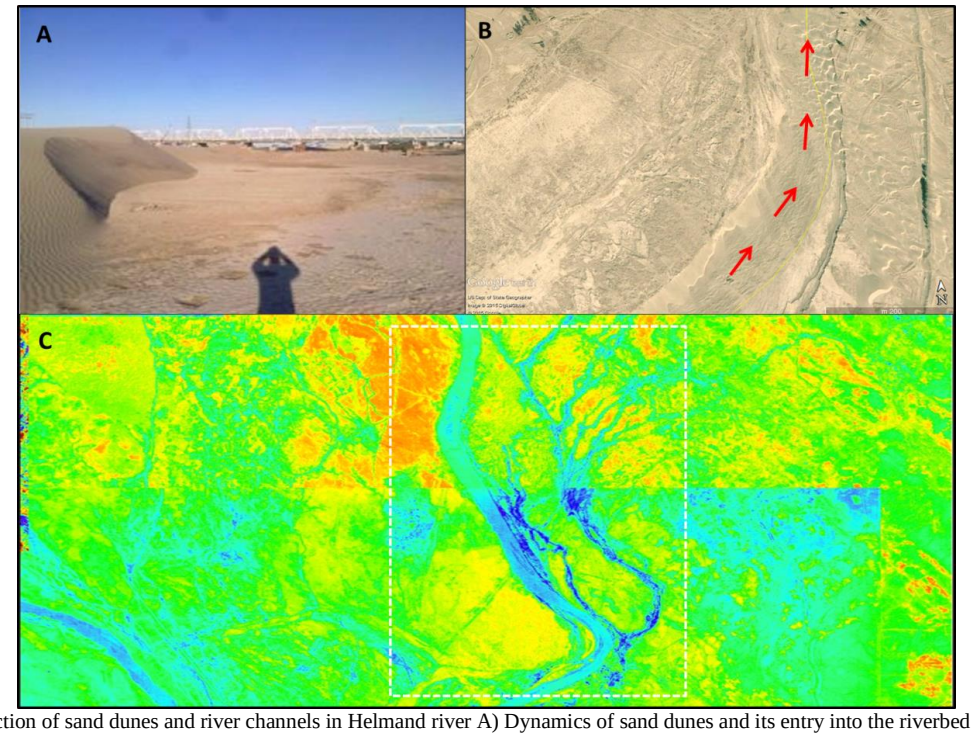

Fig. 8. Interaction of sand dunes and river channels in Helmand river A) Dynamics of sand dunes and its entry into the riverbed B) Covering the riverbed with sediments C) Changing the river channel pattern and turning it into an arterial pattern

3.1. Evaluating the type of interactions

As mentioned above, in this study, we classified the interactions into five different processes. The results of each of these classes made it clear that most interactions are related to the fully windy process (43.7%). This is natural because sand dunes are more prevalent in areas that are arid and somewhat semi-arid, with winds dominating most areas. After the wind process, balanced and more river processes each have a high frequency with 18.7% in the range. These processes are mostly in the semi-arid and marginal areas of the dry areas as the dominant factor. In some arid areas, the river is flooded in the rainy season, but in the dry season, the riverbed is waterless and dry. This is an intermittent process in which about 12.5% of the research area is dominated by this. Due to the fact that rivers reach dry areas at the end of their route, they do not have much power and cannot become the dominant factor in this area, and some rivers in semi-arid areas are flooded due to their watery bed. As a dominant factor, in this study, only about 6.2% of all ranges in the areas of this process are predominant and the main responsible for changing the face of the earth (Fig. 9).

