NEW MEDIT

CIHEAM BARI

MEDITERRANEAN JOURNAL OF ECONOMICS, AGRICULTURE AND ENVIRONMENT

SPECIAL ISSUE / SEPTEMBER 2021

SPECIAL ISSUE

Innovation and Sustainability of Agri-Food System in the Mediterranean Area

New Medit 2021 / Issue n. 3

Bononia University Press

ISSN: 1594-5685
www.newmedit.iamb.it


CIHEAM
BARI

NEW MEDIT

MEDITERRANEAN JOURNAL OF ECONOMICS, AGRICULTURE AND ENVIRONMENT

SPECIAL ISSUE / SEPTEMBER 2021

Innovation and Sustainability of Agri-Food System in the Mediterranean Area

New Medit 2021 / Issue n. 3

Editor-in-chief
Maurizio Raeli

Managing Editor
Giulio Malorgio

Institutional Relations Manager
Debora Degl'Innocenti

Editorial office
Bononia University Press
Via U. Foscolo, 7
40123 Bologna (Italy)
tel.: +39 051 232882
fax: +39 051 221019
email: newmedit@iamb.it

Paper submission
http://www.newmedit.iamb.it

Publisher
Bononia University Press
Via U. Foscolo, 7
40123 Bologna (Italy)
tel.: +39 051 232882
fax: +39 051 221019
email: comunicazione@buponline.com

Subscription rate
Print: Italy: € 40; Foreign: € 90.

Subscription office
ordini@buponline.com

Abstract and Index citation
NEW MEDIT is indexed in: SCOPUS, EBSCO, ISI Web Science, CAB Abstracts, EconLit, AGRIS/FAO database

Web page
http://www.newmedit.iamb.it

ISBN: 978-88-6923-859-8

ISSN: 1594-5685

ISSN online: 2611-1128

Graphic Layout
DoppioClickArt – San Lazzaro (BO)

Cover design
Debora Degl'Innocenti

Registrazione
Tribunale Ordinario di Bari, n. 1546 del 4/1/2002

Direttore Responsabile
Giulio Malorgio

NEW MEDIT è associato alla

Innovation in North African agriculture and food

Tarek Ben Hassen*, Hamid El Bilali**

DOI: 10.30682/nm2103k
JEL codes: O3, O13, Q01, Q1

Abstract

Innovation plays an essential role in addressing the interlinked environmental, social, and economic challenges facing the agri-food sectors in the North Africa region. This systematic review analyses the state of research on innovation in North African agri-food sector and investigates whether sustainability is addressed in the research strand. The analysis shows an increasing interest in the research field, although many publications are authored by scholars based in institutions outside North Africa. Most of the selected documents deal with crops and the production stage of the food chain. The focus is generally on technical innovations while social, organizational, and marketing ones are overlooked. There are growing attempts to connect innovation to sustainability and sustainable development by moving towards the concept of 'sustainable innovation'. Factors hindering agri-food innovation relate to policy, research, institutional environment, extension, and human capital. The promotion of innovation in the North African agri-food sector is crucial to unlock the sector's potential and improve its competiveness, resilience, and sustainability.

Keywords*: Agri-food, Maghreb, North Africa, Product innovation, Process innovation, Organisational innovation, Marketing innovation, Sustainable innovation, Sustainability.*

1. Introduction

Innovation is rather an ambivalent term with different understandings (Shaver, 2016). Joseph Alois Schumpeter (1934, 1942) is widely considered the first scholar to feature innovation as a central driver of economic development. Since then, the field has evolved dramatically with a proliferation of innovation definitions (Table 1). Menrad and Feigl (2007) argue that innovation refers to the production, diffusion, and translation of knowledge into new products, techniques, and services. Different categorisations of innovation exist in the literature. Indeed, Garcia and Calantone (2002) found 15 different ways of categorizing innovation. The variations in the use of the term 'innovation' depend on, inter alia, where the innovation is located in the value chain (e.g. product, process or organizational), the novelty of the knowledge underlying it, and/or the extent of its economic/market impact (Twomey and Gaziulusoy, 2014). Stummer *et al.* (2010) suggest that innovations can be categorized according to innovation type (product, process, service, market), change scope (incremental, radical, reapplied), dimension (objective, subjective), or innovation development way (closed or open). The OECD and Eurostat (2005) distinguish between product, process, marketing, and organizational innovations. In-

* Department of International Affairs, College of Arts and Science, Qatar University, Doha, Qatar.
** International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM - Bari), Valenzano (Bari), Italy.
Corresponding author: thassen@qu.edu.qa

Table 1 - Some definitions of innovation.

Definition of innovation	*Source*
The implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations (p. 46)	OECD and Eurostat, 2005
New ways of doing things. This includes not only science and technology but – crucially – the related array of new ideas, institutions, practices, behaviors and social relations that shape scientific and technological patterns, purposes, applications and outcomes (p. 1)	STEPS Centre, 2010
Innovation is the creation of better or more effective products, processes, services, technologies, or ideas that are accepted by markets, governments, and society. Innovation differs from invention in that innovation refers to the use of a new idea or method, whereas invention refers more directly to the creation of the idea or method itself (p. 62)	Sterrenberg *et al.*, 2013

novations in the agriculture and food sectors can be classified using the same categories (Avermaete *et al.*, 2004; Avolio *et al.*, 2014).

A richer and more nuanced picture of innovation has emerged over the last decades (Smith *et al.*, 2010; Twomey and Gaziulusoy, 2014). Indeed, there has been a shift from a research-centered innovation concept to innovation due to interactions among several actors and stakeholders in an innovation system (Hekkert *et al.*, 2007; World Bank, 2006). Agricultural Innovation System (AIS) concept emerged in response to shortcomings of linear technology transfer (Röling, 2009). It highlights that multiple sub-systems within agriculture (e.g. education and training, extension, research, public institutions, farmers and their groups, donors) are crucial in agricultural innovation (World Bank, 2012). Indeed, AIS is characterized by dynamic interactions among different private, civil society and academic actors involved in creating, disseminating, adapting, and using knowledge (IICA, 2014; OECD, 2013; World Bank, 2006). Meanwhile, the main functions of the Agricultural Knowledge and Information System (AKIS) are fostering mutual learning and encouraging knowledge sharing and use (FAO and World Bank, 2000). The AKIS concept has evolved to 'Agricultural Knowledge and Innovation System' as it was opened up to more innovation support (Klerkx *et al.*, 2009).

Innovation is widely recognized as a driver of sustainable development (European Political Strategy Centre, 2016; Leach *et al.*, 2012; STEPS Centre, 2010). Indeed, innovation, science, and technology (IST) can play an essential role in addressing the interlinked environmental, social, and economic challenges facing humanity (STEPS Centre, 2010; United Nations, 2012a). Innovation is seen as a route to economic growth and finding practical solutions to real problems (STEPS Centre, 2010). The contribution of innovation to sustainable development and sustainability is emphasized in several global strategic and policy documents (United Nations, 1992, 2002, 2012b; WCED, 1987), including the 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs) (United Nations, 2015).

Over the last decades, innovation has become central also in the debate on the nexus between agriculture and sustainability (Ben Hassen and El Bilali, 2020; EIP-AGRI, 2013; El Bilali, 2018a, 2018b, 2019a; FAO, 2012, 2013; Global Harvest Initiative, 2016; IPES-Food, 2015; Royal Society, 2009). It is widely admitted that the transition to sustainable agriculture and food systems requires 'sustainable innovation'. In this regard, different models of sustainability-oriented innovation (e.g. ecological innovation, eco-innovation, environmental innovation, frugal innovation, responsible innovation, open innovation, green innovation, inclusive innovation, social innovation) have been promoted (Charter and Clark, 2007; El Bilali, 2018b; Network for Business Sustainability, 2012; STEPS Centre, 2010). Innovation is considered crucial to ensure agriculture development, adapt to climate change, and achieve food security (European Com-

mission, 2016; HLPE, 2019; IAASTD, 2009; IICA, 2014; Royal Society, 2009; UNCTAD, 2017; World Bank, 2007). Innovation can also improve food system resilience and resource use efficiency in agriculture (HLPE, 2017).

