Food and Agriculture Organization of the United Nations

Feasibility study for application of digital technologies for improved traceability and transparency along the agrifood value chains

Case studies in the Near East and North Africa Region

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Abbreviations and acronyms

ACC	Agricultural Credit Corporation
ADAFSA	Abu Dhabi Agriculture and Food Safety Authority
ADE	Emirate of Abu Dhabi
AEC	Agriculture Export Council
AI	Artificial intelligence
AIC	Applied Innovation Centre
AVC	Agrifood value chain
BBTS	Blockchain-based Traceability System
CTE	Critical tracking event
DPG	Digital public good
EGP	Egyptian Pound
EIDPF	Emirates International Date Palm Festival
ERP	Enterprise resource planning
ETRACE	Egyptian Traceability Centre for Agro-Industrial Exports
EVOO	Extra virgin olive oil
FAO	Food and Agriculture Organizations of the United Nations
FIEMIS	Food Import and Export Management Information System
GAP	Good agricultural practices
GCC	Gulf Cooperation Council
GIS	Geographic information system
GSMA	Global System for Mobile Communications Association
HACCP	Hazard analysis and critical control point
HEIA	Horticultural Export Improvement Association
ICT	Information and communications technology
IFC	International Finance Corporation
IOC	International Olive Council
ISO	International Organization for Standardization
ITU	International Telecommunication Union

KDE	Key data elements
KIAAI	Khalifa International Award for Date palm and Agricultural Innovation
KII	Key informant interview
MALR	Ministry for Agriculture and Land Reclamation
MCIT	Ministry of Communications and Information Technology
MIS	Market information system
MoA	Ministry of Agriculture
MOCCAE	Ministry of Climate Change and Environment
MPED	Ministry of Planning and Economic Development
MTI	Ministry of Trade and Industry
NARC	National Agriculture Research Centre
NFSA	National Food Safety Authority
NENA	Near East and North Africa
NYIOOC	New York International Olive Oil Competition
OECD	Organisation for Economic Co-operation and Development
OIN	Office of innovation
ONH	National Olive Oil Board Office Tunis (Office National de l'Huile de Tunisie)
PBDAC	Public Bank for Development and Agricultural Credit
RCAD	Regional Commissions for Agricultural Development
RNE	Regional Office for Near East and North Africa
SIAN	Italian Informative Agricultural System
SME	Small and medium enterprise
TT	Traceability and transparency
UAE	United Arab Emirates
UNFPA	United Nations Population Fund
UNIDO	United Nations Industrial Development Organisation
UPEHC	Union of producers and exporters of horticultural crops
USD	United States Dollar
UTAP	Tunisian Union of Agriculture and Fisheries
UTICA	Tunisian Union of Industry, Commerce and Handicrafts
VC	Value chain
WEF	World Economic Forum
WFP	World Food Programme

Glossary

Traceability is "defined as the ability to discern, identify and follow the movement of a food or substance intended to be or expected to be incorporated into a food, through all stages of production, processing and distribution."[a]

Transparency is "the idea of demonstrating the quality of a product by capturing quality data, such as product certifications, throughout the whole of the supply chain."[b] The information is shareable for all value chain actors and that enhances price visibility and consumer insights for producers.[c]

Digital traceability and transparency systems are the technologies providing significant benefits "such as increased traceability, accuracy, security, efficiency, real time controllability and reduced labour cost."[d] For instance, in agrifood industry, by installing sensors on machines, data are collected to optimize production, precisely inform consumers about the food origin and production stages of a product. "The data is collected automatically and securely all throughout the journey providing a genuine guarantee of transparency."[e]

The blockchain-based traceability system or network offers participating retailers, suppliers, growers and food industry providers with data from across the food ecosystem to enable greater traceability, transparency and efficiency. Using blockchain for trusted transactions, food can be quickly traced back to its source in as little as a few seconds instead of days or weeks. Unlike traditional databases, the characteristics of blockchain, granting permission and making transactions that are endorsed by multiple parties, enables network members to gain a new level of trusted and immutable information.[f]

Data governance refers to the decisions to be made and data management involves implementing the decisions.[g] The data governance is the framework for assigning decision related rights in order to be able to adequately handle the data.[h] Data governance framework can become a regulatory framework, for example the European Union General Data Protection Regulation. The Data Management Body of Knowledge (DMBOK) wheel,[i] which is another good example of a data governance framework that has ten dimensions.

Data management involves the practice of implementing and applying the principles of a data governance framework. For example, data standardization can be a principle or dimension of a data governance framework, but the actual implementation of data standardization is a form of data management.

a. **FAO.** 2017. *Food traceability guidance.* Rome, Food and Agriculture Organization of the United Nations. https://www.fao.org/3/I7665EN/i7665en.pdf

b. **Onofrio, M.** 2018. *Traceability and transparency in agri-business.* London, Challenge Advisory https://www.challenge.org/knowledgeitems/traceability-transparency-in-agri-business/

c. **Owen, R.** 2021. *The growing demand for transparency in the produce aisle.* AG Daily. https://www.agdaily.com/insights/transparency-in-the-produce-aisle/#:~:text=Farmer%20acceptance%20of%20transparency%20technology%20is%20growing%20for,part%20of%20the%20chain%20above%20and%20below%20them

d. **Aysenur, B.**, et al. 2018. Digital traceability through production value chain. In: Industry 4.0: *Managing the digital transformation* (pp.251-265). Switzerland, Springer International Publishing. https://doi.org/10.1007/978-3-319-57870-5_15

e. **VINCI.** 2022. *Digital traceability – guaranteeing transparency for consumers.* https://www.vinci.com/vinci.nsf/en/news-update/pages/digital_traceability_guaranteeing_transparency_for_consumers.htm

f **IBM.** 2018. *IBM Food Trust Expands Blockchain Network to Foster a Safer, More Transparent and Efficient Global Food System.* https://newsroom.ibm.com/2018-10-08-IBM-Food-Trust-Expands-Blockchain-Network-to-Foster-a-Safer-More-Transparent-and-Efficient-Global-Food-System-1

g. **Alhassan, I. Sammon, D. & Daly, M.** 2016. *Data governance activities: an analysis of the literature, Journal of Decision Systems,* 25:sup1, 64-75, DOI:10.1080/12460125.2016.1187397

h. **Otto, B.** 2011. Organizing data governance: Findings from the telecommunications industry and consequences for large service providers. *Communications of the Association for Information Systems*, 29(1), 3.

i. **Dama International, Inc.** DMBOK v2 image. https://www.dama.org/cpages/dmbok-2-wheel-images

Executive summary

Agrifood systems in the Near East and North Africa (NENA) region face multiple challenges including scarcity of water and arable land, vulnerability to climate change, protracted crises and rapid population growth and urbanization. Food security and nutrition are threatened particularly in rural areas. Meanwhile, the region loses over 11 percent of food on average between farm and retail and 30 percent of fresh produce is lost post-harvest including fruits and vegetables, which are key for both provision of a healthy diet and the incomes of smallholder producers.

