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Assessing cross border land cover changes in a water-stress context: the Syrian-Turkish Jezira region over the last three decades

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ABSTRACT

The Upper Mesopotamia region, also called Jezira, is a rural plain split by the Syrian-Turkish border. The region was subject in the last three decades to prominent changes to the land cover, mainly due to the vast development of irrigation projects from both sides of the border. The research aims at detecting differences to the trend of land cover changes between the adjacent territories.

The study makes use of Remote Sensing change detection techniques, applied to Landsat satellites images from 1984 to 2015. Considering the arid to semi-arid climate characteristic of the region, the analysis takes into consideration the local water management policies and drought events.

As an output, the research quantifies the direction of the surface changes occurred in several intermediate times, underlining the differences across the border. The study highlights how surrounding conditions can intensify the impact of drought periods, such as the 2006–2010 drought that severely affected the Syrian territory.

1. Introduction

The Tigris-Euphrates Basin, variously known as the Fertile Crescent or also Mesopotamia, has been a central location of human development throughout history, and is often referred to as the 'cradle of civilization' (De Châtel, 2014a; Hole and Smith, 2004). The fertile plain located in the Upper Mesopotamia corresponds to the Jezira region, which is the Arabic word for 'island': the region is nestled among the Tigris river on the East, the Euphrates river to the West and the Anatolia mountains on the North, across the present border between Turkey and Syria.

Since the 90 s, Jezira region has been theater of vast irrigation projects that transformed the landscape and the local agricultural practices. While both sides of the border shared meteorological and geographical characteristics, the land cover exhibited different patterns during time. This fact makes Jezira a convenient case study to proof the strength of Remote Sensing (RS) in detecting surface cover change and its relevance for stakeholders and decision makers, especially for arid and semi-arid areas of the Earth, so called the drylands.

In desertification studies, RS is an effective and powerful tool for detecting surface changes over large spatial and temporal scales (Aplin, 2009; Singh, 1989; Sui et al., 2008). The soil reflectance and the vegetative mass contributions play the major roles in change detection in drylands, thus when applied to this specific context, RS techniques developed or commonly used for vegetated areas need to be handled with care (Higginbottom and Symeonakis, 2014; Huete et al., 1985). On the other hand, drylands have advantageous weather characteristics, such as dry and cloudless conditions which remain unchanged for a long part of the year, that are ideal for change detection studies. Specific desertification indicators have been used and developed in literature, for instance indicators of land degradation (soil erosion, soil salinization (Metternicht and Zinck, 2003)), land use changes (expansion of agricultural or urban areas), bare soil expansion, drought and changing vegetation (perennial plant cover and biomass) (Albalawi and Kumar, 2013; Dawelbait and Morari, 2011).

The present study makes use of Land Use and Land Cover Change (LULCC) detection analysis techniques, in particular a RS methodology tested for multi-year surface changes detection in drylands. In RS two different types of change detection methods are usually employed: supervised and unsupervised techniques. Supervised techniques require a preliminary knowledge of the area in order to carry out a classification of the image, while unsupervised procedures are used in absence of samples or previous information on the ground. Despite this advantage, the interpretation of the results of unsupervised techniques is often more uncertain. The adopted methodology seeks to overcome this issue by combining two unsupervised techniques, with the aim of providing more and complementary information for the interpretation of the change. Even though the methodology was previously presented by Zanchetta and Bitelli (2017), this study applies it to a broad region crossing some national borders, taking into account for the first time the

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territorial adjacency. Earlier studies explored LULLC in the region, but they took into account only limited areas in either Syria or Turkey (Hirata and Miyazaki, 2001; Hole and Zaitchik, 2007; Ozdogan et al., 2006; Udelhoven and Hill, 2009; Yuksel, 2012; Zaitchik et al., 2002). The present research instead considers the geographical area as a whole. In this sense, the adjacency plays a significant role, helping to explain the change and to exclude geographic and climate factors as a cause, since they are common to the two sides of the border.

Landsat images are utilized for the change detection analysis from 1984 to 2015. In the considered time frame several factors can have played a consistent role, such as the ongoing Syrian conflict and the long-lasting period of consecutive droughts that affected the region from 2000 to 2010 (ACSAD - ISDR, 2011).

The discussion on whether and how politics and climate conditions correlate is beyond the aim of the present research. Regarding the Syrian civil war, in particular, the debate is still open, as testified by recent papers (Hendrix, 2017; Gleick, 2017; Kelley et al., 2017; Selby et al., 2017). Nonetheless, several studies agree in asserting that between 2006 and 2010 the whole Fertile Crescent experienced a significant drought (Gleick, 2014), the worst from the beginning of the XX century, as by the drought index used by Kelley et al. (2015). In Syria this event added up to the consequences of an earlier 2000s drought, inducing the displacement of many people from rural areas to urban settlements, food insecurity (more than one million people affected in 2012 (FAO, 2012)) and unemployment growth. Several authors point out that it was not the drought alone responsible for the crisis, which eventually broke out in the conflict in 2011, but a series of social, economic and political factors (De Châtel, 2014b). The Jezira region, that used to ensure the national autonomy in terms of wheat production (it was previously known as 'the Syrian bread basket' (FAO, 2009)), ceased to fulfill this task by 2008 (Gleick, 2014).

