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TRANSITION FROM SURFACE TO DRIP IRRIGATION IN MOROCCO: ANALYSIS THROUGH THE MULTI-LEVEL PERSPECTIVE

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ABSTRACT

Agriculture uses more than 80% of water resources in Morocco. The sector is inefficient in terms of water use due to the dominance of surface irrigation. To address this issue, there have been efforts in Moroccan strategies to convert surface irrigation to localized one. This paper analyses the dynamics of conversion from surface irrigation to drip irrigation in Fez-Meknes region (north-eastern Morocco) through the lens of the Multi-Level Perspective (MLP) on socio-technical transitions. MLP framework suggests that transitions are the results of dialectic interactions among a niche (cf. novelty of drip irrigation), a regime (cf. traditional system of surface irrigation) and the socio-technical landscape (e.g. policies). MLP was complemented with a multi-capital approach to better assess transition impacts. Results show that the area equipped with drip irrigation in Fez-Meknes region increased from 2174 ha in 2008 to 39290 ha in 2016. Different programs have been implemented in the framework of the Green Morocco Plan to foster irrigation transition e.g. the National Irrigation Water Saving Program (PNEEI), launched in 2007, aims to convert 550,000 ha to localized irrigation (e.g. drip irrigation) in 15 years. Thanks to these programs, financial and technical support has been provided to farmers to promote the adoption of water-saving irrigation techniques and practices. Farm-level results show that transition to localized irrigation decreases irrigation water use, increases yields and profitability (cf. gross margin per ha), and improves water productivity. Despite an enabling policy landscape and positive transition impacts, surface irrigation is still maintained in the region and farmers are reluctant to change for many reasons (e.g. age and education level, unclear land tenure, financial and administrative difficulties). Efforts are still needed to train farmers on irrigation scheduling and on the use of smart irrigation techniques to save water. Further research is required to better

understand current bottlenecks in the irrigation transition process and design appropriate and context-specific transition governance strategies.

Keywords: *Sustainable agriculture, Irrigation, Multi-Level Perspective, Sustainability transitions, Multi-capital model.*

INTRODUCTION

The agricultural sector is one of the pillars of the Morocco's economic and social development. The indicators on employment, value added, food self-sufficiency and foreign trade show the decisive position occupied by this sector in the national economy (e.g. Doukkali et al., 2003; HCP, 2017; MAPMDREF, 2018). Agriculture plays a crucial role in rural employment. Rural population accounts for nearly 45% of Morocco's population. Direct employment in agriculture alone accounts for 80% of rural employment and almost 50% of employment at the national level. In some areas, agriculture accounts for between 80% and 100% of rural income (HCP, 2017). The agricultural sector still contributes significantly to the gross domestic product (GDP). Depending on annual climatic fluctuations, this contribution is between 12 and 24%. In retrospect, the share of agricultural value added in the GDP decreased from 23% on average in the 1960s to 17% in the 1990s. In absolute terms, however, the agricultural value added nearly doubled between the 1970s and the 1990s; from 10.5 billion to 19 billion in constant Moroccan Dirhams (MAD) of 1980. The irrigated agriculture sector, whose contribution to agricultural value added averages around 45%, is a real catalyst for the national economy and plays a key buffer role especially during drought periods (MAPMDREF, 2018). Food self-sufficiency is a fundamental objective of agricultural policy in Morocco. Thanks to irrigated agriculture, among others, the country covers a large part of its basic food needs, despite the continued increase in domestic demand and changing climate. Moreover, the agricultural sector plays an important role in national foreign trade. Agricultural exports account on average for nearly 18% of exports value. Irrigated agriculture provides, on average, 75% of agricultural exports (MAPMDREF, 2018). Despite all the above-mentioned positive impacts generated by agriculture in Morocco, this sector remains the highest consumer of the scarce water resources; about 80% of water resources in the country is used in irrigation (DRH, 2016). The inefficiency of irrigation water use is due to the dominance of surface irrigation. Conscious of the problem of the management and saving of water, the public authorities have invested considerably for a better valorisation of the country's limited water resources through the Green Morocco Plan (PMV) and the National Irrigation Water Saving Program (PNEEI), which have encouraged farmers to convert from surface irrigation to localized irrigation. In order to understand this ongoing transition, this article analyses the dynamics of conversion from surface irrigation to localized irrigation systems in Fez-Meknes region (north-eastern Morocco) through the Multi-Level Perspective on socio-technical transitions (MLP) and to assess the impacts of this transition with a multi-capital approach.