Traceability and transparency is ineffective throughout many food value chains (VCs) in NENA. However, traceability and transparency can help trace food origins, provide information throughout the VCs and detect potential bottlenecks in a timely manner, while sharing all data to enhance price visibility and inform consumers. The weakness has resulted in inefficient management of the supply chain, which can potentially cause food loss; weak food quality and safety controls; a high risk of non-compliance with quality standards; low exportability; information asymmetries; and unfair value distribution, which all lead to low value addition and thus meagre incomes for small and medium-sized actors. In fact, statistically, the NENA region lags behind other regions in growth of value addition in agriculture (0.6 percent in NENA as compared to the word average of 2.6 percent between 2011 and 2020).[a]

One way to address these issues is to employ digital technologies that can play an important role in ensuring traceability and transparency, which can quickly help detect potential bottlenecks in the food supply chain and data can be shared in real time to improve price visibility and consumer insights. Although consumers have been paying increasing attention to this area of work, few studies have analysed the feasibility of adopting digital technologies to improve traceability and transparency in the region. This is the starting point of this study.

The present study takes the approach of a case study to understand the digital landscape in NENA, examine barriers and feasibility, provide possible solutions and suggest roles for the various stakeholders. Two regionally strategic horticulture value chains were selected for practical recommendations arising from this study. Four countries were analysed where there are different information and communications technologies (ICT) and market environments: date palm in Egypt and the United Arab Emirates (UAE), and olive oil in Tunisia and Jordan. The study outlines how the situation in the VCs in each country affects the feasibility of using digital technologies by focussing on three main criteria: benefit, barrier and enabler so as to identify the gaps to be addressed before technologies can be adopted.

The benefits of adoption can be an important incentive that can encourage value chain actors to invest. Barriers to adoption include state of the ICT infrastructure, digital skills, data management and standardisation, perceived costs, technology availability, VC governance, social and cultural norms, which can all influence decisions to adopt and apply a new technology. Enablers, such as government support in regulatory frameworks and access to finance can encourage or discourage private sector engagement with digital transformation, which could be the key to mainstreaming a new system. This report also sheds light on the potential impact adoption of digital technologies can have on improving traceability and transparency in the three dimensions of sustainability (economic, social and environmental) to ensure alignment with the FAO mandate, areas of work and priorities.

a. **World Bank.** No date. *World Development Indicators. Washington D.C.*, USA. https://databank.worldbank.org/source/world-development-indicators

Based on the result of the analyses, this paper confirms that under conditions, where benefits are realized, barriers are lowered and drivers work effectively, and the adoption rate of digital technologies to improve traceability and transparency can be increased. Depending on the status of all criteria examined, different possible solutions and pathways are identified with required actions in each VC. For instance, the perceived costs of adopting digital technologies are significantly high, combined with the low level of recognition of the potential benefits, which can cause VC actors to be hesitant about investing. Hence, possible ownership of technology development is suggested and the level of applicable existing technologies is described; emphasis is placed on the need to raise awareness and for government support to strengthen the enabling environment to facilitate further investment.

The potential impacts on all three sustainability dimensions have been confirmed as positive, with foreseen benefits for small and medium-sized producers as well as small and medium enterprises (SMEs). The report also reveals that data standards, data governance and data interoperability is of generic importance in benefitting from the technologies for improved traceability and transparency. In addition, regarding the high level of commonalities in the structure and features of the two selected VCs in the research target countries, the paper concludes that the recommendations can be extended to all horticulture VCs at the regional level.

It is noteworthy that the coordinated mechanism among stakeholders – government, private sector (including SMEs and producers) and international development agencies – should be in place for the sustainable operation of digital technologies. Government can play a crucial role in creating an enabling environment to facilitate adoption of digital technologies; the private sector is the main actor that will recognize benefits and can have a vast influence upon appropriate implementation of digital technologies. International development agencies should take responsibility for ensuring equal access and proper use of the technologies for sustainable development of the agrifood value chain (AVC) by focussing on addressing the digital divide.

The enormous untapped potential of digital technologies has long been recognized by all stakeholders in the agriculture sector in the NENA region. Traceability is key to food safety and quality, as well as the efficient use of resources that directly contribute to a healthy diet, better livelihoods and the environment. Transparency promotes fair value distribution and the efficiency of markets, which can result in more inclusive and competitive VC development, particularly for the most vulnerable such as smallholder producers.

Therefore, the NENA region should act on the recommendations to facilitate digital transformation to improve traceability and transparency; reinforce linkage and preparedness for new business opportunities; ensure the flow of unadulterated information and fair value distribution along the agrifood value chains of small and medium-sized producers and promote socioeconomic and environmental sustainability in the agrifood sector for all.

1. Introduction

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1.1 Background

Developing efficient, resilient and inclusive agrifood systems is key to ensuring food and nutrition security, and socioeconomic and environmental sustainability. In the Near East and North Africa region (NENA), agrifood systems face inherent challenges such as the scarcity of water and arable land, vulnerability to climate change, protracted crises, rapid population growth and urbanization.[1] While food production is threatened, the demand for food is projected to increase. The negative effects of conflicts have exacerbated food demand; climate induced crises; increasing international prices for food and fertilizers; and the economic slowdown and disruption in the supply chain caused by the COVID-19 pandemic.