Innovation in the agriculture and food sectors is particularly crucial for those countries where agriculture is still relevant for its contribution to the national gross domestic product (GDP) and employment and/or face food insecurity and malnutrition problems. This is the case of the countries of North Africa (viz. Algeria, Egypt, Libya, Morocco, and Tunisia). Data from the World Bank (2021a) show that the contribution of agriculture, forestry, and fishing to GDP is 12.4% in Algeria, 11.0% in Egypt, 1.8% in Libya, 12.2% in Morocco, and 10.4% in Tunisia. Meanwhile, employment in agriculture ranges from 34% in Morocco to 10% in Algeria, 23% in Egypt, 19% in Libya, and 13% in Tunisia (World Bank, 2021b). Data from the State of Food Security and Nutrition in the World 2020 (FAO *et al.*, 2020) shows that, during the period 2017-2019, the prevalence of moderate or severe food insecurity among the total population was 17.6% in Algeria, 34.2% in Egypt, 35.9% in Libya, 25.9% in Morocco, and 20.0% in Tunisia. However, the North African countries still have a low propensity for innovation (Radwan, 2018). Indeed, the most recent edition of the Global Innovation Index (Cornell University *et al.*, 2020) shows that these countries have low scores and rankings: Algeria scored 19.48 (max. 100) and ranked 121 (out of 131); Egypt, 24.23/100 and 96/131; Morocco, 28.97/100 and 75/131; and Tunisia, 38.98/100 and 78/131. In this context, there has been so far no comprehensive analysis of how innovation in the regional agri-food sector is addressed in the scholarly literature. To fill this gap, the present systematic review analyses the state of research on innovation in agriculture and food in North African countries. The paper also investigates whether and how sustainability is addressed in the research strand. It combines bibliographical and topical analyses of the scholarly literature.

2. Methods

The article draws upon a systematic review of all documents indexed in the Web of Science (WoS) and follows the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Moher *et al.*, 2009). A search was carried out on December 30, 2020, using the following search query: *(innovation OR*

Table 2 - Systematic review: process of eligible documents selection.

Selection steps	*Number of selected documents*	*Number of excluded documents and exclusion reasons*
Initial search on WoS	132	--
Screening of records based on titles	132	10 documents excluded because they deal with countries outside North Africa e.g. Ethiopia, Greece, Iran, Israel, Netherlands, Portugal, South Africa, Spain
Screening of records based on abstracts	122	37 documents excluded: 2 documents that do not deal with North Africa / North African countries 22 documents that do not address innovation 12 documents that do not deal with agriculture and/or food 1 document without abstract
Scrutiny of full-texts	85	47 documents excluded: 5 documents that do not address North Africa 35 documents that don't deal with innovation 3 documents that do not address agriculture and/or food 4 reviews
Inclusion in the systematic review	38	--

innovative) AND (agriculture OR agro OR horticulture OR food OR crop OR vegetable OR fruit OR cereal OR livestock OR animal OR fish) AND ("North Africa" OR "South* Mediterranean" OR Maghreb OR "Morocc*" OR Algeria OR Tunisia OR Libya OR Egypt)*. The literature search yielded 132 documents. The selection of the eligible documents was informed by El Bilali (2019b, 2020) and El Bilali and Ben Hassen (2020). Table 2 describes the steps of the selection process. In particular, the eligibility of documents included in the review was checked based on three different criteria: (i) geographical coverage (viz. the selected document deals with one or more countries in North Africa); thematic focus (viz. the selected document addresses both innovation *and* agri-food sector); and document type (viz. the selected document is a journal article, a book chapter or a conference paper; letters to editors, commentaries and/or notes were not included). Only documents that meet all the above criteria were included in the systematic review.

Titles screening allowed excluding 10 documents that do not refer to North Africa; documents covering wider geographical areas (e.g. Near East and North Africa, Mediterranean, Africa) were kept for further analysis. Other 37 documents were discarded following abstracts scrutiny as they do not meet at least one of the inclusion criteria. Furthermore, 47 articles were excluded after the analysis of full-texts. Articles that report only the results of research activities without any explicit reference to innovation were discarded. Since the paper deals with research on innovation in the agri-food sector, further 4 review articles were excluded at this step. Hence, only 38 documents were selected (Table 3). The selected documents included 34 articles and 4 conference papers.

Both bibliographical and topical analyses were addressed in the systematic review of the scholarly literature on innovation in the North African agri-food sector (Table 4).

As with any systematic review, the present article has some limitations. Indeed, the results (cf. selected documents) are affected by the initial search and the selection process. First, the choice of Web of Science as a search database implies that only 'quality' scholarly literature was included in the systematic review. Therefore, the pieces of research published in journals that are not indexed in WoS (e.g. in general, only

Table 3 - List of the selected documents.

Publication year	*Number of documents*	*References list*
2020	14	Abbassy and Ead, 2020; Ameur *et al.*, 2020; Badraoui *et al.*, 2020; Ben Rejeb *et al.*, 2020; Bouissil *et al.*, 2020; Bouzid *et al.*, 2020; Dolinska *et al.*, 2020; Froebrich *et al.*, 2020; Ghareeb and Seif, 2020; Hamad *et al.*, 2020; Jovanovic *et al.*, 2020; Naouri *et al.*, 2020; Souli *et al.*, 2020; Zahran *et al.*, 2020
2019	3	Badaoui *et al.*, 2019; Dhraief *et al.*, 2019; Le and Dhehibi, 2019
2018	5	Braiki *et al.*, 2018; Fouad *et al.*, 2018; Narvarte *et al.*, 2018; Singh, 2018; Stilt, 2018
2017	2	Dolinska, 2017; Difallah *et al.*, 2017
2016	3	Callieris *et al.*, 2016; Daoudi and Lejars, 2016; Khaled and Segni, 2016
2015	2	Labbaci *et al.*, 2015; Naouri *et al.*, 2015
2013	2	Ameur *et al.*, 2013; Lin *et al.*, 2013
2012	1	Salhi *et al.*, 2012
2010	1	Le Gal *et al.*, 2010
2009	2	Aziza *et al.*, 2009; Kuper *et al.*, 2009
2008	2	Chisenga, 2008; King, 2008
2007	1	Codron *et al.*, 2007

Table 4 - Analyses performed in the systematic review.

Item	*Description*
Bibliographical analysis	Bibliometrics: sources/journals, research areas, authors, institutions/ affiliations. Research geography: North African countries considered
Topical analysis	Agriculture subsectors: crop production (and main crops addressed), animal production and fisheries
	Stages of the food chain (viz. production, processing, distribution/ retail/ marketing, consumption)
	Types of innovation
	Innovation and sustainability: whether sustainability is addressed and how
	Barriers to and proposals for fostering innovation in the agri-food sector

journals with impact factor, except those indexed in Emerging Sources Citation Index, which are under evaluation for the attribution of impact factor), as well as grey literature (e.g. reports), are not included in this article. Second, the results of the search are also affected by the choice of the search terms, although different synonyms were used to broaden the initial screening basis. Third, the selection of articles is affected by the researchers' background and their understanding of innovation, which is complicated by the ambivalence of the concept, especially in the agri-food sector.

3. Results and discussion

3.1. *Bibliographical metrics and research geography*

Table 5 shows the bibliometrics of the selected documents (e.g. journals, research areas, authors, affiliation organizations, countries). The analysis of the selected documents suggests increasing interest in research on innovation in the North African agri-food sector. Indeed, the *annual output* of articles in the considered period (2007-2020) ranges from one in 2007 to 14 in 2020. However, the average annual output in the period 2007-2020 is less than 3 documents.

Regarding *sources*, the bibliographical results show that the most important publication outlets are *Cahiers Agricultures* (6 documents), *Irrigation and Drainage* (4 documents), and *New Medit* (4 documents). Nevertheless, the findings of research on innovation in the North Africa agri-food sector were published in 25 other journals and proceedings. It comes as no surprise that half of the selected documents can be related to the *research area* of agriculture (19 documents). Other prominent research areas include environmental sciences – ecology (7 documents), science technology (5 documents), and water resources (5 documents). However, the selected documents can be categorized into 10 other research areas (e.g. engineering, chemistry, business economics, computer science, information science), which shows that the research field spans multiple disciplines.