MATERIAL AND METHODS

The present paper is based on a combination of secondary and primary data. Primary data were collected through a questionnaire with 76 farmers to assess the impacts of the transition from surface to localized irrigation. Secondary data were obtained from different sources such as the Provincial Agricultural Department in Meknes and El Hajeb concerning all information related to the conversion from surface irrigation to localized irrigation within the region (areas, subsidy procedures, etc.).

The study was conducted in Fez-Meknes region located in the Saïss plain (Figure 1). This plain covers 220,000 ha and is characterized by a high agricultural potential due to the presence of fertile soils and medium-depth underground aquifers (Berriane, 2002). The provinces of Meknes and El Hajeb were chosen as a study site. This choice is justified, on the one hand, by the average annual decrease of the piezometric level of the groundwater estimated at 3 m (Faysse et al., 2012; Quarouch et al., 2014) explaining the huge water consumption. On the other hand, this choice is also based on the evolution of areas equipped with drip irrigation especially that many farmers have benefited from the subsidies to convert from surface to drip irrigation. The choice of the studied crops (i.e. onion, potato, peach/nectarine and plum) was made based on the dominant cropping pattern as well as on the high crop water requirements in the study area.

In the context of the present study, conversion from surface irrigation to localized irrigation is considered as an example of transition. The analysis encompasses transition dynamics and transition impacts. The analysis of transition dynamics was carried out according to the analytical framework, based on the Multi-Level Perspective, proposed by El Bilali and Probst (2017). For this case study, the niche is drip irrigation system, the dominant system (cf. regime) is surface irrigation system and the landscape encompasses all water policies developed by the public authorities. As regards the determination of the type of transition, reference is made to the method developed by Geels and Schot (2007) while for the identification of the current transition phase the S curve of transition suggested by Rotmans et al. (2001) was used.

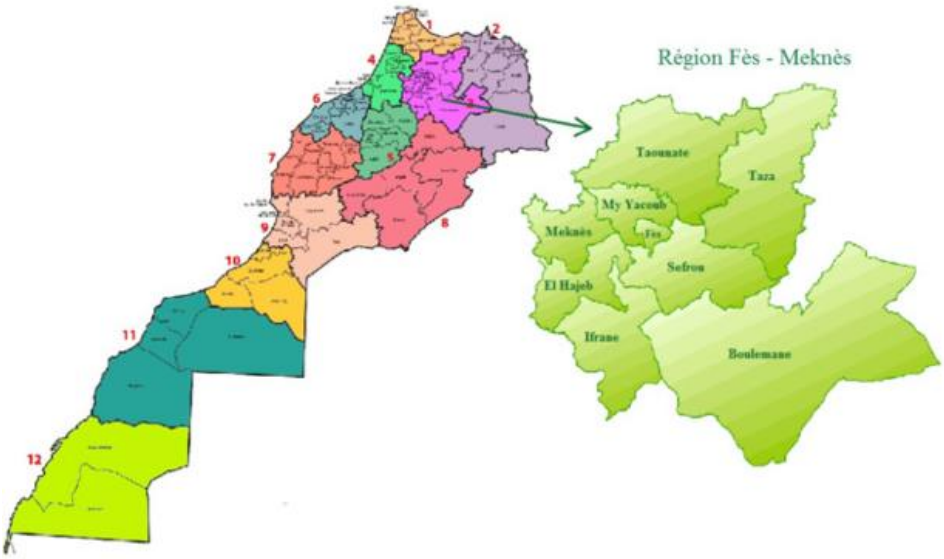

Figure 7. Location of Fez-Meknes region.

For the assessment of the impacts of conversion from surface system to drip irrigation system, a multi-capital model developed by Garrabé (2008) was followed to see the interaction between the different forms of economic, natural, human, social and institutional capitals (Garrabé et al., 2012). Given the problematic of the valuation of water resources, the paper zooms on the natural capital by considering three parameters namely irrigation water consumption, irrigation water use efficiency and water valuation (Bouaziz and Belabbes, 2002). Data on irrigation water consumption were collected through interviews with farmers and/or by making direct measurements within farms. The water use efficiency (WUE) was calculated dividing the obtained yield on the provided water quantity: *WUE = Yield (kg/ha) / Water used for irrigation (m^3/ha)*

The objective is to define how many kilograms can be produced by one cubic meter of water. The water valuation explains how much benefit a cubic meter of the provided water can generate in Moroccan dirhams (MAD).

