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## Interplay between river dynamics and international borders: The Hirmand River between Iran and Afghanistan

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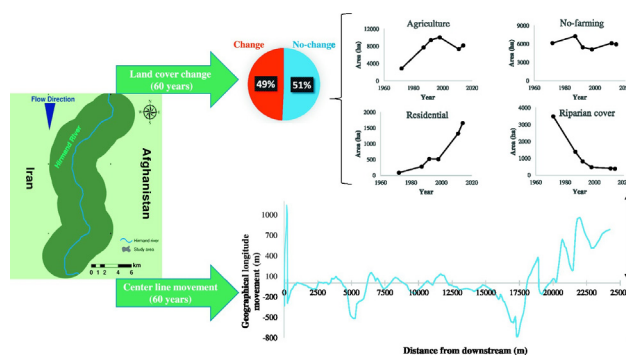
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### HIGHLIGHTS

- Spatio-temporal changes of international border between Iran and Afghanistan were detected.
- Land cover types in Hirmand river floodplain changed extremely.
- The active channel spends a narrowing process.
- The center line of Hirmand river almost moved to Afghanistan area.

### GRAPHICAL ABSTRACT



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### ABSTRACT

Fluvial dynamics in riverine borders can play an important role in political relationships between countries. Rivers move and evolve under the influence of natural processes and external drivers (e.g. land use change in river catchments). The Hirmand River is an important riverine border between Iran and Afghanistan. The present study shows the evolution and lateral shifting of the Hirmand River along the international border (25.6 km) over a period of 6 decades (1955–2015). Seven data series of aerial photos, topographic maps and Landsat images were used to analyze land cover and channel changes in the study reach. The land cover has changed dramatically on both sides of the border during the last 6 decades, especially in the Afghan part. Overall, 49% of all land surface changed its cover type, especially the area of agriculture and residential land contributed to that, with an increase in surface area of about 4931 ha and 561 ha, respectively. On the other hand, the natural cover and water bodies decreased to 38% and 63%, respectively. The impact of these land use changes on the morphological evolution of Hirmand River was investigated in 5 sub-reaches. We found an average decrease of the active channel width of 53% during 60 years and the average River Network Change Index for the whole study reach during 60 years was  $-1.25$  m/year. Deposition and narrowing turned out to be the main processes occurring within the study reach. Furthermore, due to natural riverine processes the Hirmand River has moved towards Afghanistan (37 m on average) and lateral shifting was found to be up to 1900 m in some sections.

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## 1. Introduction

Freshwater resources such as lakes and rivers are the most politicized natural resources (Elhance, 2000; Ettehad, 2010; Yannopoulos et al., 2015). There are 263 rivers worldwide that cross borders between two or more countries (Ettehad, 2010). Wolf et al. (2005) stated that international basins cover more than 45% of Earth's land surface. With an increasingly water-stressed world, shared water resources can therefore be used as political means (Dinar et al., 2015; Kilic et al., 2015). In addition, more than the 40% of world population depend on international rivers and about 25% of these people live in developing countries (Ettehad, 2010; Islam and Susskind, 2015; Dolatyar and Gray, 2016). The struggles and conflicts for shared water resources increase political tensions between neighboring countries (Vörösmarty et al., 2000; Lane et al., 2015; Dolatyar and Gray, 2016). Elhance (2000) showed that there are more than 300 treaties dealing with shared water resources between countries.

Historically, rivers have been a good choice for boundaries between countries, because of their potential defensive capability and presumed clarity on the ground. However, because rivers are dynamic natural features, the shifting of rivers due to natural erosion and sedimentation processes can create political issues between countries in terms of boundary definitions (Wolf et al., 1999; Conway, 2005; Donaldson, 2011). In addition, as natural resources that are shared, river boundaries are vulnerable to disputes concerning aspects of water management (Sadoff and Grey, 2002). Barnaby (2009), stated that riverine borders always created struggles between countries because of the natural river dynamics, and even caused wars between neighboring countries (Yoffe et al., 2003; Swatuk and Motsholaphoko, 2008). Not all rivers cause political problems, typically meandering rivers are less disputed as they are more stable and move gradually than braided rivers that can shift over large distances within one flooding event (Wolf, 1995; Zawahri and Gerlak, 2009).