The bibliographical analysis shows that the most productive, prominent *author* is Marcel Kuper (4 documents). Nevertheless, the fact that most of the authors have only one article might imply that there is no specialization in the research field, which, in turn, might be due to the lack of long-term, structural programs, and investments. The analysis of *affiliation countries* suggests that, surprisingly, the most active country in the research field is France (18 documents). Affiliation North African countries include Algeria (10 documents), Morocco (10 documents), Tunisia (9 documents), and Egypt (5 documents), while none of the selected documents is authored by researchers based in Libya. A large share of the selected documents is authored by researchers based outside North Africa; either in Sub-Saharan Africa (e.g. Ethiopia, Ghana, Mali, Mozambique, South Africa, Tanzania), Asia (e.g. China, India, Jordan, Lebanon, Saudi Arabia, Sri Lanka), Europe (e.g.

Table 5 - Bibliographical metrics: top ten journals, research areas, authors, institutions, and countries.

Journals (a)*	*Research areas (b*)*	*Authors (c*)*	*Organizations (d*)*	*Countries (e*)*
Cahiers Agricultures (6)	Agriculture (19)	Kuper, M. (4)	CIRAD (13)	France (18)
Irrigation and Drainage (4)	Environmental Sciences - Ecology (7)	Bouarfa, S. (3)	INRAE (8)	Algeria (10)
New Medit (4)	Science Technology (5)	Dolinska, A. (3)	AGROPARISTECH (6)	Morocco (10)
Agricultural Systems (2)	Water Resources (5)	Habtu, S. (3)	Université de Carthage (6)	Tunisia (9)
Sustainability (2)	Engineering (4)	Hartani, T. (3)	LISODE (5)	Egypt (5)
	Chemistry (3)	Zairi, A. (3)	CGIAR (4)	Spain (4)
	Energy - Fuels (3)		Université de Montpellier (4)	England (3)
	Business Economics (2)		Centre National de la Recherche Scientifique - CNRS (3)	Ethiopia (3)
	Computer Science (2)		IAV HASSAN II; Mekelle University; Wageningen University Research (3)	Netherlands; Germany; Ghana; Mozambique; Saudi Arabia; South Africa; USA (2)

** Figures in brackets refer to the number of documents by journal (a), research area (b), author (c), affiliation organisation (d), or affiliation country/territory (e).*

England, Germany, Greece, Italy, Netherlands, Spain) or North America (Canada, USA). This might indicate the weakness of the research systems in North Africa and/or lack of attention to research on innovation in the agri-food sector in the region. Meanwhile, the most prominent organizations in the research field are based outside North Africa, namely CIRAD, INRAE, and AGROPARISTECH, based in France. Nevertheless, many domestic organizations are active in research on innovation in the agri-food sector (e.g. Université de Carthage – Tunisia; IAV Hassan II – Morocco; Ecole Nationale Polytechnique Algeria). Also, some regional organizations, such as the International Center for Agricultural Research in the Dry Areas (ICARDA), are active in the research field.

The analysis of the *geography of research* shows that not the same attention is dedicated to all North African countries (Table 6). Indeed, the highest number of the selected studies was performed in Algeria, followed by Tunisia, then Egypt, and Morocco. This is rather surprising considering that Egypt is the most populous country in the region. However, these results are in line with the Global Innovation Index - GII (Cornell University *et al.*, 2020) where Morocco (75/131) and Tunisia (78/131) have better rankings than Egypt (96/131), while they might suggest that Algeria (rank 121/131 in GII) outperforms in the agri-food sector. In the meantime, no study was performed in Libya, which indicates a considerable research gap in the country. This result might be due to the low importance of the agri-food sector in the national GDP and the country's political instability. Moreover, there is no single article that addresses innovation in the agri-food sector in the whole North Africa, but there are some multi-country studies. For instance, Ameur *et al.* (2020) map innovative agro-ecological practices in the irrigated plains of Algeria, Morocco, and Tunisia. Meanwhile, Kuper *et al.* (2009) use a learning-oriented and network-based approach to analyze irrigation

Table 6 - North African countries where the research was performed.

Country or region (number of articles)	*References*
Algeria (8)	Badaoui *et al.*, 2019; Bouzid *et al.*, 2020; Daoudi and Lejars, 2016; Difallah *et al.*, 2017; Khaled and Segni, 2016; Naouri *et al.*, 2015; Naouri *et al.*, 2020; Salhi *et al.*, 2012
Egypt (6)	Ghareeb and Seif, 2020; Hamad *et al.*, 2020; Abbassy and Ead, 2020; Le and Dhehibi, 2019; Stilt, 2018; Zahran *et al.*, 2020
Morocco (6)	Ameur *et al.*, 2013; Badraoui *et al.*, 2020; Bouissil *et al.*, 2020; Codron *et al.*, 2007; Fouad *et al.*, 2018; Labbaci *et al.*, 2015
Tunisia (7)	Aziza *et al.*, 2009; Ben Rejeb *et al.*, 2020; Braiki *et al.*, 2018; Callieris *et al.*, 2016; Dhraief *et al.*, 2019; Dolinska, 2017; Souli *et al.*, 2020
North Africa* (2)	Ameur *et al.*, 2020; Kuper *et al.*, 2009
Africa** (3)	Dolinska *et al.*, 2020; Froebrich *et al.*, 2020; Jovanovic *et al.*, 2020
Global*** (6)	Chisenga, 2008; Le Gal *et al.*, 2010; King, 2008; Lin *et al.*, 2013; Narvarte *et al.*, 2018; Singh, 2018

** This category includes documents dealing with at least two countries from North Africa.*
*** This category includes documents addressing at least a North African country and another one from Sub-Saharan Africa.*
*** This category includes documents dealing with at least another country outside Africa.*

management approaches in the Maghreb (viz. Algeria, Morocco and Tunisia). Furthermore, there are some Africa-wide studies; for example, Dolinska *et al.* (2020) analyse lessons learnt from implementing the Community of Practice (CoP) concept, with the active involvement of farmers, in innovation platforms in Tunisia, Mozambique and Ethiopia. Similarly, Jovanovic *et al.* (2020) provides a comparative analysis of the impacts of different innovative practices on crop yield and productivity in Ethiopia, South Africa and Tunisia. Froebrich *et al.* (2020) analyse innovation in irrigated smallholder agriculture in five African countries (viz. Ethiopia, Mali, Mozambique, South Africa and Tunisia). Further articles, have a more global perspective. For instance, Singh (2018) sheds light on the state and prospects of Indian innovative technologies into the African agriculture.

3.2. *Agriculture subsectors and food chain stages*

The analysis of the selected literature shows that it is biased towards crop production. Indeed, out of the selected documents, only 6 deal with animal production (Aziza *et al.*, 2009; Dhraief *et al.*, 2019; Dolinska, 2017; Hamad *et al.*, 2020; Le Gal *et al.*, 2010; Stilt, 2018), and one with fisheries (Fouad *et al.*, 2018). As for crop production, the addressed crops include citrus (Ben Rejeb *et al.*, 2020), date palms (Bouissil *et al.*, 2020; Khaled and Segni, 2016; Souli *et al.*, 2020), wheat (Bouzid *et al.*, 2020; Jovanovic *et al.*, 2020), potato (Bouzid *et al.*, 2020; Jovanovic *et al.*, 2020), and tomato (Badaoui *et al.*, 2019; Codron *et al.*, 2007; Dolinska *et al.*, 2020). In general, the focus is on cash, export crops rather than staple ones. Other papers deal with agriculture innovation in general, or agricultural knowledge and innovation system (AKIS), without focusing on any specific crop (Braiki *et al.*, 2018; Chisenga, 2008; Dolinska *et al.*, 2020; Froebrich *et al.*, 2020; Labbaci *et al.*, 2015; Le Gal *et al.*, 2010; Le and Dhehibi, 2019; Zahran *et al.*, 2020). A few articles address mixed farming; for instance, Ameur *et al.* (2020) analyze innovative agro-ecological practices that aim at livestock integration in cropping systems to provide multiple ecosystem services in the North African irrigated plains.

