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Making sense of on-going dynamics and innovations in oases and newly irrigated areas of North African arid regions: towards more sustainable development pathways

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Introduction

Irrigated agroecosystems in arid North African regions have undergone major transformations in recent decades. Among these systems, oases, often created centuries ago, were marked by well-structured social organisations for water and land management. Most of these oases used a three-level cultivation system, mainly date palms at the top, arboriculture in the middle and seasonal crops at the bottom (Veyrac-Ben Ahmed and Abdedayem, 2017). Water management and farming practices in these oases have undergone many changes (Moussaoui, 2021) along with profound socioeconomic changes, particularly due to the migration of oasis inhabitants (De Haas, 2006) and the development of tourism (Battesti, 2009). More generally, the effects of globalisation are clearly visible in the oases (Lavie and Marshall, 2017). These changes are often analysed through

the prism of the rupture versus the continuity of modes of production and lifestyle (Bouaziz *et al.*, 2018; Lavie and Marshall, 2017). Indeed, changes have been a source of development opportunities and have enabled the renewal of oases – disproving predictions of their collapse (Veyrac-Ben Ahmed and Abdedayem, 2017). However, change also implies risks, including unsustainable use of soil and water, declining biodiversity, and increasing social inequalities (Santoro, 2022).

Alongside the age-old oasis irrigation systems, newly irrigated areas began emerging from the 1980s in Morocco, Algeria and Tunisia (hereafter North Africa). They emerged from farmers' private initiatives or in the framework of public policies (Amichi *et al.*, 2020; Daoudi *et al.*, 2021; De Haas, 2006; Elder, 2022; Mekki *et al.*, 2013). Saharan agriculture "... has conquered new lands, has renewed its methods, and presents itself as a vast

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pioneer front, multiform and multi-local” (Côte, 2022). In many arid regions of North Africa, these newly irrigated areas, often termed extensions, are now much larger than traditional oases.

The two types of irrigated areas, the age-old ones and the new ones, are sometimes contrasted using dualities, such as “complex agrosystems” versus “monocropping” or “family farming” versus “investor-owned farming” (Veyrac-Ben Ahmed and Abdedayem, 2017). In practice, interactions between the two spaces can be intense. For instance, many of the farmers who invest in newly irrigated areas come from oases and reproduce water management and farming practices used in the oases (Hamamouche *et al.*, 2018).

Actors of North African arid regions have experimented a large set of innovations which also contributed to above-mentioned irrigated agroecosystem dynamics. The innovations included: 1) water use and management (e.g., groundwater recharge, reuse of treated waste water, drip irrigation, Naouri *et al.*, 2017); 2) farming practices (e.g., agro-ecology or organic practices) and agricultural value chains (e.g., certification, Benziouche, 2017); 3) new modes of governance and organisation of territories (e.g., local development organisations, new modes of intervention of public actors and donors, Hamamouche *et al.*, 2022).

There is a need to understand the dynamics of these irrigated agroecosystems, particularly because the diversity of emerging forms of agriculture blurs past typologies, and the pace of change remains unabated. There is also a need for a better understanding of the way agricultural innovation systems operate today, as the relations between public and private actors and access to information have evolved considerably in recent decades. The aim of this special issue is to contribute to understanding these changes, with special attention paid to the way actors of these agroecosystems describe them, formulate related problems and introduce innovations to face existing problems and to tap new opportunities. Some of the questions at the core of this issue are: How are the changes undergone by these spaces manifest and what are the socio-economic and agricultural trajectories

of the actors who bring them about? What are the new socio-economic, agricultural and spatial logics that are driving changes and innovations in these areas? How are productive resources (water, land, capital) exploited and managed in the different agroecosystems?

Most of the studies that led to the articles in this special issue were conducted in the framework of the Massire¹ research project (2019-2024) in Drâa Tafilalet Region in Morocco, Ghardaïa Region in Algeria, and Kebili and Medenine Regions in Tunisia. The aims of the Massire project are to: 1) identify, characterise and test innovations related to water governance, agricultural systems and rural development; 2) strengthen the capacities of stakeholders and exchange networks for the design and implementation of these innovations. Two studies reported in this special issue were implemented in the same regions but in different institutional settings. The study by Farolfi *et al.* (2022) was carried out as part of the project ‘Innovation and socio-economic development for a sustainable oasis’ (IDES) while the study by Saidani *et al.* (2022) was part of the Massire project and the Transformation to Groundwater Sustainability project.