The field study was carried out through a random and simple sampling of 76 agricultural farms sharing the two irrigation techniques, spread over 15 rural communes: Boufakrane (5 farms), Oued Jdid (4), M'haya (7), Majjate (8), Sidi Slimane Moul Al Kifane (4), Ait Ouallal (3), Ait Naamane (4), Sbaa Aiyoun (8), Ain Taoujdate (7), Ait Boubidmane (5), Bitit (6), Laqsir (4), Ait Yaazem (4), Jahjouh (4) and Ras Ijerri (3). The field study focused on the aspects relating to production systems, crop rotations, crop water consumption, irrigation frequency, operating expenses by crop, crop yields and prices by crop.

RESULTS AND DISCUSSION

The area of localized irrigation *niche* has been growing steadily in Fez-Meknes region for a decade (Figure 2), especially since 2008 with the launch of the Green Morocco Plan (PMV). The incentive scheme can cover up to all the costs of localized irrigation for farms of less than 5 ha and 80% for farms over 5 ha. In the context of PMV, the objective of area converted to localized irrigation is set at 550,000 ha by 2020. Compared to this objective, nearly 483,000 ha have already been achieved i.e. 88% of the target (MAPMDREF, 2018). As for *transition phase*, the S curve of transition proposed by Rotmans et al. (2001) suggests that irrigation transition in Fez-Meknes region has reached the acceleration / breakthrough phase. The period before the launch of PMV can be considered as pre-development phase while the launch of the Green Morocco Plan represents the moment of take-off. While Rotmans et al. (2001) considers that during the acceleration phase 'visible structural changes take place through an accumulation of socio-cultural, economic, ecological and institutional changes that react to each other', it seems that institutional/political changes have been predominant in the irrigation transition process and it is not clear whether the socio-cultural changes that took place are enough (in terms of speed and direction) to accommodate them. The pattern of transition shown in the curve is far from being typical as, surprisingly, the period of pre-development seems rather short. This – combined with the features of the acceleration phase described above – can have long-term implications in terms of the sustainability of transition as farmers had short time for learning about and adapting their farming system management to drip irrigation. At the end of the day, drip irrigation represents an innovation for farmers in the region, which implies that its introduction brings about some changes (cf. embedding processes) in the whole farm management system.

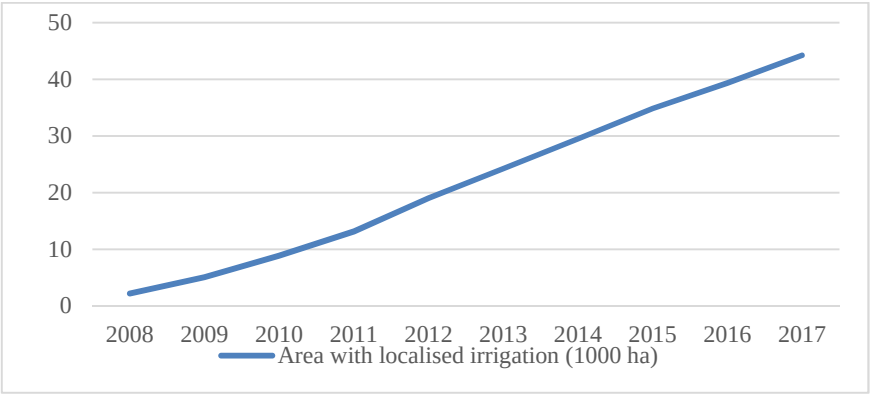

Figure 8. Evolution of cumulative area with drip irrigation in Fez-Meknes region from 2008 to 2016.

Source: Authors' elaboration based on data from the Provincial Agricultural Department in Meknes (2018).