As for the *stages of the food chain*, most of the selected documents deals with the upstream (cf. production) of the food chain; downstream

(cf. marketing/consumption) and intermediate stages (e.g. packing, processing) are generally overlooked. Regarding production, the selected documents focus, among others, on water resources management and irrigation (Ameur *et al.*, 2013; Difallah *et al.*, 2017; Ghareeb and Seif, 2020; Jovanovic *et al.*, 2020; Kuper *et al.*, 2009; Le and Dhehibi, 2019; Naouri *et al.*, 2020; Narvarte *et al.*, 2018; Salhi *et al.*, 2012) and pest management (Bouissil *et al.*, 2020). Some articles take a more holistic approach and deal with different types of innovative practices. For instance, Ameur *et al.* (2020) map innovative agro-ecological practices that aim to improve soil fertility management, increase agricultural production, or provide multiple ecosystem services in North African irrigated plains. Bouzid *et al.* (2020) analyze the level of innovation among Algerian durum wheat and potato producers regarding soil fertility management and fertilization, pest control, and mechanization. Likewise, King (2008) describes different innovative practices for the management of marginal drylands relating to rangeland rehabilitation, water management, and sustainable cultivation of crops, as well as animal husbandry. Other articles deal simultaneously with different stages by addressing the whole agri-food value chain or supply chain (Badraoui *et al.*, 2020; Lin *et al.*, 2013). Only few articles deal with processing and processed products such as citrus-based jellies (Ben Rejeb *et al.*, 2020) and poultry meat (Hamad *et al.*, 2020). Callieris *et al.* (2016) are among the few scholars that focus on consumption and analyze Tunisian consumer behaviors towards organic agri-food products. Interestingly, some articles deal with agri-food waste management (Badaoui *et al.*, 2019; Khaled and Segni, 2016; Lin *et al.*, 2013; Souli *et al.*, 2020).

3.4. *Types of innovation*

Most of the selected documents deal with technical innovations, while social, organizational, and marketing ones are generally overlooked. Technical innovations refer to new technologies and practices. These include new machines, seed varieties, fertilizers, or pesticides (Singh, 2018), and other new technologies used at the farm level. Indeed, different articles deal with water resources management and irrigation technologies such as drip irrigation (Ameur *et al.*, 2013; Naouri *et al.*, 2015, 2020; Salhi *et al.*, 2012) and mechanized raised-bed technology (Le and Dhehibi, 2019). The addressed product innovations regard new agri-food products such as reduced sugar citrus-based jellies (Ben Rejeb *et al.*, 2020), probiotic cell-free supernatants for inhibition of meat infection (Hamad *et al.*, 2020), alginate from Moroccan brown algae (Bouissil *et al.*, 2020) and Ecoponics tomatoes in Morocco (Codron *et al.*, 2007).

The adoption of new farming systems can be considered a process innovation. Examples include precision agriculture (Singh, 2018), agro-ecology (Ameur *et al.*, 2020), Saharan agriculture (Daoudi and Lejars, 2016; Naouri *et al.*, 2015), conservation agriculture (King, 2008; Labbaci *et al.*, 2015; Singh, 2018) or mixed animal-crop farming (King, 2008; Le Gal *et al.*, 2010). Process innovations also include methods for the conversion and consequent use of different types of waste, such as anaerobic digestion (Souli *et al.*, 2020), drying in solar greenhouses (Badaoui *et al.*, 2019), fermentation for the production of bioethanol (Khaled and Segni, 2016). These innovative processes generally refer to the second generation waste valorization and re-use strategies for the production of high-value products (e.g. fuels, chemicals) rather than conventional waste processing (e.g. incineration, composting) (Lin *et al.*, 2013). Different process innovations help increasing the involvement of various stakeholders (e.g. farmers) in the development and diffusion of innovations in the agri-food sector such as the implementation of the community of practice (CoP) concept in innovation platforms (Dolinska *et al.*, 2020) or through multi-stakeholder consultation processes (Braiki *et al.*, 2018) and simulation games (Dolinska, 2017).

Organizational innovations are related to the increasing use of ICT in managing farms (Chisenga, 2008). Indeed, some articles address the use of ICT in agriculture and the agri-food sector in North Africa (Abbassy and Ead, 2020; Chisenga, 2008). Technologies addressed in this respect include the Internet of Things (IoT)

(Abbassy and Ead, 2020). Organizational innovations also regard the restructuring of the whole AKIS by shifting from fragmentation to integration (Zahran *et al.*, 2020) or new ways of governance of the agri-food value chain and supply chain (Badraoui *et al.*, 2020; Fouad *et al.*, 2018). For instance, Badraoui *et al.* (2020) analyze innovative practices relating to horizontal logistics collaboration in Morocco's agri-food supply chains. Similarly, there is more recourse to renewable energy sources at the farm level, such as using photovoltaics in large power irrigation systems (Narvarte *et al.*, 2018) to adapt agriculture to climate change. In the category of organizational innovations, all decision support systems and modeling tools such as those that help in water management can also be enumerated (Difallah *et al.*, 2017; Ghareeb and Seif, 2020; Jovanovic *et al.*, 2020; Kuper *et al.*, 2009).

Only a few articles refer explicitly to marketing innovations (Bouzid *et al.*, 2020; Callieris *et al.*, 2016). In fact, referring to Tunisian consumers' behavior towards organic agri-food products, Callieris *et al.* (2016) point out that "*marketing innovations are necessary to make organic foods available at affordable prices especially to promising organic consumers*" (p. 53). Meanwhile, Bouzid *et al.* (2020) analyze the factors affecting the adoption of innovation among Algerian durum wheat and potato growers and argue that "*innovations in marketing and sustainable techniques are non-existent for durum wheat producers, while some organizational and marketing innovations are observed among potato producers*".

Some articles refer simultaneously to different types of innovations. For instance, Aziza *et al.* (2009) analyze the adoption of technical (e.g. early weaning food supplementation, crossing Sicilo-Sarde with Sardinian breed) and organizational (e.g. breeders' associations membership) innovations in dairy sheep breeding in Tunisia as well as their impacts on the flock performance.

Moreover, Stilt (2018) mentions another type of innovation, namely 'constitutional innovation,' referring to changes made in Egypt's 2014 Constitution to ensure animal protection. Similarly, Singh (2018) uses the term 'agronomic innovations' when referring to novel agricultural management practices such as inter-cropping and no-till/zero-till agriculture. On the one hand, this shows the dynamism of the field of innovation studies and, on the other hand, its ambivalence and lack of consistency in the use of the term 'innovation'. Furthermore, the literature analysis shows that the distinction between product innovation, process innovation, and organizational innovation is not always clear-cut and straightforward in the agri-food sector. For instance, the adoption of product innovation, such as drip irrigation, is a process that can be considered as a 'process innovation.' Furthermore, the adoption of a new, innovative technology often implies changes in the whole farm's management and organization, thus qualifying for being considered an 'organizational innovation'.

