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Reconstructing the historical water regime of the contributing basins to the Hawizeh marsh: Implications of water control structures

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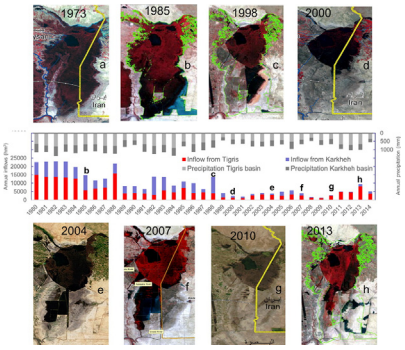
HIGHLIGHTS

- The Mesopotamian Marshes (MM) have been degrading in last the few decades.
- Water regime in contributing basins of Hawizeh marsh, southern MM, was studied.
- Significant reductions in inflows to Hawizeh marsh were seen in 1990's and 2000's.
- Water abstraction by dams and reduction in precipitation affected the inflows.
- Planned dams pose threat for the revival of Hawizeh marsh.

GRAPHICAL ABSTRACT



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ABSTRACT

The Hawizeh marsh, a unique wetland which is part of the Mesopotamian marshes, is recognized as a wetland of international importance. The marsh has been shrinking and there has been little research into its degradation. This study aims to reconstruct historical water regimes in the contributing basins (Tigris and Karkheh river Basins, TKRB) to investigate factors that have affected the wellbeing of the marsh. The Soil and Water Assessment Tool (SWAT) was used for this study. The model was calibrated and validated using nine river gauging stations. Results indicated that inflows to the marsh decreased by 65% and 80% in the '90s and 2000s, respectively, compared to the '80s. The reductions in streamflow were caused by decrease in precipitation and water abstraction. The annual precipitation decreased by 14% and 38% in the '90s and 2000s, respectively, compared to the '80s. Highest water abstraction was seen in Karkheh dam which caused a reduction of 45% in the annual streamflows. Average annual evaporative losses from Tharthar lake (2700 km^2) were very high (2260 hm^3 [cubic hectometer]). Although the Hawizeh marsh has been shrinking for the last three decades, recent satellite images (2013) have shown that the marsh has been reviving, mainly due to increased precipitation from 2011 to 2013. The revival of the marsh is promising; however, if the planned dams on TKRB are implemented, the future of the marsh remains uncertain. The sustainability of the Hawizeh marsh will require integrated water resources management among the riparian countries to rehabilitate and maintain this unique wetland.

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1. Introduction

The Mesopotamian marshes, often referred to as the Iraqi marshes, are mostly located in southern Iraq and a portion of southwestern Iran. They are mainly fed by the Tigris and Euphrates rivers. They were once considered as "the cradle of western civilization" and the Garden of Eden (Richardson, 2005). They are among the largest wetlands in the world, and cover an area of >20.000 km^2. They are divided into three major marsh areas: the Central Marshes which lie between the Tigris and Euphrates rivers, the Hammar Marshes which lie south of the Euphrates river, and the Hawizeh Marshes which lie east of the Tigris river.

The Mesopotamian marshes was home to an indigenous population of marsh dwellers, commonly called the Marsh Arabs or Ma'dans, who have a special place in the anthropological and cultural literature for their alluring way of life, living in harmony and relative isolation within the marsh environment for the past 5000 years on man-made reed islands and along the periphery of the marshes (Richardson, 2005). The Ma'dans are completely dependent on the abundance of marsh resources for their survival with activities including fishing, rice cultivation, buffalo breeding and reed weaving (Alwash, 2013; UNSECO, 2003). The marshes were the permanent habitat for millions of birds and a flyway for millions more migrating between Siberia and Africa (Richardson, 2005). Moreover, the marshes were spawning and nursery grounds for coastal fisheries (UNEP, 2003) as well as a natural filter for waste and pollutants in the Tigris and Euphrates rivers that protects the Persian Gulf (Maltby, 1994; Richardson, 2005; UNEP, 2001).

The northern areas of Mesopotamia (upper Iraq) are largely used for rain-fed agriculture; however, agriculture in southern Mesopotamia is only possible through irrigation. Irrigated agriculture has been made possible by the construction of different water diversion and storage infrastructures for the last 6000 years (Postel, 2001). Infrastructure development in Mesopotamia successfully formed the world's first irrigation-based agricultural civilization. However, this success has been at the cost of the ecosystem since the time of the ancient Sumerians (Postel, 2001). Recent developments, particularly during Saddam Hussein's regime, caused a complete destruction of the entire wetland ecosystem (Alwash, 2013). Furthermore, numerous water control structures, including >30 dams, were built along the Tigris and Euphrates rivers by Turkey, Syria, Iraq and Iran, which exacerbated the degradation of the Mesopotamian ecosystem. As a result of this human intervention, <10% of the marshes in Iraq remain as fully functioning wetlands (Richardson, 2005).