These macro-economic and social environments have stimulated the transformation of the agrifood value chains (AVCs) in NENA. Over the last decade, the volume of primary production showed a stable growth of 1.2 percent annually, whereas processed agrifood products were 3.1 percent,[2] and the food retail market in the region is expected to grow at an annual rate of 5.0 percent between 2020 and 2026.[3]

However, data suggest that AVCs in NENA have untapped opportunities for value addition. The NENA region's annual growth in value-added for agriculture was only 0.6 percent between 2011 and 2020, as compared to the world average of 2.6 percent.[1] Added value from food and beverage manufacturing in 2018 averaged USD 2.5 billion among NENA countries, whereas among Organisation for Economic Co-operation and Development (OECD) countries,[4] generated value addition is on average USD 24.5 billion. In particular, NENA has weak traceability and transparency throughout many food value chains (VCs), therefore, digital technologies could contribute to tracing food origins, providing information throughout the VCs and detect potential bottlenecks in a timely manner, while sharing all data to enhance price visibility, commodity flow and inform consumers.

Together with the limited capacity of logistics and the cold chain,[5] this weakness has led to inefficient supply chain management, which can potentially cause food loss; weak food quality and safety controls; a high risk of non-compliance to quality standards and rejection for export. Information asymmetries can lead to producers' low bargaining power and high transaction costs, and thus unfair value distribution for small and medium-sized actors such as smallholder producers and SMEs; for instance, on average, over 11 percent of food is lost between farm and retail in NENA.[6]

The unit rejection rate for export is higher in most countries in NENA than other regions because of food quality and safety issues: 43 and 39 percent of the reasons for rejection stem from problems related to labelling and contamination or hygiene conditions respectively.[7] Fair value distribution has been interrupted by information asymmetry (unequal access to information). For example, smallholder farmers dominate onion production in Egypt but only take 20 percent of total added value, while intermediaries take 60 percent and make minimal investments.[8]

Digital technologies can play an important role in ensuring quality control by enhancing the traceability of food origins and transparency of information throughout all VC stages, which can address the aforementioned challenges faced by small and medium-sized actors in NENA. According to the World Economic Forum (WEF) (2019),[9] technologies can strengthen the capacity of traceability and result in improved transparency and value across the supply chain by ensuring the collection of comprehensive and consistent data along the supply chain; real-time tracking of collected data; easy aggregation; integration; analysis and sharing of data.

Addressing the challenges faced by small and medium-sized actors in the VC, and unleashing the potential of traceability and transparency requires a high level of collective engagement that involves all AVC actors to

ensure functionality. These AVCs actors are continually seeking opportunities to transform their businesses and ensure they become more cost-effective and competitive. Since 2020, the COVID-19 pandemic has led to an increasing number of digital solutions that facilitate connectivity and reduce the barriers to the flow of goods in the region. In the NENA region, the Global System for Mobile Communications Association (GSMA) report shows that the number of mobile internet users exceeded 300 million in 2021 (70 percent of the population) with 4G as a leading mobile technology, with 5G services projected to reach an adoption rate of 17 percent by 2025.[10] According to the International Telecommunication Union (ITU), NENA's ICT development index[11] is estimated at 5.28 versus 4.93 for the world average; the penetration rate of active mobile-broadband subscriptions is 67 percent versus 87 percent and 41 percent respectively in Asia–Pacific and Africa; 30 percent of total connections in NENA have 4G; 65 percent of individuals have basic ICT skills in 2020; and ICT prices are affordable with mobile data and voice basket representing only 2 percent of gross national income (GNI) per capita in 2021. Nevertheless, as shown by the recent publication, digital technologies for improving traceability and transparency in NENA are still in their infancy and the region is not yet ready to take advantage of the opportunities.[12,13]

1.2 Rationale

Rationale of the study subject

To achieve sustainable transformation of agricultural value chains, through application of digital technologies, it is pivotal to "design systems to support the most vulnerable, least-connected farmers, and employ technology and data to create business models for new income streams, while ensuring that systems of redress and feedback exist for those in the system to highlight problems and find solutions."[14] Thus, it is necessary to analyse how the regional characteristics of agrifood systems affect the feasibility and type of digital technologies to apply and analyse how the technologies can benefit marginalized populations such as small and medium-sized producers and SMEs.

In view of this regional context in NENA, a feasibility study was undertaken on application of digital technologies to improve traceability and transparency along AVCs and improve our understanding of the readiness (maturity) of the olive oil and date sectors, benefits of the technologies in generating profits, in relation to their potential for enhancing inclusion and sustainability of rural communities, and the responsibilities of different actors in applying and promoting the digital technologies.

There are several reasons why it is important to study digital traceability and transparency systems in AVCs in the NENA region:[15]

- **Food safety and quality**: Improved traceability and transparency by digital technologies can help ensure food safety by tracking the journey of food products from farm to table and identify any potential contamination or safety issues. This can help protect consumers, maintain the quality of food products and increase marketability of produce particularly for small and medium-sized producers.

- **Consumer confidence**: In the NENA region, consumers are increasingly concerned about the origin and quality of the food they consume. By providing transparent and accurate information about the journey of food products, digital traceability and transparency systems can increase consumer confidence in the food they buy and consume, and increase willingness to pay for premium products that could contribute to higher income-generation for the most vulnerable actors.

- **Supply chain efficiency**: By improving visibility and accountability in the AVCs, improved traceability can help streamline operations and reduce inefficiencies. This can result in cost savings for producers, distributors and retailers.

- **Fair value distribution**: Consumers are more aware of ethical and social information underlying a specific product.[16] Improved transparency, achieved by digital technologies, can address information asymmetry for marginalized VC actors such as the small and medium-sized and can ensure value is equally distributed to enable sustainable production.

- **Sustainability:** Traceability systems can be used to support sustainable practices by tracking and verifying environmentally responsible production methods, reducing food loss, and minimizing CO_2 emissions from logistics and distribution. Traceability can address the issues related to the inefficient use of natural resources by smallholder producers and low capacity of business operations in small and medium enterprises (SMEs).

- **Food fraud prevention**: Digital traceability systems can help prevent food fraud by ensuring food products are accurately labelled and preventing the intentional misbranding of food products. Producers can decrease the risk of negative impacts of a distorted market mechanism, stabilize the source of income and improve the evaluation of produce quality.