Four topics

The articles in this special issue are organised in four topics: evolving agroecosystems, water use and governance, innovation and entrepreneurial systems, and emerging value chains.

Changing agroecosystems

Benmoussa *et al.* (2022) characterise the dynamics of irrigated systems based on palm groves in Kebili Region, Tunisia, where traditional oases have been three-layered, whereas, at the outset, the newly irrigated areas only had one layer comprised of the Deglet Noor date cultivar. The study shows that this typology no longer applies. Newly irrigated areas may contain higher crop diversity than expected and may be organised in two or layers like in the oases. In contrast, high crop diversity and the

¹ www.massire.net.

three layers were found to be less frequent than expected in traditional oases. Water availability and irrigation frequency emerge as key factors in the layout of irrigated areas in Kebili Region.

Mekki *et al.* (2022) assess changes in the agricultural landscape in the same Kebili Region. These authors also provide an overview of the socio-economic and environmental drivers of these changes, and analyse local actors' perceptions of these changes. The study highlights the need for contextualised analysis of the heterogeneous trajectories of extension areas to inform a much-needed multi-stakeholder dialogue on the future of the extensions.

Er-rayhany *et al.* (2022) describe the range of different farm profiles in newly irrigated areas in the Todgha Valley of Drâa Tafilalet Region, Morocco. Their paper identifies three types of farms. The first refers to small farms where people move to obtain housing and to look for new work opportunities on other farms. The second type is comprised of medium-sized farms where farmers seek to reproduce the three-layered crop production system used in traditional oases but where the fields are larger. The third type is comprised of large farms where investors practice capital-intensive agricultural production.

Sraïri and Naqash (2022) analyse the uses of available labour and capital in oases in the same Drâa-Tafilalet Region. This study points out that date palm cropping can exist in positive synergy with other farm activities in farming systems which combine crop production and livestock breeding. Date wastes and cereal straw are used to feed the livestock. The livestock supplies the farmers with manure, but also with milk and meat, whose sale enables the purchase of agricultural inputs. Farming practices that tap these positive synergies are time consuming, consequently labour availability is the key to fostering a circular economy.

Water use and governance

Farolfi *et al.* (2022) describe the sustainability concerns currently facing traditional oases in Kebili Region, mainly due to increasing difficulty in accessing irrigation water. This situation requires alternative water management ap-

proaches in which local actors collaborate and contribute to the design of new rules. Farmers in the Jemna oasis are clearly aware of the limited availability and poor quality of the groundwater resource but do not believe these problems cause conflict among farmers. Rather, they consider that collaboration among farmers will be more effective in solving possible conflicts and ensuring better water management in the oasis than rules and regulations issued by existing organisations. These observations have important implications for policy-making, as the farmers' willingness to collaborate is crucial for a new approach to water management in oases.

Saidani *et al.* (2022) analyse the practices used by farmers located in traditional oases and in the extension areas of the M'zab Valley in Ghardaïa Region, Algeria, to secure access to irrigation water. Farmers apply centuries-old know-how from the traditional oases to install devices to facilitate groundwater recharge in the extensions. Reinventing circular practices in these agricultural extensions will enable more environmentally sustainable forms of agriculture.

Innovation systems and entrepreneurial systems

Ould Rebai *et al.* (2022) report on the diffusion of a low-cost artisanal pivot irrigation technique from the Suf Valley, Algeria, to other Saharan regions and even to Saudi Arabia and Sudan. The diffusion of the pivot technique was enabled by extending the innovation system to trusted innovation intermediaries in new settings. These intermediaries played an active role in adapting the technology and provide advice and maintenance services to farmers. However, manufacturers maintain tight control over production and after-sales services in the new settings. This model allows the manufacturers to secure intellectual property and maintain a monopoly.

Oulmane *et al.* (2022) analyse how the innovation system has influenced the development of the dairy sector in Ghardaïa Region, Algeria. Market restructuring and farmers' organisations are the main factors which have a positive influence on the dairy sector. However, several factors are obstacles to the functioning of the in-

novation system in this sector, in particular lobbying by the dairies and the asymmetry of power between dairy farmers and agrifood companies, lack of collaboration and interaction between actors, lack of coordinated knowledge development, and lack of formal financing mechanisms to invest in livestock.