1.1. Overview of the water resources management

The water sources in the Jezira region are groundwater sources and surface water originating from the Euphrates river, its tributaries and karstic springs (Ain Al Arus and Ras Al Ayn, see Fig. 1). In terms of land use, in general the areas in the immediate proximity to the water beds are fertile, while the remainder of the area is semi-arid steppe-land.

Focusing on the watershed basin, the Euphrates basin is characterized by an arid to semi-arid climate: the mean annual precipitation ranges from abundant in the Northern mountainous area (1000 mm), to scarce rates in Southern Syria (175 mm) and Iraq (75 mm) (UN-ESCWA and BGR, 2013). In terms of surface, the Euphrates is the main contributor to the Tigris-Euphrates-Shatt Al Arab basin, and it is shared among several riparian countries (47% Iraq, 28% Turkey, 22% Syria, minor percentages Jordan and Saudi Arabia, see Fig. 1) (UN-ESCWA and BGR, 2013). Three major tributaries flow into the Euphrates in Syria (Sajur, Balikh, Khabour) and South of the Khabour there are no other tributaries to the Euphrates in Syria or Iraq.

Until the 1960s, Iraq was the main user of the Euphrates' waters, while in Syria limited irrigation was practiced, mostly along the riverbed and in the floodplains (Beaumont, 1996). As of the mid 1960s, Syria and Turkey's usage of the river changed from downstream diversion schemes to upstream water storage projects, with the dual aim of generating hydro-electricity and providing large quantities of water for irrigation purposes (Beaumont, 1998). The agricultural development was motivated by the increasing population pressure since the 50 s, both in Turkey and Syria, with the need to raise the standard of living in the bordering provinces (Beaumont, 1978).[1]

The first big dams were completed in the early 1970s, and in the 1990s several massive water projects were implemented in both riparian Countries (see the main dams shown in Fig. 1, right insert) (Hole, 2009). In Turkey the ambitious Southeastern Anatolia Project (GAP, from the Turkish acronym) led to the creation of several dams, as it is the case of the Ataturk Dam.[2] This dam is by far the largest one in the basin (Beaumont, 1998) and supplies water through huge tunnels (Urfa o Halama tunnels) to the rural Şanlıurfa-Harran plains and the Ceylanpinar plains, in Turkey (Beaumont, 1996; Yuksel, 2012).

In Syria, studies and surveys on the feasibility of vast irrigation projects - realized by international agencies like FAO and USDA – supported the development of large water structures (Hole and Zaitchik, 2007). The consequent water system development caused significant changes to the social system, such as the displacement of villages located on the dams catchment area. Farmers were urged to adapt to different irrigation system and the landscape changed from rain-fed (especially in the Northern plains, see the 'limit for dry farming' in Beaumont, 1996) and floodplain irrigation, to irrigation, by canals or by pumped groundwater, spread along the steppe and in areas considered suitable for agricultural usage (see Zaitchik et al., 2002 for a detailed RS analysis of this topic). The massive water engineering structures and groundwater withdrawal, much beyond the basin capacity (Gleick, 2014), affected eventually the Euphrates flow regime, whose seasonality and amount decreased compared with the previous unaltered conditions (UN-ESCWA and BGR, 2013).

The above listed impacts become more remarkable in light of the absence of solid agreements between the three riparian countries regarding the shared water (FAO, 2009). Negotiations were attempted in a number of occasions, leading eventually to bilateral agreements on water allocation between Iraq and Syria (in 1990, after an escalation that culminated in a war threat from Iraq in 1974) and between Turkey and Syria in 1987. A Joint Technical Committee and a Memorandum of Understanding among the three countries were achieved in 2009. Nonetheless since the starting of the Syrian Civil War, in 2011, these agreements have been suspended (Beaumont, 1998; Gleick, 2014; UN-ESCWA and BGR, 2013).

2. Materials and methods

2.1. Study area

The study area covers 64,800 km^2 in a region comprised between 38E/35N and 37E/42N long/lat (see Fig. 2). It was chosen in order to include several irrigated and cultivated lands around the Syrian-Turkish border, referring to the ESA GLOBCOVER 2009 Project land cover map.[3]

The study area specifically comprises the Şanlıurfa-Harran (Urfa) irrigated plains in Turkey on the West, the Balikh-Sajur river from North (Ain Al Arus spring) to South at its junction with the Euphrates river, including the rural area, so-called 'horseshoe', around the town of Raqqa (canalized water from the Baath Dam). Eastwards the area covers the steppe up to the Khabur river bed. The latter is easily recognizable by the funneled shape made up by its two tributaries, the one coming from Ras Al Ayn spring (West) and the Jaghjagh river (East) originating from the karstic springs near Qamishli.

Above this area, beyond the border, lay the Ceylanpınar plains. On

[1] In Syria an exceptional population growth over the past 60 years induced a drastic drop in water availability per person per year (pppy), from 3 million people in 1950 with over 5500 m^3 pppy, to over 22 million in 2012 with below 760 m^3 pppy by 2012 (De Châtel, 2014a), which categorized Syria as a scarce country as per water availability in 2012 (scarcity is under 1000 m^3 pppy) (Gleick, 2014).

[2] The GAP project foresees the overall construction of 22 dams and 19 hydropower projects on the Euphrates and Tigris rivers. The project has nowadays almost reached completion, despite international and local criticism concerning its implementation (Sowers et al., 2011).

[3] http://epic.awi.de/31014/16/GLOBCOVER2009_Validation_Report_2-2.pdf.