3.5. Innovation and sustainability in the agri-food sector in North Africa

There is no earmarked analysis of the relation between innovation and sustainability/sustainable development. Similarly, there is no explicit reference to the concept of 'sustainable innovation'. However, some articles refer to the nexus between innovation and sustainability. First, innovation is presented as a tool to address many sustainability challenges. These challenges relate to environmental issues such as the scarcity of water resources (Ameur *et al.*, 2013; Difallah *et al.*, 2017; Ghareeb and Seif, 2020; Jovanovic *et al.*, 2020; Kuper *et al.*, 2009; Le and Dhehibi, 2019; Naouri *et al.*, 2020; Narvarte *et al.*, 2018; Salhi *et al.*, 2012), waste (Badaoui *et al.*, 2019; Khaled and Segni, 2016; Lin *et al.*, 2013; Souli *et al.*, 2020), agro-ecosystem disturbance and biodiversity loss (Ameur *et al.*, 2020) or land degradation (King, 2008; Labbaci *et al.*, 2015; Singh, 2018); social issues such as migration (Daoudi and Lejars, 2016; Naouri *et al.*, 2015); or economic issues such as the improvement of the competitiveness and marketing of agri-food products (Callieris *et al.*, 2016). For instance, Ameur *et al.* (2020) point out that irrigated agriculture in North Africa is subject to multiple threats (e.g. soil degradation, natural resources depletion, unequal access to resources and information, difficult market access), so farm-

ers move to alternative farming practices (e.g. agro-ecology) to sustain their farming systems, incomes and livelihoods. Similarly, Ghareeb and Seif (2020) put that "Managing the increasing water demands in Egypt, with limited water resources, urges Egypt to find innovative and sustainable approaches for management, and make use of modern information and communication technologies (ICT) to build decision support systems (DSS)".

Second, many scholars address different features of 'sustainable innovation', such as the inclusion of concerned stakeholders, especially farmers (Braiki *et al.*, 2018; Dolinska, 2017; Dolinska *et al.*, 2020). Indeed, different papers introduce the concepts of AKIS (Zahran *et al.*, 2020), agricultural innovation systems (Naouri *et al.*, 2020), or innovation platforms (Dolinska, 2017; Dolinska *et al.*,2020) as ways to ensure the practical and functional inclusion of all stakeholders involved in the innovation process. In this respect, Zahran *et al.* (2020) argue that "Agricultural knowledge and innovation system (AKIS) has a strong potential to enhance economic performance of farming and contribute to agricultural sustainability, as it may increase synergies and complementarity among actors".

3.6. Barriers to and proposals for fostering innovation in the agri-food sector

Different articles analyze the factors that, positively or negatively, affect the adoption of innovations in the North African agri-food sector. These include socio-demographic/human, technological, economic, and institutional/political factors (Table 7). However, it seems that the influence of these factors is context-specific and their statistical significance, as well as effect direction (positive/negative), are dependent on many variables. For instance, Dhraief *et al.* (2019), referring to factors affecting innovative technologies (IT) adoption by livestock holders in Tunisia, point out that "economic and so-

Table 7 - Factors affecting the adoption of innovation in the agri-food sector.

Categories of factors	*Examples*	*Sources*
Socio-demographic and human	Education	Bouzid *et al.*, 2020; Dhraief *et al.*, 2019; Le and Dhehibi, 2019; Salhi *et al.*, 2012
	Age	Bouzid *et al.*, 2020; Dhraief *et al.*, 2019; Le and Dhehibi, 2019
	Experience	Dhraief *et al.*, 2019
	Availability of family labour	Dhraief *et al.*, 2019; Le and Dhehibi, 2019
Institutional and political	Membership in associations	Dhraief *et al.*, 2019; Le and Dhehibi, 2019
	Access to extension and advisory services	Dhraief *et al.*, 2019
	Subsidies and marketing guarantee policies	Bouzid *et al.*, 2020
Economic and financial	Size of cattle flocks	Dhraief *et al.*, 2019
	Off-farm income	Dhraief *et al.*, 2019
	Access to credit	Dhraief *et al.*, 2019; Le and Dhehibi, 2019
	Investment needed and adoption/use cost	Ameur *et al.*, 2020; Salhi *et al.*, 2012
	Farm size	Le and Dhehibi, 2019
Technological/ technical	Ease of technology use	Dhraief *et al.*, 2019
Other factors	Land tenure	Bouzid *et al.*, 2020
	Infrastructure	Zahran *et al.*, 2020
	Crop type	Salhi *et al.*, 2012

cio-demographic factors such as farmer education, size of cattle flocks and off-farm income were statistically significant and had positive influence on technology adoption while age and farmer experience had significant and negative effects on IT adoption" (p. 3). Zahran *et al.* (2020) argue that "legal and regulatory frameworks, lack of infrastructure, and weak role of intermediary organizations are the main barriers that AKIS faces" in Egypt.

Scholars also made several proposals to foster innovation development, dissemination, and uptake in the North African agri-food sector. A particular focus is put on enhancing human capital (Bouzid *et al.*, 2020; Dhraief *et al.*, 2019) through education and training, as well as the creation of an institutional and political environment (Bouzid *et al.*, 2020; Dhraief *et al.*, 2019; Dolinska *et al.*, 2020; Labbaci *et al.*, 2015; Singh, 2018) that is conducive for and enabling for innovation in agriculture. Also, the role of extension and advisory services (Dhraief *et al.*, 2019) in disseminating innovation among farmers and producers seems crucial. In this respect, Dhraief *et al.* (2019) suggest that "Government should focus on educating young farmers with large cattle flock size and off-farm income to enhance the adoption of IT for livestock holders. It should also intensify training programs for farmers and for extension agents with the collaboration of the project managers and the involvement of the profession and the private sector" (p. 3). Singh (2018) focuses on improving political environment to foster mechanisation in agriculture and argues that governments should "… create conducive environment for successful agricultural mechanization, remove restrictions to choice, leasing or credit programmes for imported machinery as well as locally produced machines, support information for better decision making by farmers, legislation for safe, durable and reliable machinery and equipment" (p. 31). Labbaci *et al.* (2015) conclude that strengthening collective action (cf. organization of work, monitoring, and evaluation development, research and development, etc.) is vital to promote conservation agriculture and ensure its sustainability in Middle Sebou region in Morocco.

4. Conclusions

The present article provides a comprehensive analysis of the state of research on innovation in the North African agri-food sector. It suggests increasing interest in the research strand. However, a large share of the analyzed research outputs is authored by scholars based in institutions outside North Africa, especially in Europe (e.g. France). The literature analysis shows that it is biased towards crop production (e.g. citrus, wheat, and potato); only a few articles deal with animal production and fisheries. Most of the selected documents deal with the upstream (cf. production) of the food chain; downstream and intermediate stages are generally overlooked. Similarly, a large share of the analyzed documents deals with technical innovations while social, organizational, and marketing ones are generally disregarded. Technical innovations refer to new technologies and practices. Some scholars refer to 'constitutional innovation' and 'agronomic innovation', which shows the dynamism of innovation studies and the lack of consistency in the use of the term 'innovation'. Furthermore, the distinction between product innovation, process innovation and organisational innovation is not always clear-cut and straightforward in the agri-food sector. There is no earmarked analysis of the relation between innovation and sustainability or sustainable development. However, innovation is presented as a tool to address many sustainability challenges (environment, economic, social) and many scholars address different features of 'sustainable innovation' such as the inclusion of concerned stakeholders. Different articles analyse the socio-demographic, technological and institutional factors affecting innovation adoption. Moreover, scholars highlight the need for enhancing human capital as well as the creation of an enabling institutional and political environment to foster innovation in the agri-food sector.

Innovation is crucial in addressing the unprecedented and interdependent environmental, economic and social challenges that the North African agri-food sector is facing. Therefore, it is crucial to develop an AKIS that promotes sustainability-oriented innovation. This is particularly important to address and mitigate the

consequences of the COVID-19 on the North African agri-food sector. Indeed, innovation seems vital to improve sustainability and increase the resilience of the regional agri-food system. The development of an operational and highly performing AKIS in North Africa requires moving towards sustainability-oriented innovation in the agri-food sector accompanied by policy measures, effective monitoring and evaluation tools alongside the engagement of relevant actors and stakeholders (from research, education, extension, policy, business, civil society) and the leverage of sufficient investments for long-term programs and strategies. While the focus on technical innovation is still necessary to modernize the regional agri-food sector, more attention should be paid to soft innovations relating to the social and organizational domains. In this regard, the adoption of systemic innovation models and approaches results is crucial to foster the transition towards sustainable, efficient, and resilient agri-food systems in the region.

References

Abbassy M.M., Ead W.M., 2020. Intelligent Greenhouse Management System. In: *6th International Conference on Advanced Computing and Communication Systems (ICACCS)* (March 06-07, 2020, Coimbatore, India). Piscataway, NJ: IEEE, pp. 1317-1321.