Transition pathways suggested by Geels and Schot (2007) are derived mainly from sustainability transitions literature focused on energy and transportation sectors, which may suggest that they are not completely fit-for-purpose to describe transition processes in other sectors (e.g. agriculture, water). That being said, the pathway that seems more adapted to describe the conversion to drip irrigation is 'technological substitution'. In fact, public institutions in Morocco (cf. landscape) put forward a huge incentive system at a moment when the niche (i.e. drip irrigation) was sufficiently developed, the latter has broken through and replaced, to large extent, the existing regime (cf. surface irrigation). Drip irrigation is a technology that consists on the installation of an underground piping system and also apparent pipes equipped with water distributors (drippers). The water under pressure can be distributed all over the covered area within the farm and provided in the vicinity of the plant. The particularity of the system is the use of low flow rates and low water quantity with a high irrigation frequency leading to an important water saving, conditioned by a mastery of this technique. In contrary, surface irrigation is based on the land gravity, where the water can be distributed from the upstream (highest altitude point) to downstream (lower altitude point) within the farm leading to water losses by percolation and evaporation. Nevertheless, the pattern of transition accommodates also other transition pathways such as 'reconfiguration pathway'. In fact, it is worth nothing that drip irrigation innovation was adopted by farmers in Fez-Meknes region to solve local problems (cf. increasing water scarcity) and such adoption, subsequently, triggered further adjustments not only in irrigation systems and farm management but also in regional agriculture.

In the context of irrigation development in Morocco, irrigated land has grown from about 150,000 ha in 1960 to nearly 1.6 million ha in 2010 (Alloussi and Anbari, 2012). The socio-technical *landscape* in Morocco is largely favourable for irrigation transition. As part of PMV, the country considers adaptation to climate change a priority, particularly through water saving, with a target of 1.4 billion cubic meters of water savings per year. These savings would allow the extension of the irrigated area by 550,000 ha without increasing the irrigation water use amount (MAPMDREF, 2018). Water is at the heart of the transversal reforms of the Green Morocco Plan, through: developing means of mobilization of conventional and unconventional water resources; valuation of water resources allocated to irrigation; establishing a highly incentive pricing for water saving and valuation; promoting a policy of voluntary management of agricultural water demand through, inter alia, activation of a true water police, generalization of water-saving irrigation techniques. For that, various specific programs have been put in place (Boularbah et al., 2107):

- The National Irrigation Water Saving Program (PNEEI): It aims to convert 555,000 ha to localized irrigation over 15 years (2007 – 2022) with a budget of 37 billion MAD.
- Irrigation Extension Program: It aims to extend irrigated area in Morocco by 155,000 ha over 12 years (2008 – 2020) with a budget of 19.5 billion MAD.

- Public-Private Partnerships (PPP) in irrigation: They aim to improve the quality of irrigation services and to ensure the sustainability of irrigation infrastructure in irrigation schemes through the active participation of water users and the private sector.

Three major motivations are put forward to promote drip irrigation in Morocco: (i) labour saving and reduction of workload through irrigation system automation (drip irrigation monitoring requires less manpower and automation of watering of the different farm plots facilitates work organization); ii) improvement of agricultural products quality and quantity (this is ensured by the rationalization of the inputs of water and fertilizers and a better intra-plot distribution with consequent improvement of yields); and iii) the saving of water irrigation. Despite all its advantages, there is an incomplete transition as some farmers are still reluctant to transition to localized irrigation systems. Many farmers in the survey sample would like to convert to localized irrigation but various constraints hamper that. The principal ones relate to administrative complexity and bureaucracy, land tenure and financing. The problem of financing is mentioned as the main reason for the non-conversion. The farmers declare they had the intention of converting their irrigation system to localized irrigation, but the lack of financial means and the difficulty of obtaining credit from the suppliers of irrigation equipment, while being forced to anticipate almost 50% of the drip irrigation system cost, prevent them from realizing it. Some other farmers filed their grant applications but did not follow up them claiming that the procedure is complex and that obtaining the subsidy is not guaranteed as it is not released until after drip irrigation project implementation. Another problem mentioned by some farmers is that of land status due, among others, to the Islamic inheritance rules. They argue that since there is co-ownership, the realization of the conversion project requires the agreement of all the coheirs, which arises problems regarding the multiplicity of decision-makers and even of lack of trust. They state that the co-heirs do not want the farm to be entrusted, by proxy, to only one of them.