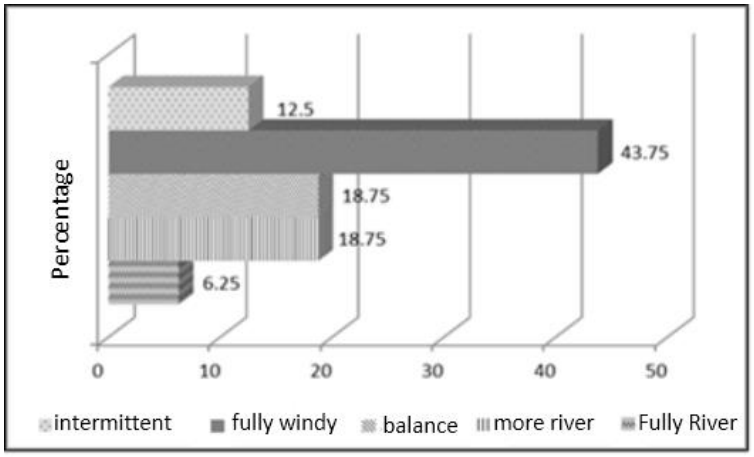

Fig. 9. The type of interactions in the study area

3.2. The relation between the type of processes and sand dunes

In this study, the results showed that there is a significant relationship between the type of sand dunes and the types of processes; Wherever the longitudinal sand dune expands, due to the development of the hills and the increase in sand supply, the dominant process is the windy one (about 50%). In fact, the wind has such a power that it has been able to expand. The sands and the formation of sand dunes become longitudinal. The next processes that are active in longitudinal sand dunes are the balanced process and the mostly fluvial process, each of which is 25% active in the range. The interaction of these processes is on the margins of dry areas where the river and wind are almost equally influential. In places where transverse sand dunes are spreading, due to the role of wind in the expansion of hills, the dominant factor in about 50% of the range is the wind process, but in these areas, unlike areas where longitudinal hills are spread, because the wind power has decreased and also the river power has increased; In addition to the fact that the "mostly fluvial process" and the "balanced process" each are more than 16 percent active, the mostly fluvial process is equally dominant (16.6%). In the case of places where farms are expanding, the results show that the dominant process in most of these areas is an intermittent process with about 70% dispersion, and the next process is the wind process with about 30% of the next factor. This is understandable because the Barkhans are active hills that spread in arid areas. In the dry seasons, when the river becomes less watery, due to the dynamism of the Barkhans, they enter the riverbed; However, in more humid seasons, due to the increase in river flow and the increase of humidity in the region, the activity of the Barkhans decreases and the river prevents them from spreading (Fig. 10).

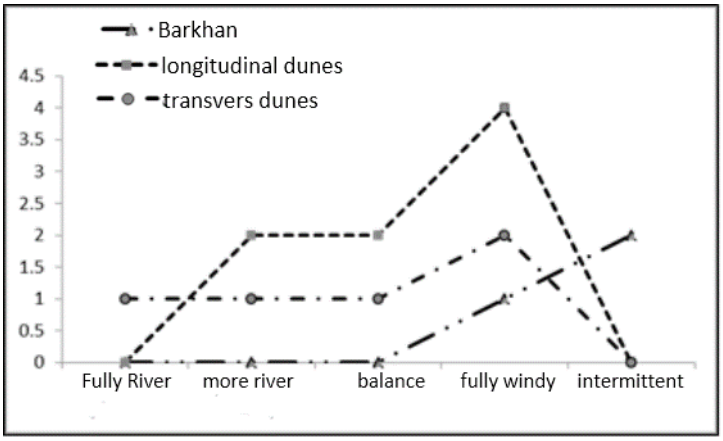

Fig. 10. The relationship between the type of interactions with the viewing rate of the sand dunes pattern

3.3. The relationship between processes and river patterns

The results of this study revealed that there is a significant relationship between the processes and the multidisciplinary model, so that this pattern is formed in more than 80% (4 sites) in the areas where the wind process has been dominant and about 20 Percentage occurs in places where the dominant factor in the process is intermittent. This is understandable because this pattern is more dynamic and less stable, so it can form in places with unbalanced (intermittent) systems or places with more unstable sediments. However, no significant relationship was found between the meandering pattern and the processes. This pattern is distributed in areas where the dominant factor of the process was mostly fluvial, balanced and completely windy. In each of these processes, about 27.2% is distributed. Forming about 9.2 %, It was mostly fluvial and intermittent (Fig. 11).

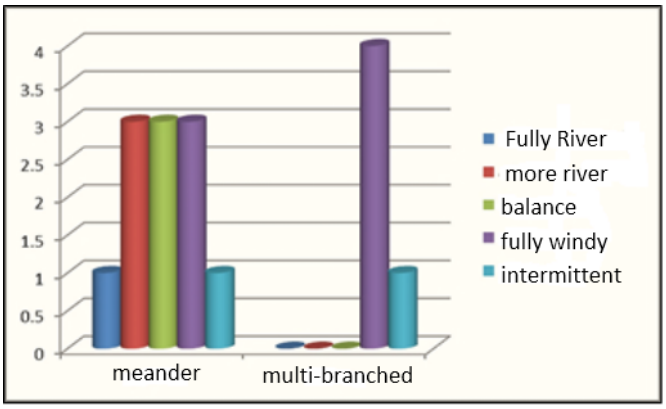

Fig. 11. Relationship between the type of interactions and the pattern of rivers

4. Conclusion

In this study, sixteen sites in different parts of the country were selected to study and evaluate the type of interaction between the wind process and the river process. Based on the results, it was found that the interaction between water and wind processes is widely effective in the formation of landscapes and morphology of areas affected by the presence of rivers and sand dunes. In this study, three variables were analyzed to discover the relationships between rivers and sand dunes. These three variables include the channel pattern, the sand dunes pattern, and the type of inter-process interaction. The results showed that the channel pattern and sand dunes were influential in the interactions between river and wind processes. In this regard, it was found that there is a significant relationship between the type of sand dunes and river pattern, which is more related to the dynamism of sand dunes, so that in places where sand dunes are less active in those places, the river pattern is more meandering, and in places where the sand dunes are more active and dynamic, the river pattern tends to be multi-branched. Based on these issues, longitudinal sand dunes tend to be parallel to the river channel, while the crescent-shaped sand dunes (Barkhan) are often active perpendicular to the river, which fills the river channel with sediment and deflection and changes the direction of the river channel. It also sheds light on the relationship between processes and sand dunes, because sand dunes are widespread in arid areas and in these areas rivers do not have much power, so the dominant factor is the wind process. This factor causes the sand dunes to expand and create sandy fields. However, as we move from the arid and desert areas to the margins, the power of the rivers increases and the windy and watery process get closer. Regarding the relationship between processes and river patterns, the results showed that wherever the wind process is dominant, the canal pattern is usually multi-branched and arterial. However, little connection was found between the meandering pattern and the processes. Of course, Connell's model also follows other issues such as river flow, which in this study we considered the study of these cases because it is based on the identification of visual features between the river process and sand dunes.

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