Hanafi *et al.* (2022) study to what extent projects funded with the support of international cooperation have built the capacities of actors involved in local entrepreneurial “ecosystems” in Kebili and Medenine Regions, Tunisia. These projects generally involve actions based on the existing ecosystems that are implemented by public actors responsible for supporting entrepreneurship. However, they include few actions designed to build the capacities of these actors, to evaluate the functioning of entrepreneurial ecosystems, and to promote coordination between these projects.

Emerging value chains

Emerging value chains are considered a promising way to foster local development and sustainability of agroecosystems in arid North African regions. Saffron production has been relaunched in Algeria in the last decade and the article by Benmihoub *et al.* (2022) analyses the emerging saffron value chain in Ghardaïa Region. This local saffron value chain has several strengths, including its potential profitability and the quality of the product, and is capable of grasping opportunities, e.g., the growing national demand for healthy natural products. However, its performance is limited by several weaknesses (e.g. producers’ skills, marketing) and threats (fraud or counterfeiting related to imported saffron), mainly related to the institutional deficiencies.

Koussani *et al.* (2022) describe the characteristics of and challenges to expansion of the production and marketing of Zarazi table olives in Medenine Region, Tunisia. The olives are characterised by well-defined traditional production and processing but are almost only consumed locally, due mainly to the lack of market outlets. So far, local inhabitants and development actors have paid little attention to this particular

product. Workshops organised in the area helped shed light on the potential of this value chain and enabled the identification of possible actions to promote it.

Lessons learned

Increased diversity among – not necessarily within – farming systems

Intensive production of high-value agricultural goods has emerged in all the study regions. For instance, this is the case of Mejhoul dates and watermelons in Drâa Tafilalet Region, dairy farming and maize in Ghardaïa Region, and Deglet Noor dates in Kebili Region. The impact of the increased production of high-value crops on the diversification of farming systems is mixed. In Drâa Tafilalet Region, the expansion of watermelon cultivation led to a decrease in crop diversity and in livestock breeding (Sraïri and Naqash, 2022). Conversely, in Kebili Region, water availability is a major factor enabling crop diversity, which may be higher in extensions than in traditional oases (Benmoussa *et al.*, 2022). In extension areas in Drâa Tafilalet Region and in those located in the periphery of traditional oases in Ghardaïa Region, some farmers replicate the logics of three-layer cropping and are aware of the link between cropping and livestock breeding. The articles in this special issue confirm that the distinction between traditional oases, characterised by three layers of production and livestock breeding on the one hand, and extension areas focusing on monoculture on the other hand, is no longer applicable (Hamamouche *et al.*, 2018; Peano *et al.*, 2021).

The interactions between the components of complex irrigated farming systems in arid North African regions are not yet well understood. For instance, this is the case of how irrigation water supplied to palm trees also benefits crops growing below the trees, or the agronomic and economic impacts of the use of manure. In order to characterise existing farming systems and possibly inform a discussion between actors about their respective functioning and performance, more detailed research is needed on the interac-

tions between the components of these farming systems, in terms of biological processes, water use, labour requirements, and economic values.

Water management from farm to socio-ecosystem level

The articles of this special issue underline the variety of farm level innovations implemented to enable a sufficient supply of irrigation water. Farms located in extensions adapt the centuries-old practices used in traditional oases to increase their access to water, e.g. digging canals to collect flood water for irrigation in Drâa Tafilalet Region (Er-rayhany *et al.*, 2022), or systems to enhance groundwater recharge in Ghardaïa Region (Saidani *et al.*, 2022). What is more, a series of innovations has been developed to enhance the efficiency of irrigation practices at farm level: drip irrigation is now widespread in the study regions in all three countries, low-cost irrigation pivots are widely used in Ghardaïa Region, and solar panels are now the main source of energy for the irrigation of palm groves in extension areas of Kebili Region.