Ameur F., Amichi H., Leauthaud C., 2020. Agro-ecology in North African irrigated plains? Mapping promising practices and characterizing farmers' underlying logics. *Regional Environmental Change*, 20(4): 133. https://doi.org/10.1007/s10113-020-01719-1.

Ameur F., Hamamouche M.F., Kuper M., Benouniche M., 2013. The domestication of a technical innovation: Diffusion of drip irrigation in two villages in Morocco. *Cahiers Agricultures*, 22(4): 311-318. https://doi.org/10.1684/agr.2013.0644.

Avermaete T., Viaene J., Morgan E.J., Pitts E., Crawford N., Mahon D., 2004. Determinants of product and process innovation in small food manufacturing. *Trends in Food Science & Technology*, 15(10): 474-483. https://doi.org/10.1016/j.tifs.2004.04.005.

Avolio G., Blasi E., Cicatiello C., Franco S., 2014. The drivers of innovation diffusion in agriculture: evidence from Italian census data. *Journal on Chain and Network Science*, 14(3): 231-245. https://doi.org/10.3920/JCNS2014.x009.

Aziza M., Raoudha K., Gley K., 2009. The adoption of technical and organizational innovations and their impacts on the dairy sheep breeding in Tunisia. *New Medit*, 8(3): 36-40.

Badaoui O., Hanini S., Djebli A., Haddad B., Benhamou A., 2019. Experimental and modelling study of tomato pomace waste drying in a new solar greenhouse: Evaluation of new drying models. *Renewable Energy*, 133: 144-155. https://doi.org/10.1016/j.renene.2018.10.020.

Badraoui I., van der Vorst J., Boulaksil Y., 2020. Horizontal logistics collaboration: an exploratory study in Morocco's agri-food supply chains. *International Journal of Logistics Research and Applications*, 23(1): 85-102. https://doi.org/10.1080/13675567.2019.1604646.

Ben Hassen T., El Bilali H., 2020. Knowledge and Innovation in Agriculture: Contribution to Food Security and Sustainability. In: Leal Filho W., Azul A., Brandli L., Özuyar P., Wall T. (eds.), *Zero Hunger. Encyclopedia of the UN Sustainable Development Goals*. Cham: Springer, pp. 1-11. https://doi.org/10.1007/978-3-319-69626-3_108-1.

Ben Rejeb I., Dhen N., Kassebi S., Gargouri M., 2020. Quality Evaluation and Functional Properties of Reduced Sugar Jellies Formulated from Citrus Fruits. *Journal of Chemistry*, 2020: 1-8. https://doi.org/10.1155/2020/5476872.

Bouissil S., El Alaoui-Talibi Z., Pierre G., Michaud P., El Modafar C., Delattre C., 2020. Use of Alginate Extracted from Moroccan Brown Algae to Stimulate Natural Defense in Date Palm Roots. *Molecules*, 25(3): 720. https://doi.org/10.3390/molecules25030720.

Bouzid A., Boudedja K., Cheriet F., Bouchetara M., Mellal A., 2020. Facteurs influençant l'adoption de l'innovation en agriculture en Algérie. Cas de deux cultures stratégiques : le blé dur et la pomme de terre. *Cahiers Agricultures*, 29: 15. https://doi.org/10.1051/cagri/2020013.

Braiki H., Burte J., Imache A., Hassenforder E., Habaieb H., Bouarfa S., 2018. Expérimenter la concertation : une clé pour des politiques environnementales plus efficaces ? Une démarche multi-acteurs innovante en Tunisie centrale. *Cahiers Agricultures*, 27(1): 15003. https://doi.org/10.1051/cagri/2017064.

Callieris R., Brahim S., Roma R., 2016. Different consumer behaviours for organic food in Tunisia. A cluster analysis application. *New Medit*, 15(2): 53-62.

Charter M., Clark T., 2007. *Sustainable Innovation - Key conclusions from Sustainable Innovation*

Conferences 2003-2006 organised by The Centre for Sustainable Design. https://research.uca.ac.uk/694/1/Sustainable_Innovation_report.pdf.

Chisenga J., 2008. The E-Agriculture Initiative: Achieving the MDGs through Sharing of Innovative Experiences. In: Njobvum B., Koopman S. (eds.), *Libraries and Information Services Towards the Attainment of the UN Millennium Development Goals*. IFLA Publications 134. München: K.G. Saur, pp. 57-71.

Codron J.M., Bouhsina Z., Fort F., Rouvière E., 2007. Economic and institutional conditions for valuing Moroccan ECOPONICS tomatoes both in the export and the domestic markets. *Acta Horticulturae*, 747: 47-56. https://doi.org/10.17660/ActaHortic.2007.747.3.

Cornell University, INSEAD, WIPO, 2020. *The Global Innovation Index 2020: Who Will Finance Innovation?* Ithaca / Fontainebleau / Geneva: Cornell University / INSEAD / WIPO. https://www.wipo.int/global_innovation_index/en/2020.

Daoudi A., Lejars C., 2016. From oasis agriculture to Saharan agriculture in the Ziban region in Algeria. Actors of dynamism and factors of uncertainty. *New Medit*, 15(2): 45-52.

Dhraief M.Z., Bedhiaf S., Dhehibi B., Oueslati-Zlaoui M., Jebali O., Ben-Youssef S., 2019. Factors affecting innovative technologies adoption by livestock holders in arid area of Tunisia. *New Medit*, 18(4): 3-18. https://doi.org/10.30682/nm1904a.

Difallah W., Benahmed K., Draoui B., Bounaama F., 2017. Linear Optimization Model for Efficient Use of Irrigation Water. *International Journal of Agronomy*, 2017: 1-8. https://doi.org/10.1155/2017/5353648.

Dolinska A., 2017. Bringing farmers into the game. Strengthening farmers' role in the innovation process through a simulation game, a case from Tunisia. *Agricultural Systems*, 157: 129-139. https://doi.org/10.1016/j.agsy.2017.07.002.

Dolinska A., Oates N., Ludi E., Habtu S., Rougier J., Sanchez-Reparaz M., Mosello B., Yazew, E., Kifle M., Fissehaye D., Arega G., Tamele H.F., Barberá G.G., D'Aquino P., 2020. Engaging Farmers in a Research Project. Lessons Learned from Implementing the Community of Practice Concept in Innovation Platforms in Irrigated Schemes in Tunisia, Mozambique and Ethiopia. *Irrigation and Drainage*, 69(S1): 38-48. https://doi.org/10.1002/ird.2222.

EIP-AGRI, 2013. *Strategic Implementation Plan: European Innovation Partnership - "Agricultural Productivity and Sustainability" (EIP-A)*. Directorate-General for Agriculture and Rural Development. https://ec.europa.eu/eip/agriculture/en/publications/strategic-implementation-plan-european-innovation.

El Bilali H., 2018a. Innovation in the Agro-Food Sector: From technical Innovation-centred Approaches to Sustainability Transition Processes. *International Journal of Agricultural Management and Development*, 8(2): 201-218. http://ijamad.iaurasht.ac.ir/article_540497_8525c5026915e791263e1dd94387c27e.pdf.

El Bilali H., 2018b. Relation between innovation and sustainability in the agro-food system. *Italian Journal of Food Science*, 30(2): 200-225. https://doi.org/10.14674/IJFS-1096.

El Bilali H., 2019a. Innovation-Sustainability Nexus in Agriculture Transition: Case of Agroecology. *Open Agriculture*, 4(1): 1-16. https://doi.org/10.1515/opag-2019-0001.

El Bilali H., 2019b. Research on agro-food sustainability transitions: where are food security and nutrition? *Food Security*, 11(3): 559-577. https://doi.org/10.1007/s12571-019-00922-1.

El Bilali H., 2020. Transition heuristic frameworks in research on agro-food sustainability transitions. *Environment, Development and Sustainability*, 22(3): 1693-1728. https://doi.org/10.1007/s10668-018-0290-0.