Rationale for selection of sector and country

Rationale for selecting the horticulture sector

This study specifically focuses on the horticulture sector in the NENA region for the following reasons:

- **High value crops/cash crop:** Horticultural crops usually have higher value-addition and a comparative advantage compared to staple crops. The study aims to provide possible recommendations with a particular focus on the horticulture sector to increase profitability for small and medium-sized producers and enterprises.

- **Contributions to food security and nutrition:** Horticultural products contain a variety of nutrients for healthy diets and improved well-being of populations but most of them, such as fresh vegetables and fruits, are perishable and contribute to increased food loss and waste. Therefore, immediate action is required to attain efficient supply chain management for horticultural products so as to improve food security and nutrition.

- **Land and water scarcity**: NENA countries are mostly affected by climate change and face increasing difficulties in terms of arable land and water scarcity, thus posing challenges to cultivating and producing quality horticultural crops. The adoption of digital technologies can help improve not only productivity but also quality and marketability.

- **Demand for traceability and transparency**: Currently, the region is not very competitive on the international market, partly because of the limited capacity to meet international quality standards and the labelling and certifications required by different export destinations. Horticultural products are relatively perishable and the existing quality control system is underdeveloped. Moreover, consumers have become more cautious about sourcing sustainable products, while unfair value distribution is likely to occur with horticultural crops, as opposed to staple, since intermediaries control market information for export. Consequently, the demand for food traceability and transparency has forced NENA countries to address the above-mentioned issues along the horticulture VCs.

Rationale for selecting date palm and olive oil VCs in the horticulture sector

The study will dig deep into the two selected VCs – **date palm and olive oil** as representative subsectors in the horticulture sector to further analyse the need for digital solutions to improve traceability and transparency. The study can confidently claim the results of the case studies that focus on these two VCs can form the basis of the recommendations for the horticulture sector in the region, for the following reasons:

- **Well-established VC**: Date palm is considered as one of the most strategic crops and an important source of income in the region. Similarly, olive trees are valued by NENA countries and particularly represent Mediterranean culture. Both crops have a long history of being cultivated and are widely accepted by the population as traditional diets. The NENA countries have a considerable share of world production (76 percent for date palm and 30 percent for olives in 2020);[17] therefore, both crops are regarded as well-established VCs meeting the basic conditions for improvement in traceability and transparency.

- **Growing export demand**: NENA countries have a comparative advantage in producing date palm and olive oil, leading to a thriving domestic market and increasing demand from the international market. Growing demand drives the development of the subsectors and the need to adopt digital traceability and transparency systems to meet international export requirements.

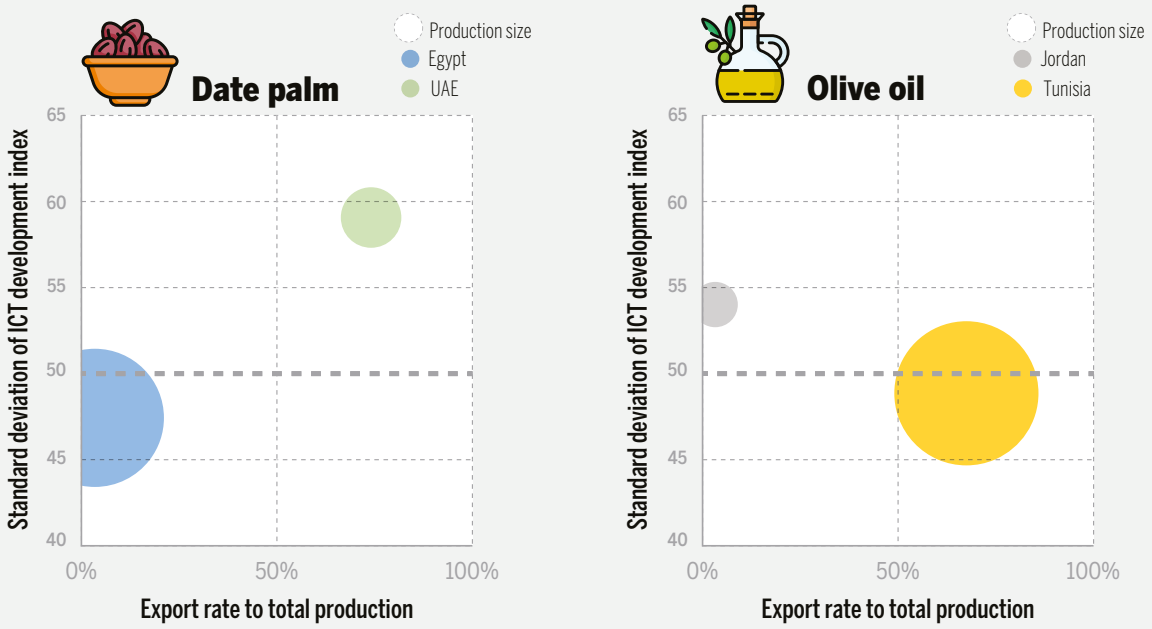
- **Social inclusion and environmental sustainability:** Date palm and olive oil are produced largely in rural areas by small and medium-sized producers and represents a substantial potential for employment. Moreover, both VC products are relatively tolerant to arid conditions. Adoption of digital traceability and transparency systems in the VCs can contribute to the inclusion of women and youth, job creation and increased incomes for small and medium-sized producers. Environmental sustainability may also contribute to improved use of natural resources and positively impact the climate.

Please see Annex 1 for the selection criteria and rationale.

Rationale for country selection

This study selected four countries in the NENA region for case studies to explore the commonality and scalability of digital solutions, as applied to VCs, and to provide possible recommendations for the entire horticulture sector at the regional level. Taking into account geographic diversification and the variety of characteristics in the VCs, in terms of market environment and digital landscape across the NENA region, the study selected two contrasting countries per VC. Each country represents a specific context including size of production, access to markets and ICT development. These countries are Egypt and the United Arab Emirates (UAE) for an analysis of date palm, and Jordan and Tunisia for olive oil,[18] see Figure 1. Egypt, for instance, produces more dates but is less export-oriented and has less developed ICT than the UAE date palm VC. All four selected countries have varying conditions of production, export and ICT development.

Figure 1: Bubble chart of country positioning



*Bubble size indicates the relative production size between countries in each VC. The X-axis indicates the export rate (proportion of export quantity in total production) showing if a country is export-oriented for the target VC. The Y-axis indicates a standard deviation of ICT development index among the four countries (50 is an average, the score above 50 means the ICT is more advanced than others and vice versa), which shows the relative development level of ICT in each country.

