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Status quo and present challenges of the sustainable use and management of water and land resources in Central Asian irrigation zones - The example of the Navoi region (Uzbekistan)

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ABSTRACT

Soil salinization is a major problem in many arid and agriculturally used regions and Central Asia is a prime example for this. Intensive irrigation, saline water resources, shallow groundwater tables and high evapotranspiration rates lead to the enrichment of salts in the top soils and a reduced soil productivity in the Central Asian lowlands. This is aggravated by a strong socioeconomic growth which results in an increase in the water consumption and the intensification of the farming practices (e.g. fertilizer application). This article analyses these problems for the Navoi province in Uzbekistan, a region located in the lower reaches of the Zarafshan River in the Kyzyl Kum desert. Between 2000 and 2015 detailed data on the groundwater table, groundwater salinity and the soil salinity were collected, complemented by meteorological data, soil characteristics, water use, and fertilizer statistics. Based on these datasets the ameliorate soil conditions in the Navoi irrigation zone and their temporal dynamic were assessed.

The results show that both the groundwater and soil salinity have improved slightly during the last 15 years. Especially the percentages of samples with a high salinity have been reduced significantly. In 2015 only 0.7% of the irrigated soils have been categorized as highly saline while 71.3% were only slightly saline and 18.3% non-saline, while those values for the year 2000 were 6.1%, 51.5%, and 13.2%. The ameliorate soil conditions, on the other hand, have not improved accordingly, but showed a slight deterioration, even if they are overall satisfactory in 79.6% of the area. The percentage of irrigated soils with an unsatisfactory condition has increased from 3 to 13.9% between 2000 and 2014. This development is not related to any climatological, soil or groundwater parameters, so that the impacts of an increased water usage for urban and industrial purposes (and the related effects on the water quality), as well as the increased fertilizer application, seem to be a possible explanation for the observed trend.

The results show the impact of the low efficiency of the irrigation and drainage system, which is outdated, not well maintained and thus often failing, on the groundwater level and the soil salinization, but also how the attempts to update the system during the recent years has led to a slight improvement of the soil and groundwater salinity.

1. Introduction

Desertification is a global problem threatening the livelihood of millions of people in arid and semiarid regions. It is defined as land degradation caused by climatic variability and human activities, with land degradation itself being defined as the loss of the biological and/or economic productivity (Adeel et al., 2005; D'Odorico et al., 2013). Soil erosion and salinization are the main causes for this loss of productivity (Adeel et al., 2005; Amezketa, 2006; Thomas and Middleton, 1993), putting a special emphasize on the scientific analysis of these processes and their connections to land use practices and climate variability (Al-Ghobari, 2011; Geist and

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Lambin, 2004; Ravi et al., 2010; Salama et al., 1999; Sivakumar, 2007; Smedema and Shiati, 2002; Verón et al., 2006). The arid regions in continental Asia – from the Taklamakan desert to the Aral Sea basin are especially susceptible to desertification due to their land-locked nature, high population and economic dynamic and an above average vulnerability towards climate change (Alibekov and Alibekova, 2007; Dubovyk et al., 2012; Groll et al., 2013, 2015). The lowlands of the Aral Sea basin in Central Asia, the main centers of the regional desertification dynamic, are characterized by a flat topography with a low natural drainage, high groundwater tables and geological formations rich in salts (Ibrakhimov, 2004; Panin, 1968; Pankova et al., 1996). In combination with the hot and arid climate, these lowlands are prone to naturally occurring soil salinization (Akcura et al., 2008). Due to intensive irrigation farming activities, the countries in the lower Aral Sea basin, especially Turkmenistan, Uzbekistan, and Kazakhstan also have a high potential for the secondary salinization of their irrigated lands (Hbirkou et al., 2011; Kitamura et al., 2006). This man-made component of the soil salinization is aggravated by a strong economic and population growth in combination with a high vulnerability towards climate change in the sensitive arid lowlands, which will lead to a pronounced decrease in the water availability and an increase in the water consumption during the next decades (Chub and Ososkova, 2008; Dukhovny and de Schutter, 2011; Groll et al., 2015). In Uzbekistan, the agriculture is the most important economic sector, contributing about 18% of the GDP and 27% of the total employment. The irrigation farming produces more than 90% of the agricultural yield and also consumes more than 90% of the available annual water resources (Alihanov, 2008; Chub and Ososkova, 2008; Opp et al., 2016). As the salinization reduces the efficiency of the agrarian production (Bucknall et al., 2003), the much-needed food security for the growing Central Asian population is threatened. This leads to a shift from cotton as the main crop towards winter wheat, forage crops and vegetables (Umarov, 2013), but especially to an accelerated expansion of the irrigated areas into marginal areas, further increasing the unsustainable use of the limited water resources as well as the secondary salinization. Regions especially affected by this development are the lower reaches of the Syrdarya, Amudarya, and Zarafshan River as well as the delta ecosystems of the Priaralie (Chub and Ososkova, 2008; Dukhovny and de Schutter, 2011). Since the middle of the 20th century, these regions have been exposed to soil salinization, water, and wind erosion and, in parts, are severely polluted with heavy metals, fluorides, and agrochemicals (Alihanov, 2008; Groll et al., 2015; Umarov, 2013). Furthermore the extensive and unsustainable land use and the insufficient maintenance of the irrigation and drainage networks caused a rise of the groundwater level as well as an increase of the groundwater mineralization, resulting in the dramatic deterioration of the ameliorate condition in the irrigated areas during the last 20 years (Alihanov, 2008; Umarov, 2013).