El Bilali H., Ben Hassen T., 2020. Food Waste in the Countries of the Gulf Cooperation Council: A Systematic Review. *Foods*, 9(4): 463. https://doi.org/10.3390/foods9040463.

European Commission, 2016. *European research and innovation for food and nutrition security*. Working document. https://ec.europa.eu/transparency/documents-register/detail?ref=SWD(2016)319&lang=en.

European Political Strategy Centre, 2016. *Sustainability Now! A European Vision for Sustainability*. EPSC Strategic Notes, 18. https://www.eesc.europa.eu/sites/default/files/files/rapport_kff.pdf.

FAO, 2012. *Greening the Economy with Agriculture*. Rome: FAO. http://www.fao.org/docrep/015/i2745e/i2745e00.pdf.

FAO, 2013. *Climate-Smart Agriculture. Sourcebook*. Rome: FAO. http://www.fao.org/climate-smart-agriculture-sourcebook/en.

FAO, IFAD, UNICEF, WFP, WHO, 2020. *The State of Food Security and Nutrition in the World 2020. Transforming food systems for affordable healthy diets*. Rome: FAO. https://doi.org/10.4060/ca9692en.

FAO, World Bank, 2000. *Agricultural Knowledge and Information Systems for Rural Development. Strategic Vision and Guiding Principles*. Rome: FAO.

http://www.fao.org/fileadmin/templates/ERP/2013/link_publications/AKIS.pdf.

Fouad F., Tourabi A., Lakhnati G., 2018. The innovation process impact on the new product performance: a case study. *International Journal of Innovation Science*, 10(3): 385-412. https://doi.org/10.1108/IJIS-08-2017-0071.

Froebrich J., Ludi E., Bouarfa S., Rollin D., Jovanovic N., Roble M., Ajmi T., Albasha R., Bah S., Bahri H., Barberá G., Beek C., Cheviron B., Chishala B., Clercq W., Coulibaly Y., Dicko M., Diawara B., Dolinska A., … Zairi A., 2020. Transdisciplinary Innovation in Irrigated Smallholder Agriculture in Africa. *Irrigation and Drainage*, 69(S1): 6-22. https://doi.org/10.1002/ird.2400.

Garcia R., Calantone R., 2002. A critical look at technological innovation typology and innovativeness terminology: a literature review. *Journal of Product Innovation Management*, 19(2): 110-132. https://doi.org/10.1111/1540-5885.1920110.

Ghareeb M., Seif A.K., 2020. Toward development of open-source models of decision support systems for water demand management in Egypt. *Innovative Infrastructure Solutions*, 5(2): 45. https://doi.org/10.1007/s41062-020-00293-z.

Global Harvest Initiative, 2016. *Sustainability in an Uncertain Season - 2016 Global Agricultural Productivity (GAP) Report*. https://globalagriculturalproductivity.org/wp-content/uploads/2019/01/2016_GAP_Report.pdf.

Hamad G.M., Abdelmotilib N.M., Darwish A.M.G., Zeitoun A.M., 2020. Commercial probiotic cell-free supernatants for inhibition of Clostridium perfringens poultry meat infection in Egypt. *Anaerobe*, 62: 102181. https://doi.org/10.1016/j.anaerobe.2020.102181.

Hekkert M.P., Suurs R.A.A., Negro S.O., Kuhlmann S., Smits R.E.H.M., 2007. Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting and Social Change*, 74(4): 413-432. https://doi.org/10.1016/j.techfore.2006.03.002.

HLPE, 2017. *2nd Note on Critical and Emerging Issues for Food Security and Nutrition. A Note by the High Level Panel of Experts on Food Security and Nutrition (HLPE) of the Committee on World Food Security*. http://www.fao.org/fileadmin/user_upload/hlpe/hlpe_documents/Critical-Emerging-Issues-2016/HLPE_Note-to-CFS_Critical-and-Emerging-Issues-2nd-Edition__27-April-2017_.pdf.

HLPE, 2019. *Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. A Report by the High Level Panel of Experts on Food Security and Nutrition (HLPE) of the Committee on World Food Security*. http://www.fao.org/3/ca5602en/ca5602en.pdf.

IAASTD, 2009. *Agriculture at a Crossroads. International Assessment of Agricultural Knowledge, Science and Technology for Development. Global Report*. Washington: Island Press. https://wedocs.unep.org/handle/20.500.11822/9569.

IICA (Inter-American Institute for Cooperation on Agriculture), 2014. *Innovation in agriculture: a key process for sustainable development.* Institutional position paper. https://repositorio.iica.int/bitstream/11324/2607/1/BVE17038694i.pdf.

IPES-Food, 2015. *The New Science of Sustainable Food Systems: Overcoming Barriers to Food Systems Reform*. http://www.ipes-food.org/_img/upload/files/NewScienceofSusFood.pdf.

Jovanovic N., Musvoto C., De Clercq W., Pienaar C., Petja B., Zairi A., Hanafi S., Ajmi T., Mailhol J.C., Cheviron B., Albasha R., Habtu S., Yazew E., Kifle M., Fissahaye D., Aregay G., Habtegebreal K., Gebrekiros A., Woldu Y., Froebrich J., 2020. A Comparative Analysis of Yield Gaps and Water Productivity on Smallholder Farms in Ethiopia, South Africa and Tunisia. *Irrigation and Drainage*, 69(S1): 70-87. https://doi.org/10.1002/ird.2238.

Khaled M.T.O., Segni L., 2016. First generation bioethanol from some varieties of dates grown in the region of El-Oued in the south of Algeria. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, 7(3): 668-672.

King C., 2008. Sustainable Management of Marginal Drylands (SUMAMAD): Sharing Success Stories from Indigenous, Adaptive and Innovative Approaches. In: Lee C., Schaaf T. (eds.), *The Future of Drylands. International Scientific Conference on Desertification and Drylands Research* (June 19-21, 2006, Tunis, Tunisia). Dordrecht: Springer, pp. 747-761.

Klerkx L., Hall A., Leeuwis C., 2009. Strengthening Agricultural Innovation Capacity: Are Innovation Brokers the Answer? *International Journal of Agricultural Resources, Governance and Ecology*, 8(5/6): 409-438.

Kuper M., Bouarfa S., Errahj M., Faysse N., Hammani A., Hartani T., Marlet S., Zairi A., Bahri A., Debbarh A., Garin P., Jamin J.-Y., Vincent B., 2009. A crop needs more than a drop: Towards a new praxis in irrigation management in North Africa. *Irrigation and Drainage*, 58(S3): S231-S239. https://doi.org/10.1002/ird.533.

Labbaci T., Dugué P., Kemoun H., Rollin D., 2015. Innovation and collective action: direct seeding of

rainfed crops in the Middle Sebou region (Morocco). *Cahiers Agricultures*, 24(2): 76-83. https://doi.org/10.1684/agr.2015.0742.

Le Q.B., Dhehibi B., 2019. A Typology-Based Approach for Assessing Qualities and Determinants of Adoption of Sustainable Water Use Technologies in Coping with Context Diversity: The Case of Mechanized Raised-Bed Technology in Egypt. *Sustainability*, 11(19): 5428. https://doi.org/10.3390/su11195428.

Leach M., Rockström J., Raskin P., Scoones I., Stirling A.C., Smith A., Thompson J., Millstone E., Ely A., Arond E., Folke C., Olsson P., 2012. Transforming Innovation for Sustainability. *Ecology and society*, 17(2): 11. https://doi.org/10.5751/ES-04933-170211.

Le Gal P.-Y., Merot A., Moulin C.-H., Navarrete M., Wery J., 2010. A modelling framework to support farmers in designing agricultural production systems. *Environmental Modelling & Software*, 25(2): 258-268. https://doi.org/10.1016/j.envsoft.2008.12.013.

Lin C.S.K., Pfaltzgraff L.A., Herrero-Davila L., Mubofu E.B., Abderrahim S., Clark J.H., Koutinas A.A., Kopsahelis N., Stamatelatou K., Dickson F., Thankappan S., Mohamed Z., Brocklesby R., Luque R., 2013. Food waste as a valuable resource for the production of chemicals, materials and fuels. Current situation and global perspective. *Energy & Environmental Science*, 6(2): 426-464. https://doi.org/10.1039/c2ee23440h.