The analysis of *transition impacts* was performed at farm level and focused on the economics of natural capital (cf. valorisation of irrigation water). The two irrigation systems were compared by farm type between the different crops chosen for three parameters, namely irrigation water consumption, water use efficiency and irrigation water valuation (Table 1). The results of this comparison show that transition in the study area generates the following impacts: a decrease in irrigation water use by 36%, 46%, 59% and 61% for onion, potato, peach/nectarine and plum, respectively; a strong increase in the valuation of irrigation water by the different selected crops, by 208%, 151%, 83% and 431%, for onion, potato, peach/nectarine and plum, respectively. With regard to profitability, the shift to localized irrigation would allow an increase of yields of the studied crops of about 49% for onion, 29% for potato, 12% for peach/nectarine and 34% for plum. In terms of profitability, this transition would lead to an increase in the gross margin per hectare of the four crops, by 44% for onion, 23% for potato, 25% for peach/nectarine and 41% for plum.

Table 1. Parameters for irrigation water valuation by crop, irrigation system and farm category.

Parameter		Onion			Potato			Peach/Nectarine			Plum		
Irrigation water consumption (1000m^3/ ha)	FC	SF	MF	LF	SF	MF	LF	SF	MF	LF	SF	MF	LF
	SI	11.9	12.7	11.1	13.5	11.9	12.7	17.3	15.3	13.9	15.9	17.3	18.7
	DI	8.1	5.4	9	7.5	6.8	6	6.2	6.1	6.4	6.1	6.6	6.3
Water Use Efficiency (kg/m^3)	FC	SF	MF	LF	SF	MF	LF	SF	MF	LF	SF	MF	LF
	SI	3.03	3.3	4.1	2.01	2.6	2.9	1.04	1.3	1.9	1.07	1.2	1.2
	DI	6.7	11.1	7.8	4.9	5.9	7.5	3.2	3.9	4.4	2.9	4.8	4.8
Valuation of irrigation water (MAD/m^3)	FC	SF	MF	LF	SF	MF	LF	SF	MF	LF	SF	MF	LF
	SI	1.5	1.6	2.1	1.7	2.5	3.2	1.3	2.2	4	0.8	1.3	1.3
	DI	3.7	7.4	4.5	4.5	5.7	8.3	2.1	4.2	7.9	2.4	6.7	10.1

Legend:

- Farm Category (FC): SF: Small Farms with less than 5 ha of utilized agricultural area (UAA); MF: Medium-sized Farms with an UAA between 5 and 15 ha; LF: Large Farms with an UAA larger than 15 ha.
- Irrigation system: SI: Surface irrigation; DI: Drip Irrigation.

Source: Authors' elaboration based on field survey results.

CONCLUSIONS

This study confirms the crucial role played by public policies in sustainability transitions. In fact, agricultural and water saving policies (e.g. PMV, PNEEI) have, to a large extent, shaped the contours of irrigation transition in Morocco. Nevertheless, while public policies are necessary and justified (given the positive natural, social and economic impacts of irrigation transition), the present study also shows that they are insufficient. Despite massive investment of the country in conversion to localized irrigation, the transition is incomplete and one can talk of a 'transition-in-the-making'. In fact, surface irrigation still persists and the two irrigation systems coexist in Fez-Meknes region and, sometimes, even at the same farm. This might be due to the fact that the opportunities/benefits created by the landscape for the niche (i.e. drip irrigation) are insufficient to encourage farmers and overcome their resistance to convert their farms given the difficulties related to the necessary learning as well as the viability of drip irrigation and the high cost of its installation. Therefore, it seems that only an incentive system is not enough to bring about the necessary genuine irrigation transition in Morocco and the public institutions should move towards a combination of incentive system for the drip irrigation niche with more pressure on the regime (i.e. surface irrigation); the latter can be done by, among others, changes in irrigation water pricing and more stringent rules regarding the use of surface irrigation especially in water-scarce regions of the kingdom and/or where water resources (both surface and underground) are depleted.

To the best of our knowledge, this is the first study that analyses irrigation transition in Morocco using MLP. The originality of the study also lies in the combination of MLP and a multi-capital approach. In doing so, the present study

also addresses in an effective way the weakness of MLP regarding the impacts of transition. In fact, while MLP seems appropriate in analysing the dynamics of transition it falls short when it comes to the assessment of transition impacts.

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