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Comparative assessment of irrigation systems' performance: Case study in the Triffa agricultural district, NE Morocco

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ABSTRACT

Programs targeting conversion to irrigation techniques promoted as water-efficient, such as drip irrigation, are multiplying worldwide with the claimed objective to secure food production while alleviating the pressure on water resources. However, there is a persisting and widespread questioning about the actual impact when implementing the techniques in the real-world context, particularly in smallholder farms. We propose a framework to support an integrated assessment of the impact on farm holding performance resulting from the conversion towards a new irrigation technique. It is implemented for a 4030 ha agricultural district in the Triffa plain of NE Morocco where increasing number of farms are changing surface to drip irrigation. The indicators within the framework are calculated using survey data from a sample of 25 farm holdings collected in 2012 and 2013. The survey data are enriched with institutional data and data estimated from hydrologic modeling. The results indicate that, in the study area, farmers engaging with drip irrigation are mainly motivated by social factors, while most environmental and economic indicators are signaling a neutral or undesirable effect resulting from the conversion to drip irrigation. These results question the relevance of the water use reduction objective underlying the ongoing national plan "Plan Maroc Vert" (PMV) that aims converting up to 50% of irrigated agricultural land in drip irrigation, and call for a stronger appropriation of this water-saving objective by the farm holders. However, limited data availability and quality did not allow to firmly demonstrate the robustness of the findings. This severe data constraint revealed the difficulty to assess the socio-eco and environmental impact of such irrigation plan in the study area, and highlights the need for a data collection, centralization, and sharing effort. Conditioned to a strong reduction in data uncertainty, the framework methodology proposed in this study can serve as a practical reference for other studies seeking for an integrated assessment of irrigation management changes.

1. Introduction

Irrigated crops contribute to 21% of total agricultural area, anduse 69% of the withdrawn water resources worldwide (AQUASTAT), making the agricultural sector the biggest consumer of water. This use of water often leads to surface and groundwater resources depletion in irrigated perimeters, which harms ecosystems and prejudices water access and food security. Therefore, the sound management of water resources in irrigated agriculture is a key for sustainable development. The most widely used indices to assess the performance of irrigated systems are the engineers' irrigation efficiency (IE), defined as the ratio of water consumed by irrigated crops to water that is diverted (Boelens and Vos, 2012; Lankford, 2012a,b; Seckler, 1996), the agronomists' water productivity (WP), defined as the ratio of crop yield to water consumed by the irrigated crop (Zwart and Bastiaanssen, 2004), and the water use efficiency (WUE), defined as the ratio of yield to water applied (Stanhill, 1986). The use of these indicators has been repeatedly questioned and criticized as they are limited to the technical performance of the irrigation technology, hence disregarding the larger context into which it is applied (Pereira et al., 2012; Perry, 2008; Willardson et al. 1994). Yet, the spatial and temporal scale dependency of the performance is obvious. For example, studies have shown that IE values can go from very poor to very good if the computation considers the fraction of "lost" water that is re-used at another point in space or time (Clarck and Aniq, 1993; Guillet, 2006). These indicators have also been criticized for not only considering the technical aspects and not the socio-economic ones (Boelens and Vos, 2012; van Halsema and Vincent, 2012). Despite these limitations, these indicators remain

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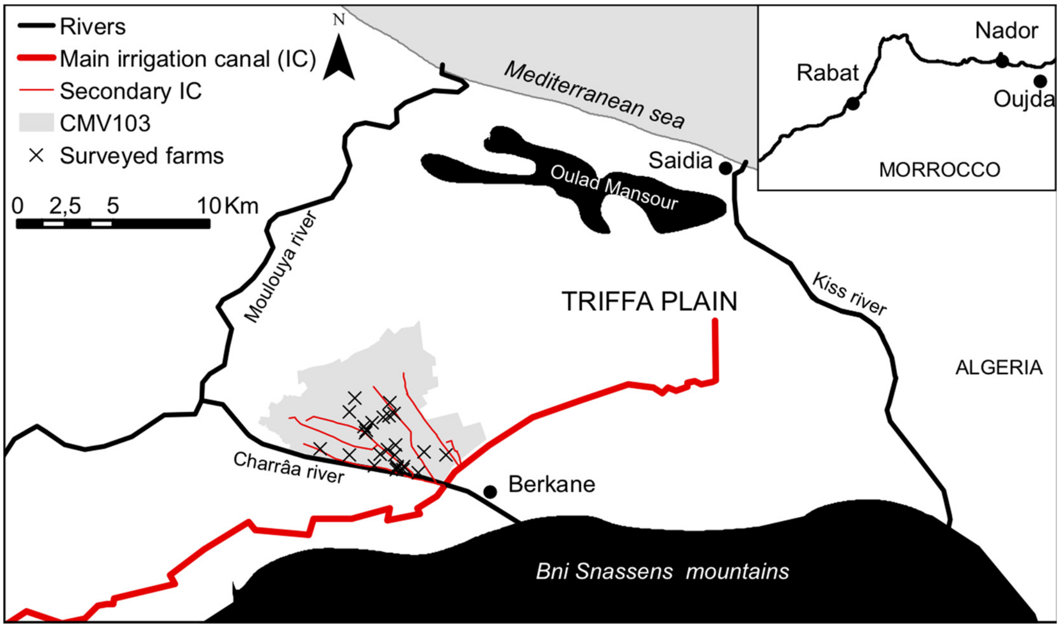

Fig. 1. Study area and localization of the surveyed exploitations.

widely used."