The Iranian international borders include land, sea, and river borders and in total are 8731 km in length. The riverine borders between Iran and its neighboring countries (seven countries) are about 1830 km or 20.9% of the total boarder length (Ettehad, 2010). To set the scene it is important to know that in Afghanistan more than 46% of surface water flows

to neighbor countries (Alim, 2006). Furthermore, an agreement between Iran and Afghanistan in 1872 (the Vein agreement) defined a segment of the Hirmand River (Common Parian) as an international border (Mojtahed-Zadeh, 2007; Bazrkar et al., 2013; Madani, 2014; Yazdani, 2016). This makes the Hirmand River one of the most important riverine borders between Iran and Afghanistan and it plays a very crucial role in the social, economic, and ecological condition of both countries, especially in the downstream sector, because the floodplain is favorable for agriculture and the Hamoon Lake is worth for its ecological conditions.

Over the last 60 years the Hirmand River has changed its morphology. This is likely due to the changes that have occurred in the hinterland. Several studies showed that the land use within a catchment has significant impact on the fluvial processes and that changes in the upstream areas of a catchment have effects on the hydrological, geomorphological, sedimentological and ecological functioning of a river (Keesstra et al., 2005; Gregory, 2006; Keesstra et al., 2009; Sanjuán et al., 2014; Zhang et al., 2015; Valipour, 2015a, 2015b, 2016).

According to the existing literature (Brice, 1960; Lagasse et al., 2004; Gordon and Meentemeyer, 2006; Dai et al., 2008; Güneralp and Rhoads, 2009; Güneralp et al., 2012; James and Lecce, 2013; Nelson et al., 2013; Belletti et al., 2016) there is a research gap on investigating riverine borders from a geomorphological point of view. Most studies on international watersheds focused on hydropolitical aspects and so far no study specifically focused on the morphological changes of a riverine border as a cause of conflict between neighboring countries. The main aim of this study is addressing the following questions: (i) how has the Hirmand River changed over the last 60 years and what has driven river dynamics; (ii) how much river dynamics have affected land use (agriculture, settlements) along the border. In order to reach this aim the following specific issues were addressed: i) to characterize river processes, in relation to different river typologies; and ii) to reconstruct past channel changes, since they are crucial for approaching problems along a “shifting” border. Finally, an outlook towards the future was attempted by interpreting past changes and present river dynamics. This will enable to make a forecast for where major changes in river morphology are likely to occur in the near future.

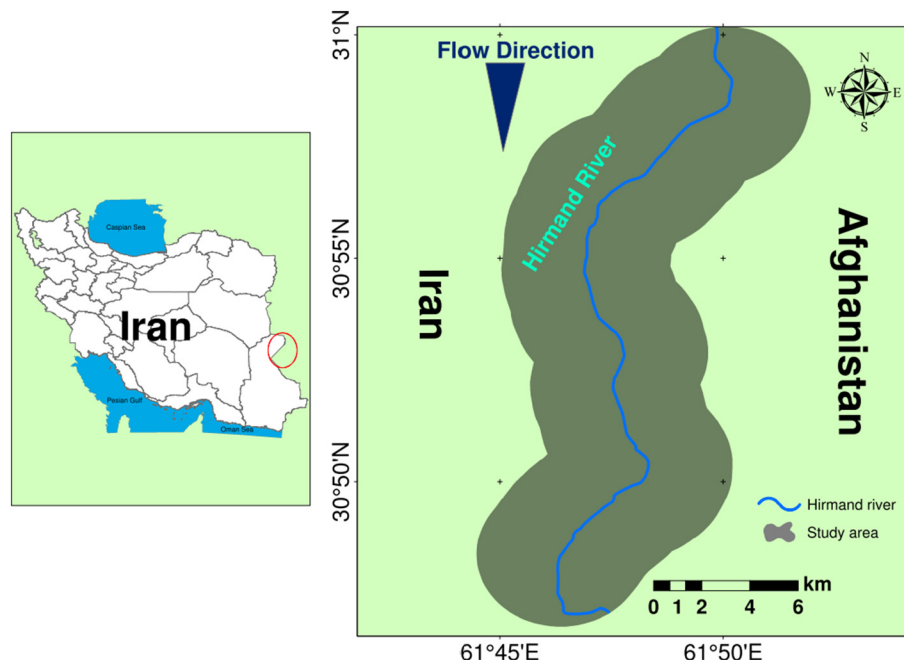


Fig. 1. Location of the study area.

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