Sources: FAOSTAT. 2022. *Trade, crops and livestock products.* Rome, FAO; ITU. 2017. *ICT development index.* Geneva, International Telecommunication Union. www.itu.int/en/ITU-D/Statistics/Pages/IDI/default.aspx.

For the reasons listed in the section *Rationale*, the study takes an open-ended approach and investigates the existing and potential application of digital technologies to improve the traceability and transparency of selected AVCs by focussing on the benefits for small and medium-sized producers and enterprises; the role of multiple VC actors and stakeholders; and the role of international development agencies, including FAO, to ensure these technologies become more inclusive and optimize their contributions to sustainability of AVCs in the region.

1.3 Objectives

The feasibility study aims to achieve the following main objectives:

- Enhance the understanding of landscape on digital traceability and transparency systems and identify potential interventions from the perspective of AVC development in the NENA region.
- Examine the barriers and adoption (including low-entry point) of digital technologies to improve traceability and transparency systems, in particular for small and medium producers and SMEs at the national and regional levels.
- Identify potential need for support to operationalize the adoption of digital technologies at the national and regional levels.

- Raise awareness, improve resource mobilization and the engagement of donors in responsible investment in digital transformation in the agrifood sector.
- Provide recommendations and a way forward for policymakers and practitioners in the enabling environment to introduce and apply digital traceability and transparency systems in AVCs in the NENA region.

1.4 Methodology

Literature review

This study is primarily based on an extensive review of the literature to understand the current situation of the target VCs and digital ecosystem to identify key challenges and the enabling environment for traceability and transparency. The literature review lays the foundation of this report. Data and information were collected from the databases of international organizations, government websites, official reports, as well as research papers. Moreover, FAO internal technical reports were consulted and used as a reference.

Key informant interviews and consultation

Key informant interviews (KIIs) with selected relevant stakeholders were conducted to fill the information gaps identified during the literature review. This step helped the authors examine the current status of the VC, the feasibility and potential impacts of possible digital solutions (see Annex 2 for the list of interviewees). The target interviewees were carefully selected, and included focal points from government institutions and the private sector, as well as technical experts from the relevant subsectors. The paper was fine-tuned and finalized during consultations with target FAO Country Offices in the NENA region and technical divisions at FAO Headquarters.

Case study approach

The approach in this study follows the VC case studies to better understand existing enabling factors, and challenges or gaps in the different VCs, when adopting digital technologies for traceability and transparency in various situations and contexts. This approach goes beyond hypothesis and observations, which are common in feasibility studies, and brings granularity to the information presented in this document. This approach has facilitated the development of practical recommendations based on data, evidence and the realities in the selected countries.

As two countries with extremely different market and digital conditions were selected for each of the VCs, the case study also contains a comparative analysis of each group of countries to identify the conditions in which the feasibility of digital solutions could be positively or negatively affected. Such comparison can contribute to possible solutions that target different levels of maturity and development. Realistic findings from the case studies are further analysed to elicit commonalities and scalability of the recommendations for the horticulture sector across the NENA countries to reach a regional conclusion about the feasibility of adopting digital technologies to improve traceability and transparency.

1.5 Conceptual framework

The conceptual framework has six elements: key guiding questions; digital ecosystem for sustainable development of VCs; digital technologies as a business opportunity; the concept of traceability and transparency; concept of horticulture VCs; and barriers to, benefits and drivers of adoption of digital traceability and transparency systems. Key criteria are defined using the framework supported by the literature.

Key guiding questions

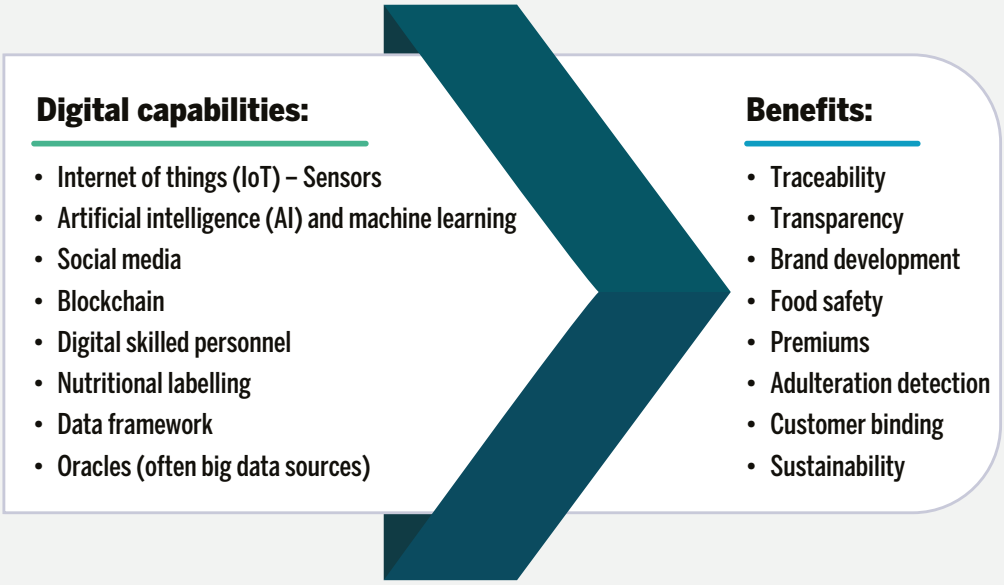
The study was developed to respond to the following questions:

- Is it feasible to apply digital solutions to improve traceability and transparency in selected VCs, and more broadly, the horticulture sector in NENA?
- What would be the recommended system for digital traceability and transparency systems and how would it be applied, and what would be the best approach to adopt in consideration of the risks and barriers to small and medium-sized producers as well as SMEs?
- What would be the role of the government and other stakeholders, including international development organizations, as well as FAO, to ensure the contribution of digital traceability and transparency systems in the sustainability and inclusiveness of the horticulture sector?

Digital ecosystem for sustainable development of agrifood value chains

First, it is necessary to understand the digital ecosystem for sustainable development of AVCs and its possible benefits. Figure 2 helps rationalize this with a capability – benefit model.