The Hawizeh marsh, unlike other marshes was not completely dried during Saddam Hussein's regime. The Hawizeh marsh became a Wetland of International Importance (a Ramsar Site) in October 2007 under the Ramsar Convention (Ramsar, 2011). However, the area of the marsh significantly reduced in 2010 and the Hawizeh marsh was listed on the Montreux Record (i.e., the list of threatened Ramsar Sites). The Hawizeh marsh is a transboundary wetland with about 75–80% of its area located in Iraq and the remainder in Iran. It is hydrologically dependent on inflows from the Tigris river on the Iraq side and by the Karkheh river on the Iran side. In the last few decades, several water control structures such as dams, barrages and levees were built on the Tigris (and its tributaries) and Karkheh rivers to control floods and facilitate irrigated agricultural production, and many more are proposed in the future (Altinbilek, 2004; Alwash, 2013; Jones et al., 2008; Richardson, 2005).

There are few examples of literature (Chen et al., 2010, 2011; Jones et al., 2008; Kavvas et al., 2011; Ohara et al., 2011) that attempted to understand the hydrology of the Tigris and Euphrates system and the impacts of water control structures and different water utilization scenarios on Central and Al-Hammar marshes which are fed mainly by the Euphrates river. Others (e.g., Ghobadi et al., 2015a) evaluated impacts of water control structures on the Karkheh river that flows into Hawizeh marsh from Iran side. There is no published literature that understands the entire hydrologic regime of the contributing basins (Tigris and Karkheh) to Hawizeh marsh and evaluate the impacts of current water control structures on inflows into the marsh. There is a need to investigate how the marsh has been affected due to upland activities over the last three decades. More specifically, how did the volumetric streamflow's at main channel and tributaries change spatially and temporally in the basin and how they affected the inflows into the Hawizeh marsh? Are water control structures responsible for the water reduction or are there other factors responsible? What's the condition of the marsh post-2010? Has it improved or further deteriorated?

The aim of this study is to use a hydrological model to reconstruct and understand the historical water regime of the last three decades for the contributing basins of the Hawizeh marsh. The objectives of this study are to (1) develop and calibrate a hydrological model in the contributing basins in order to evaluate the hydro-meteorological situation, (2) analyze annual volumetric flows and various diversions from the Tigris including its tributaries and the Karkheh river for three decades, (3) evaluate inflows and their impact on the Hawizeh marsh during the last three decades and (4) assess the implications of water control structures. The Soil and Water Assessment Tool (SWAT; Arnold et al., 1998) was used because of its proven capability to simulate large complex watersheds (Daggupati et al., 2015, 2016a, 2016b; Deb et al., 2015; Yen et al., 2016a, b). SWAT has been extensively used around the world to understand hydrological regimes and dynamic water balances of a watershed in order to investigate various water utilization scenarios for proper planning of effective water resource management.

2. Study area

The study area encompasses the Tigris and Karkheh river basins within the countries of Turkey, Iraq and Iran (Fig. 1). The catchment areas of the Tigris basin and the Karkheh basin are 248,000 km^2 and 52,000 km^2, respectively. The Tigris river starts from the small mountain lake of Hazar in southeastern Turkey and flows south along the base of the Zagros Mountains, where several left bank tributaries join, and flows into the Hawizeh Marsh. About 32% to 50% of Tigris river streamflow to the Hawizeh Marsh comes from Turkey, and the remainder is contributed by a series of major left back tributaries originating from the Zagros Mountains of Iran and Iraq (UNEP, 2001). The Karkheh river starts from the central zone of the Zagros Mountains in Iran and has two upper courses called Kashkan and Seymareh. The Kashkan and Seymareh rivers meet near Pol-e-Dokhtar and finally flow into Hawizeh marsh. Hereafter, the Tigris river and Karkheh river Basin systems will be referred as Tigris-Karkheh river basin (TKRB). The average annual rainfall in the basin ranged from 1500 mm in the mountainous regions of Turkey to 60 mm in the southwest plains of Iraq.

Most of the water control structures were constructed in recent decades, and there are several planned or under construction. In this study, the watershed was divided into three zones (Fig. 2 to Fig. 4) to describe the routing within the basin and water control structures. The time period used in this study was from 1980 to 2014, and any water control structure that became operational after 2014 was considered as planned/under construction (hereafter referred to as planned). Zone 1 (Fig. 2) shows TKRB in Turkey until the border of Iraq. It shows the schematic view of current and planned dams on the Tigris river and its tributaries. In Zone 1, there are six dams that are currently operating and four dams that are planned. Kralkizi dam is on Maden river, which is an upstream tributary of the Tigris. Dicle dam was built at the confluence of the Maden river and Dibni river where they form the Tigris river. Batman dam is on Batman river, which is a major tributary to the Tigris. Silvan and Kayser dams are under construction on the Batman river. Garzan and Alkumuru dams on Garzan and Botan rivers became operational in 2011. Illisu and Cizre dams are being constructed in conjunction near the village of Illisu - close to the border of Iraq. The greater Zab river has been the only free flowing river in the region.

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