Menrad K., Feigl S., 2007. *Innovations in traditional food products in small and medium-sized companies of the food industry: Review of literature*. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.452.1117&rep=rep1&type=pdf.

Moher D., Liberati A., Tetzlaff J., Altman D.G., 2009. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Medicine*, 6(7): e1000097. https://doi.org/10.1371/journal.pmed.1000097.

Naouri M., Hartani T., Kuper M., 2015. Mobility of rural youth and new forms of Saharan agriculture (Biskra, Algeria). *Cahiers Agricultures*, 24(6): 379-386. https://doi.org/10.1684/agr.2015.0778.

Naouri M., Kuper M., Hartani T., 2020. The power of translation: Innovation dialogues in the context of farmer-led innovation in the Algerian Sahara. *Agricultural Systems*, 180: 102793. https://doi.org/10.1016/j.agsy.2020.102793.

Narvarte L., Fernández-Ramos J., Martínez-Moreno F., Carrasco L.M., Almeida R.H., Carrêlo I.B., 2018. Solutions for adapting photovoltaics to large power irrigation systems for agriculture. *Sustainable Energy Technologies and Assessments*, 29: 119-130. https://doi.org/10.1016/j.seta.2018.07.004.

Network for Business Sustainability, 2012. *Innovating for Sustainability: A Systematic Review of the Body of Knowledge*. Prepared by Adams R., Jeanrenaud S., Bessant J., Overy P., Denyer D. Available at: https://ore.exeter.ac.uk/repository/bitstream/handle/10036/4105/Adams%202012-%20NBS%20Systematic%20Review%20Innovation.pdf?sequence=8.

OECD, 2013. *Agricultural Innovation Systems: A Framework for Analysing the Role of the Government*. Paris: OECD Publishing. https://doi.org/10.1787/9789264200593-en.

OECD, Eurostat, 2005. *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*, 3rd ed. Paris: OECD Publishing.

Radwan A., 2018. Science and innovation policies in North African Countries: Exploring challenges and opportunities. *Entrepreneurship and Sustainability Issues*, 6(1): 268-282. https://doi.org/10.9770/jesi.2018.6.1(17).

Röling N., 2009. Pathways for impact: scientists' different perspectives on agricultural innovation. *International Journal of Agricultural Sustainability*, 7(2): 83-94. https://doi.org/10.3763/ijas.2009.0043.

Royal Society, 2009. *Reaping the Benefits: Science and the Sustainable Intensification of Global Agriculture*. London: The Royal Society. https://royalsociety.org/-/media/Royal_Society_Content/policy/publications/2009/4294967719.pdf.

Salhi S., Imache A., Tonneau J.-P., Ferfera M.-Y., 2012. Determinants of conversion to drip irrigation systems by farmers: The case of the Mitidja plain in Algeria. *Cahiers Agricultures*, 21(6): 417-426. https://doi.org/10.1684/agr.2012.0598.

Schumpeter J., 1934. *The theory of economic development*. Cambridge, MA: Harvard University Press.

Schumpeter J.A., 1942. Capitalism, Socialism and Democracy. In: *Capitalism, Socialism and Democracy*. New York: Harper & Row.

Shaver E.F., 2016. *The Many Definitions of Innovation*. http://www.ericshaver.com/the-many-definitions-of-innovation/.

Singh S., 2018. Strategy, current activities and future prospect for advancing Indian agricultural machinery into the African market. *AMA, Agricultural Mechanization in Asia, Africa and Latin America*, 49(2): 31-42.

Smith A., Voß J.-P., Grin J., 2010. Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. *Research Policy*, 39(4): 435-448. https://doi.org/10.1016/j.respol.2010.01.023.

Souli I., Liu X., Lendormi T., Chaira N., Ferchichi A., Lanoisellé J.-L., 2020. Anaerobic digestion of waste Tunisian date (*Phoenix dactylifera* L.): effect of biochemical composition of pulp and seeds from six varieties. *Environmental Technology*. https://doi.org/10.1080/09593330.2020.1797900.

STEPS Centre, 2010. *Innovation, Sustainability, Development: A New Manifesto*. Brighton: STEPS Centre. http://steps-centre.org/anewmanifesto/wp-content/uploads/steps-manifesto_small-file.pdf.

Sterrenberg L., Andringa J., Loorbach D., Raven R., Wieczorek A., 2013. *Low-carbon transition through system innovation: Theoretical notions and applications. Pioneers into Practice Mentoring Program 2013*. http://www.transitiepraktijk.nl/files/Low-carbon transition through system innovation 2013 reader final.pdf.

Stilt K.A., 2018. Constitutional Innovation and Animal Protection in Egypt. *Law & Social Inquiry*, 43(4): 1364-1390. https://doi.org/10.1111/lsi.12312.

Stummer C., Günther M., Köck A.M., 2010. *Grundzüege des Innovations- und Technologie-managements*. Wien: Facultas Verlag.

Twomey P., Gaziulusoy A.I., 2014. *Review of System Innovation and Transitions Theories - Concepts and frameworks for understanding and enabling transitions to a low carbon built environment.* Working paper for the Visions & Pathways project, March 2014. Available at: https://minerva-access.unimelb.edu.au/bitstream/handle/11343/194392/Twomey_Gaziulusoy_Innovation-and-Transition-Theory.pdf?sequence=1&isAllowed=y.

UNCTAD (United Nations Conference on Trade and Development), 2017. *The Role of Science, Technology and Innovation in Ensuring Food Security by 2030*. https://unctad.org/en/PublicationsLibrary/dtlstict2017d5_en.pdf.

United Nations, 1992. *Agenda 21. United Nations Conference on Environment & Development* (3-14 June, Rio de Janeiro, Brazil). https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf.

United Nations, 2002. *Report of the World Summit on Sustainable Development* (Johannesburg, South Africa, 26 August - 4 September). https://digitallibrary.un.org/record/478154.

United Nations, 2012a. *Science, technology and innovation for sustainable development in the global partnership for development beyond 2015*. UN System Task Team on the Post-2015 UN Development Agenda. http://www.un.org/en/development/desa/policy/untaskteam_undf/thinkpieces/28_thinkpiece_science.pdf.

United Nations, 2012b. *The Future We Want. Outcome document of the United Nations Conference on Sustainable Development* (20-22 June, Rio de Janeiro, Brazil). https://sustainabledevelopment.un.org/content/documents/733FutureWeWant.pdf.

United Nations, 2015. *Transforming Our World: The 2030 Agenda for Sustainable Development.* Resolution adopted by the General Assembly on 25 September 2015. http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E.

WCED (World Commission on Environment and Development), 1987. *Our Common Future. Final Report of World Commission on Environment and Development*. http://www.un-documents.net/our-common-future.pdf.

World Bank, 2006. *Enhancing Agricultural Innovation: How to go beyond the strengthening of research systems*. Washington: The World Bank. https://doi.org/10.1596/978-0-8213-6741-4.

World Bank, 2007. *World Development Report 2008: Agriculture for Development*. Washington: The World Bank. https://openknowledge.worldbank.org/handle/10986/5990.

World Bank, 2012. *Agricultural innovation systems: An investment sourcebook*. Washington: The World Bank. https://openknowledge.worldbank.org/bitstream/handle/10986/2247/672070PUB0EPI0067844B09780821386842.pdf?sequence=1&isAllowed=y.

World Bank, 2021a. *Agriculture, forestry, and fishing, value added (% of GDP)*. https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS.

World Bank, 2021b. *Employment in agriculture (% of total employment) (modeled ILO estimate)*. https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS.

Zahran Y., Kassem H.S., Naba S.M., Alotaibi B.A., 2020. Shifting from Fragmentation to Integration: A Proposed Framework for Strengthening Agricultural Knowledge and Innovation System in Egypt. *Sustainability*, 12(12): 5131. https://doi.org/10.3390/su12125131.