Figure 2: Capability benefit model



Source: Authors adaption of van de Wetering, R., Kurnia, Sh. & Kotusev, S. 2020. The Effect of Enterprise Architecture Deployment Practices on Organizational Benefits: A Dynamic Capability Perspective. Sustainability. 12. 1-21. 10.3390/su12218902

A recent report clarified the importance of the traceability data framework behind the VC,[19] and mentioned the concepts of key data elements (KDE) at critical tracking events (CTE).[20] Every actor in the agrifood system should/could generate KDEs at CTEs. The food commodity chain can be described as eight steps: agricultural inputs; farm operations; primary commodity trade; food processing; packaging; transport; storage; retail and consumption.[21] Every step may have one or more CTE where KDEs can be collected or transmitted. All this data can help realize the desired benefits. Likewise, the date palm and olive oil VCs work traditionally in silos and consumers are not well connected with producers.

Furthermore, producers suffer from weak bargaining power because they have limited market information (transparency issue). With digital capabilities, this situation can be changed completely, provided there is a clear vision of the required digital ecosystem. Overarching institutes can be of great value, when driving development of the data framework, to ensure all stakeholders speak the same digital language through sensors, mobile phones, big data, etc. This will ensure profitability and therefore sustainability. A high level of recognition of sustainable practices is required at any point in the agrifood system and a standardized data framework would support this objective. Speaking the same digital language requires interoperability of sustainability concepts.

Digitalization as opportunity

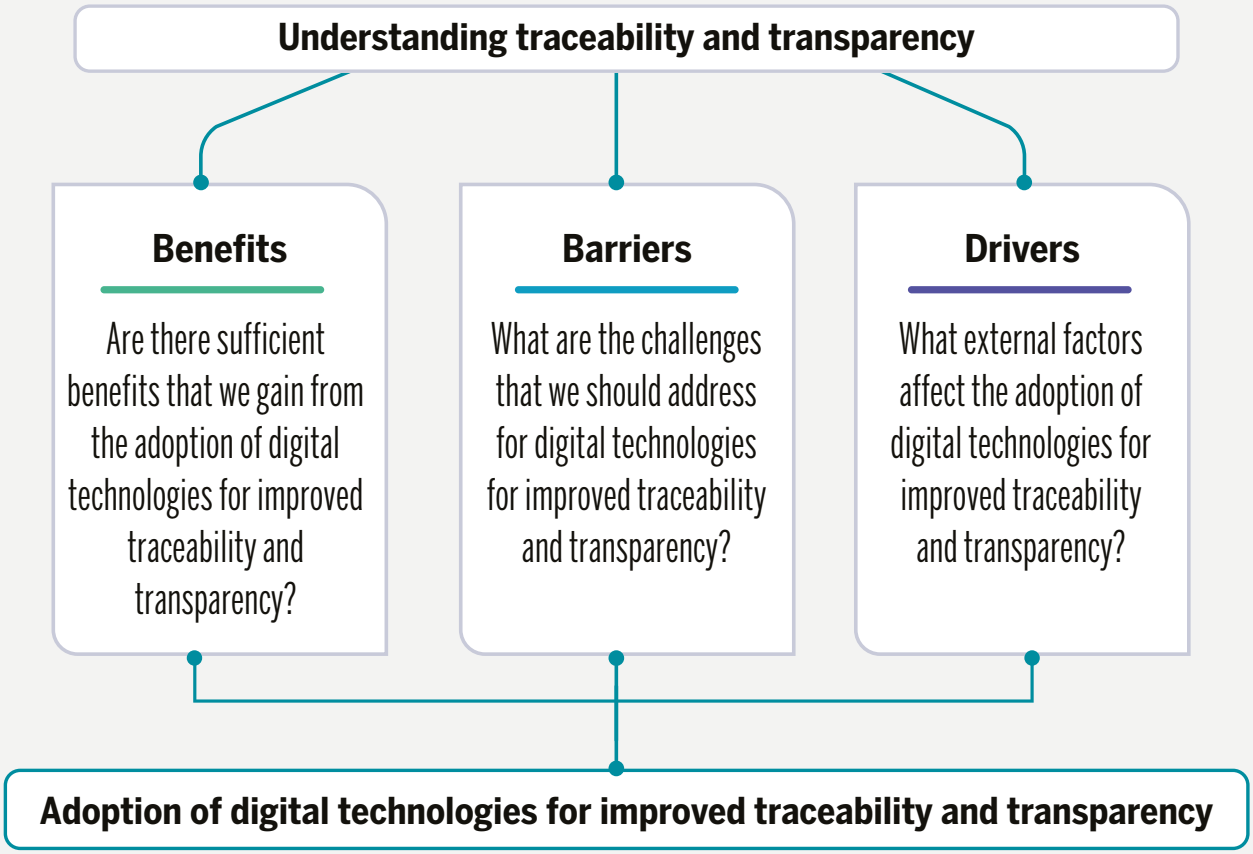
Digital technologies are becoming more available and open to everyone, thus providing potential opportunities. For example, the alliance behind digital public goods (DPG)[22] has formalized digital "things" such as open-source software, open data, open content, etc. for a more equitable world. Related to the previous section, the question is which DPGs are needed to support a flourishing sustainable agrifood system for VCs? What if all the fraud detection algorithms could be available to the public to eliminate fraud in VCs?

Every actor in the agrifood system would then only need to buy low-cost sensors to feed those algorithms. The same line of thinking can be applied to all the DPGs required to claim a premium price. If there were a plethora of DPGs for every actor in the agrifood value chain, the entry-level costs for entrepreneurs could be significantly lower. This would ultimately contribute to the promotion of inclusive agrifood systems that would benefit producers by increasing their bargaining power. Producers would gain more value by having equal access to information. Therefore, policymakers can support the large-scale development of DPGs for business development.

Adoption of digital technologies for improved traceability and transparency

Based on the theoretical framework,[23] it is important to consider the following points when adopting new technologies for improved traceability and transparency: understanding traceability and transparency, barriers to, benefits of, and drivers of adoption of digital traceability and transparency systems.