Farmers using irrigated agroecosystems in North Africa have introduced many innovations to get sufficient irrigation water based on both new farming practices and on different forms of agreements between water providers and irrigators (Daoudi *et al.*, 2017). However, these initiatives have not been matched by institutional innovations for the management of water resources at regional level (Mekki *et al.*, 2022). Groundwater depletion patterns have emerged in Kebili and Todgha Regions (Er-rayhany *et al.*, 2022; Mekki *et al.*, 2022). Stakeholders, including farmers, acknowledge the need for rules to manage groundwater resources, yet discussions have yet to take place (Farolfi *et al.*, 2022; Mekki *et al.*, 2022).

A promising yet fragile future for alternative value chains

High-profile agricultural value chains have become major pillars of local economies, a good example being the Deglet Noor value chain in Kebili Region. However, these value chains are showing signs of vulnerability. In several ar-

as, value chains for water-intensive crops have to cope with increasing groundwater depletion patterns. Moreover, some value chains, including dairy farming in Ghardaïa Region, require continuous support from the state to function, and are vulnerable to a possible decrease in state support in the future.

Other agricultural value chains may be better suited to the local environment, have less impact on it, and could become levers for more sustainable development. For instance, saffron production is well suited to the climate of Ghardaïa Region and does not require much water (Benmihoub *et al.*, 2022). Saffron production in Ghardaïa Region and table olives in Medenine Region are also of interest because they can be produced by local inhabitants who have limited access to land, capital and water, which is the case of many women and young people in arid regions in North Africa. However, these alternative value chains are not “on the radar” of mainstream public policies, which continue to favour dominant value chains. Policies are required to facilitate the development of such alternative value chains, in particular to promote producer organisations, product certification, and to facilitate access to markets. Yet such support has to be provided in a way that fosters the autonomy of the actors of these value chains.

Innovations based on active but informal cooperation between actors

The studies reported in this special issue unveil dynamic innovation systems targeting farm production techniques and agricultural value chains. These innovation systems benefit from strong connections between actors in arid areas and other actors located in other northern regions of North African countries. These connections concern the continuous development and testing of innovations and the transfer of the resulting innovations *per se*, e.g. irrigation pivots in Algeria. However, these innovation systems are not impervious to power imbalances, for instance milk prices in Ghardaïa Region (Oulmane *et al.*, 2022) or the diffusion of know-how to manufacture irrigation pivots in Algeria (Ould Rebai *et al.*, 2022). Some of these innovations could be components of pathways to-

wards more sustainable agricultural development; for instance this could be the case of artificial water recharge systems in Ghardaïa Region, provided their implementation is part of a broad catchment level approach (Saidani *et al.*, 2022).

The articles in this special issue report on innovations developed by private actors, sometimes with limited involvement of scientific research institutes. This was the case of the development of irrigation pivots in Algeria. The innovation capacities of private actors are thus frequently not visible to the public administration. In a similar way, actors of these regions have been able to cope with hazards, such as the Covid-19 crisis (Ftouhi *et al.*, 2021). However, these resilience capacities are based solely on their own means and their collective or community initiatives. The Covid-19 crisis has led citizens to question the role that the state should play to help them cope with shocks. Despite these proven capacities, involvement of citizens in public policy design is still very limited. In the four regions studied in this special issue, local development associations are *de facto* active in defining and implementing development activities at the local level but are not acknowledged as fully-fledged partners for policy design and implementation by public authorities (Hamamouche *et al.*, 2022).

Conclusion

The development and transformation of irrigated agroecosystems in arid North African regions have enabled impressive economic growth in recent decades. However many sustainability issues are emerging: most remain unanswered and some (e.g., the way solar energy can lead to inefficient irrigation practices) have not even been addressed at the time of writing. There is a need to strengthen dialogue and cooperation between public and private actors to build a shared vision of the current situation and of ways to address these issues. Such dialogue has to involve the actors of these regions, but also actors at a higher level to ensure changes in public policies. Such dialogue and cooperation can promote the resilience of local territories on the long term.

The Massire project supports multi-actor processes to assess the implementation and possible impacts of a series of innovations, which usually have interrelated technical, economic and social dimensions. These innovations include new techniques to collect and use water, promising value chains, and observatories of regional changes driven by local actors. The active participation of local actors in these processes underlines their interest in collectively “making sense” of on-going dynamics in irrigated agroecosystems and of existing and potential innovations, in order to build more sustainable development pathways.

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