IE can be separated into conveyance efficiency (ec) and application efficiency (ea) (Bos and Nugteren, 1990; Tiercelin and Vidal, 2006; van Halsema and Vincent, 2012). Conveyance efficiency mainly depends on the design and state of the hydraulic infrastructure transporting water to the irrigated field, while application efficiency is usually expressed as a function of application technique. Given the significant financial investment needed to improve ec, ea is most often used as the actionable parameter when seeking to save water during irrigation practices (Boelens and Vos, 2012; Knox et al., 2012). As a result, irrigation water application techniques characterized by higher ea values such as micro-irrigation are increasingly being promoted to improve the performance of irrigated agriculture.

Micro-irrigation is indeed considered to be water efficient and to reduce the pressure on the water resources, thereby increasing yields and economic incomes (Chandran and Surendran, 2015; Darouich et al., 2012, 2014; Garb and Friedlander, 2014).

Drip irrigation, the most widespread micro-irrigation technique, is characterized by a high uniformity of the water distribution and the capability to deliver the water directly to the root zone of the plant at a controlled timing (Goldberg and Shmueli, 1970; Tiercelin, 2006), hence theoretically minimizing evaporation and deep drainage (van der Kooij et al., 2013a). These technical specificities translate into a high potential irrigation efficiency (IE) – the ratio between the irrigation water used by the plant and applied – of drip irrigation, ranging between 70 to 95% (Fader et al., 2016; Hassanli et al., 2010; Tiercelin and Vidal, 2006; van Halsema and Vincent, 2012). These IE values outperform those of surface irrigation for which IE ranges normally between 40 and 75%. However, such a high efficiency is calculated under controlled conditions and is only achieved if the system is well designed and taken care of, and if the irrigation scheme is appropriately managed (Fader et al., 2016; Tiercelin and Vidal, 2006). Such conditions are rarely met when implemented in practical, real-world conditions (Lankford, 2012a). Additionally, adaptation of the farming practice by, for instance, increasing the irrigated land area and cropping intensity, and harvesting different crops often ensue from the modernisation of irrigated perimeters, and may result in a higher water consumption (Batchelor et al., 2014; Berbel and Mateos, 2014; Fishman et al., 2015; Lopez-Gunn et al., 2012; Olmstead, 2010; Ward and Pulido-Velazquez, 2008). Such adaptation may at end counterbalance the envisioned water saving effect of the modernization programme. Therefore, although many scientists, politics, and actors in the agricultural sector are promoting and justifying the conversion to drip irrigation as an effective strategy to tackle the water scarcity issue (e.g. Berbel and Mateos, 2014; Chandran and Surendran, 2015; Cooley et al., 2009; Evans and Sadler, 2008; Friedlander et al., 2013; Johnson et al., 2001; Khan et al., 2008; Lopez-Gunn et al., 2012; Monaghan et al., 2013; Negri and Hanchar, 1989; Olmstead, 2010), others draw attention to the divergence often existing between the potential IE obtained experimentally under controlled conditions, and the real IE once it is calculated beyond the scale of the experimental field (Lankford, 2012b; van Halsema and Vincent, 2012), and once the technique is implemented in the context of the farm holding (Batchelor et al., 2014; Boelens and Vos, 2012; Lankford, 2012b; Perry, 2011; Peterson and Ding, 2005; Pfeiffer and Lin, 2014; van der Kooij et al., 2013b; Venot et al., 2014; Ward and Pulido-Velazquez, 2008). Some of these authors attribute this divergence issue to communication failure by making, among other, a confusing use of the IE concept (Boelens and Vos, 2012; Lankford, 2012a; Perry, 2011). Venot et al. (2014) go even further by supporting that the widespread positive image of drip irrigation has been actively sustained by a group of actors to fit their values, interests, and mission. Following up on this rational, authors recommend drip irrigation conversion programs to be implemented in conjunction with educational and politic measures to ensure that the conversion to drip irrigation actually results in the completion of the water conservation objectives, and an evaluation that takes into account the context into which it is implemented (Berbel and Mateos, 2014; Darouich et al., 2014; Lopez-Gunn et al., 2012; Rodrigues et al., 2013).

Following up on these recommendations and to allow the evaluation of the actual impact of the conversion to a new irrigation technique, this study proposed and tested a framework for an integrated assessment of irrigation performance at the farm scale. The objectives underlying the implementation of the framework are (i) to overcome the limitations linked with the concept of IE, WP and WUE. As such, the notion of *performance* refers here to the integrated aspect of the evaluation and is used instead of *efficiency and productivity*; and (ii) to identify the actual factors explaining the appropriation of the drip irrigation techniques by farmers. This framework implies the evaluation of a set of indicators, and is tested in the field for the CMV103 irrigation district case study. This 4040 ha case study is situated in the irrigated