Figure 3: Framework of analysis



Source: Authors' own elaboration, adapted from Corallo, A., Latino, M.E., Menegoli, M. & Striani, F. 2020. What factors impact on technological traceability systems diffusion in the agrifood industry? An Italian survey, i, Volume 75, 2020, Pages 30-47, ISSN 0743-0167. https://doi.org/10.1016/j.jrurstud.2020.02.006

In this section, the study will elaborate the concept of traceability and transparency when applied to AVCs, as well as a few widely used digital solutions that establish systems for these two elements. Subsequently, the concept of the horticulture VC, and the existing models, will be examined in order to understand the benefits, barriers and drivers. A conceptual basis will be developed for the subsequent case studies.

Traceability

Traceability is defined as "the ability to discern, identify and follow the movement of a food or substance intended, or expected, to be incorporated into a food, through all stages of production, processing and distribution."[24] Benefits of traceability in AVCs include aiding approval from regulatory bodies for required certificates for example ECOCERT and ISO, optimizing food supply chains (e.g. reducing food loss), enhancing the ability to prevent food safety and quality issues (e.g. food fraud) and gaining customers' trust in food.[25]

The development of digital solutions includes gradually tackling complexity and ensuring that data collection and standardization become increasingly feasible and manageable. A list of examples of digital technology is provided in Table 1 and shows the possible solutions required to address the issue of traceability. These technologies are also being considered for case studies and recommendations.

Table 1: Examples of digital technology for traceability

Technology	Features	Required digital maturity[a]	Required investments	Target beneficiaries
Barcode/ QR code	"Barcodes were first introduced in the early 1970s and are still the most widely used track-and-trace technology in the food industry. The Universal Product Code (UPC) stickers on individual food packages, read by machines and scanners, contain information such as manufacturer code and product code that is verified at multiple stages across the supply chain."[b] 2D barcode, such as the QR code, is popular.	**Mid** (Requires mobile Internet access)	**Low** (Much software has been developed)	Consumers and all supply chain actors
Enterprise resource planning (ERP) and similar web-based tools	"Manage transactions of key business functions (sales, delivery, returns, production, procurement, finance)"[c] on enterprise technology. ERP is mainly used for internal management, as consumers are unable to access the database.	**Low** (Need Internet access and software)	**Low** (Much software has been developed)	All supply chain actors/ Public monitoring agencies
Radio frequency identification (RFID)	"Small RFID chips have long been used to trace data across different inventory systems. The RFID tags attached to product packages pick up the radio frequency signals sent by an RFID scanner. The RFID tags, in turn, send back signals to the RFID scanner, which decodes the encrypted data. RFID devices can be used to automatically scan products entering or leaving a facility."[b]	**High**	**Mid to High**	Advanced supply chain actors
Wireless sensor networks (WSN)	"WSN is an infrastructure-less wireless network that is deployed in a large number of wireless sensors in an ad hoc manner that is used to monitor the system, physical or environmental conditions. Sensor nodes are used in WSN with the on board processor that manages and monitors the environment in a particular area. They are connected to the Base Station, which acts as a processing unit in the WSN System. Base Station in a WSN System is connected through the Internet to share data."[d]	**High**	**High**	Advanced producers and processers
DNA barcoding	"DNA barcoding is a molecular based system, which allows scientists to identify particular species, by comparing short genetic markers in the specimen DNA with reference sequences. Its success depends on: i) the molecular variability between species and ii) the availability of high quality repositories of reference sequences."[b] DNA barcoding is mainly used for seeds, inputs and production.	**High**	**High**	Consumers/ advanced supply chain actors
Blockchain	"Blockchain technology can trace the journey of food from farm to table in order to improve transparency, speed recalls, and prevent food fraud. Blockchain-based traceability could give consumers the ability to scan a QR code displayed on the label of a food product and find out information about the product and its producers, processors, and journey, all the way back to the farm that grew it."[b]	**High**	**High**	Consumers/ advanced supply chain actors

Notes:
a The level of required digital maturity and required investments (low, medium and high) is a relative measure among the technologies to compare the requirement level, evaluated by authors.
b. eufic. 2013. *DNA testing of foods (Q&A)*. Brussels. www.eufic.org/en/food-production/article/dna-barcoding-a-new-tool-for-food-traceability;
c. World Economic Forum. 2021. *Digital traceability: A framework for more sustainable and resilient value chains*. White Paper September 2021. Geneva, WEF. www3.weforum.org/docs/WEF_Digital_Traceability_2021.pdf;
*d. GeeksforGeeks. 2020. Wireless Sensor Network (WSN). https://www.*geeksforgeeks.org/wireless-sensor-network-wsn

Sources: Kumperš–ak, *et al.*, 2019. Traceability Systems and Technologies for Better Food Supply Chain Management. *Quality Production Improvement* - QPI. 1. 567-574. 10.2478/cqpi-2019-007619; iGPS. 2020. *Food traceability technology: The tech making it easier to track food in the supply chain* https://igps.net/blog/2020/09/24/food-traceability-technology-the-tech-making-it-easier-to-track-food-in-the-supply-chain/; images from Zanzottera, L. 2017. *The role of digital technologies as support tool of agri-food traceability: a study case on the olive oil supply chain in Italy.* Politecnico di Milano. School of Industrial and Information Engineering. www.politesi.polimi.it/bitstream/10589/139321/1/2018_04_Zanzottera.pdf.

Transparency

Transparency is simply defined as "access to non-distorted, factual, relevant, and timely information about supply chain products."[25] The success of traceability and building trust is based on good transparency. In addition to mapping data along the supply chain, transparency in this report also refers to information asymmetry for all VC actors that may distort the transaction cost and distribution of fair value particularly for small and medium-sized producers. Therefore, the report focuses on both transparency of supply chain data as well as transparency of price and market information.

Real-time data and information could be realized by adopting digital solutions. With the emergence of advanced technologies such as IoT, big data, drones, remote sensing, etc. it is becoming easier to collect accurate and real-time data from the production system. Table 2 shows a list of possible digital solutions that can enhance transparency and will be taken into account in the analysis of the case study.