In consequence of this development, more than 50% of all irrigated areas in Uzbekistan were affected by salinization by the end of the 20th century. The loss of crop yields (e.g. −20 to −30% for cotton) is usually combated by an increased application of mineral fertilizers. But as these fertilizers (mostly nitrogen based) also contribute to the soil salinization, additional leaching is required, which in turn raises the groundwater table and thus accelerates the salinization process. The leaching also depletes the topsoil humus reservoirs (at present, 66% of the arable land in Uzbekistan has a humus content of less than 1%), reducing the already low soil fertility, creating a vicious circle (FAO, 2003; MAWR, 2015; World Bank, 2010).

The Navoi region is one of three Uzbek provinces along the Zarafshan River and due to its location in the arid center of the country (the Kyzyl-Kum desert takes up much of the region's area) and in the lower Zarafshan catchment, it is especially affected by soil salinization. Over the course of the last decades, details of the environmental problems of the Navoi region have been studied. Lebedev (1954) for instance analyzed the quantity and distribution of salty soils, while others conducted studies on the soil classification, the agrophysical soil properties or the salt modes in the region (Gafurova et al., 2005; Kimberg, 1975; Zvonkova, 1965). Kulmatov (2014) analyzed the problems of the sustainable management of the water and irrigated land resources as well as their protection for the whole country of Uzbekistan and for the Bukhara province (Kulmatov et al., 2015).

The study presented here focuses on the Navoi province and discusses these issues in greater detail - especially the water usage dynamics, the ground water level and mineralization, the extent of the salinization, and the ameliorate condition of the irrigated lands of the Navoi region for the time period 2000–2013.

2. Research area

The Navoi region is located in central Uzbekistan, has a size of 110,800 km^2, and a population of 0.9 million, 60% of which live in rural areas (MAWR, 2015). Large areas of the region are covered by the Kyzyl-Kum desert, so that only 4.7% of the territory is used for farming and the main population and economic centers are located in the southern part of the province, near the Zarafshan River (Fig. 1). That is also where the irrigated areas are located and the Zarafshan irrigation scheme (which is shared by the three provinces Samarkand, Navoi, and Bukhara) is, with a total size of 540,000 ha, one of the most important agricultural centers in Uzbekistan (Groll et al., 2015). The share of this irrigation scheme located in the Navoi province is with 131,800 ha smaller than in the other two provinces (MAWR, 2015, Fig. 1), but still a sizeable amount.

The relief of the Navoi region is varied. The Kyzyl-Kum Desert (elevation 75–300 m) dominates the northern parts and transitions into hills and mountains (elevation 400–600 m) in the southeastern part of the territory (e.g. the Nurata mountain range).

The climate is continental, with hot and dry summers (T_{avg} = 27–30 °C) and cold and dry winters (T_{avg} = -4-0 °C). The average annual air temperature is 15–16 °C, with 300 sunny days, an annual potential evaporation of 1900–2,000 mm and an annual precipitation of 90–120 mm, 60% of which occurs between January and April (Abdulkasimov and Abbosov, 2001).

The northern and central parts of the Navoi region are dominated by sandy desert soils which are grey-brown in color and mostly alkaline (Calcic Yermosols and Calcic Xerosols, FAO, 2003; Pankova and Konyushkova, 2013). These desert soils are characterized by a low humus content of about 0.5% and due to overgrazing, they are prone to erosion. Clayey and loamy takyr soils and sandy areas without any pedogenesis intersperse this area of the region (Fig. 2). The southern part of the Navoi region, on the other hand, is dominated by hydromorphic soils of the irrigation zone (Calcaric Gleysols, FAO, 2003, Pankova and Konyushkova, 2013). They vary in texture and color and have humus contents of 1.2–1.8% in the irrigated areas close to the Zarafshan River and of 0.6–0.9% near the periphery of the irrigated area. These humus concentrations match the national average and are the result of extensive fertilization and leaching (FAO, 2003; MAWR, 2015; World Bank, 2010). As a result, the majority of soils in the Zarafshan irrigation scheme (44%) are depleted and today have a bonitation Grade of II (areas producing 61–80% of the potential yield of 40 centners of cotton per hectare), followed by Grade III (28% of the area, 41–60% of the potential yield), Grade I (15.5% of the area, 81–100% of the potential yield) and Grade IV (12.5% of the area, 40% or less of the potential yield) (FAO, 2003). These values also reflect the national

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