Table 2: Examples of digital technology for transparency

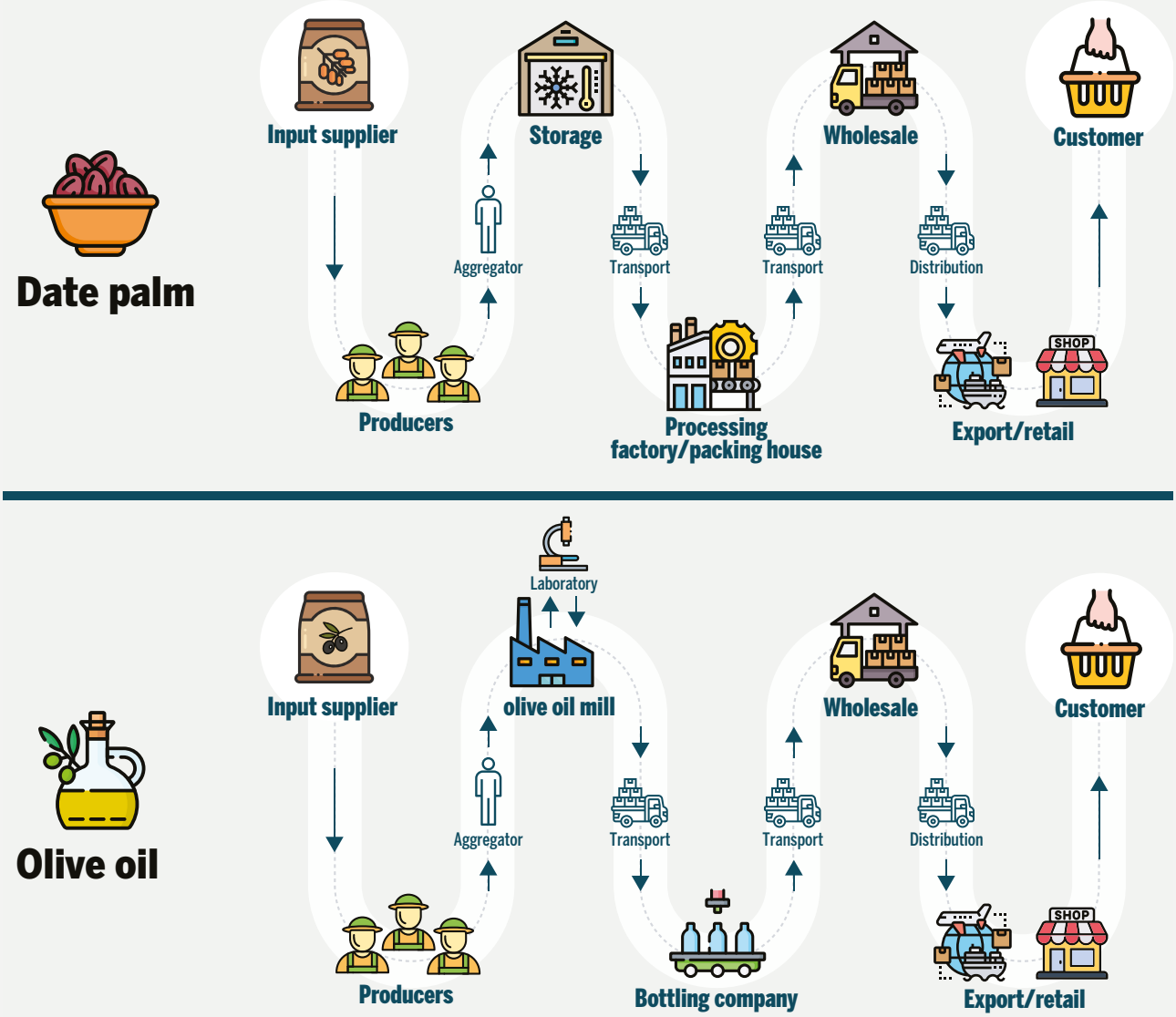
Technology	Features	Required digital maturity	Required investments	Target beneficiaries
Mobile applications	Mobile applications that embed data collection and e-payment functions that directly link producers with buyers can reduce intermediate actors and everyone can equally access information.	**Low**	**Low**	All suppliers and buyers
E-commerce (e-market place)	Link farmers/producers directly with buyers to avoid intermediaries and improve transparency of the supply chain. The products need to be qualified and certified following market standards.	**Mid**	**Mid**	All producers and buyers
Market information through digital channels	Market information system (MIS) provides real-time, tailored information. The information can be accessed through mobile applications, websites, or distributed through SMS/voice messages.	**Mid**	**Mid**	All suppliers and buyers/ government agencies
Monitoring technologies	Monitoring technologies include IoT, near-field sensing, remote sensing, satellite data, mobile phones and drones, RFID, etc.), which allow the tracking and monitoring of farm activities and generates direct, continuous, and real-time data and information.	**High**	**High**	Advanced producers and private sector
Blockchain	Algorithmic analysis built on technologies such as AI and machine learning to ensure the fidelity of shared information, including the data on transactions.	**High**	**High**	Advanced producers and private sector

Source: Authors' own elaboration adapted from Kos, D. & Kloppenburg, S. 2019. Digital technologies, hyper-transparency and smallholder farmer inclusion in global value chains. *Current Opinion in Environmental Sustainability.* 41. 56-63. 10.1016/j.cosust.2019.10.011

Horticulture value chain

As indicated in the section *Rational*, both the selected date and olive oil VCs handle traditional produce as both crops are tolerant to arid conditions and the region seeks to increase demand for export. See Figure 4, which illustrates a typical core flow for both VCs.

Figure 4: Simplified flow of date palm and olive oil value chains



Sources: Authors' own elaboration adapted from UNIDO. 2021. *Gender sensitive analysis of the palm date sector in Fayoum and Giza governorates.* Vienna; FAO & EBRD. 2015. *Tunisia. Analysis of the olive sector.* Rome, FAO & London, European Bank for Reconstruction and Development; FAO. 2019. *Dates value chain development in Egypt.* Rome, FAO. www.fao.org/egypt/programmes-and-projects/dates-palm/es/; and FAOSTAT.

Key characteristics of the date palm and olive oil VCs are as follows:

- **Long VC – High risk of supply chain inefficiency and information asymmetry:** Both VCs typically involve intermediaries, storage, processing, packaging and export companies, making the chain relatively longer than that for staples food, which has quick, direct market. A longer VC may result in higher transaction costs imposed by intermediaries and higher risk of inefficiency and information asymmetry, affecting the profitability of small and medium-sized producers. The level of VC governance is key to assuring quality and quantity of information to be registered throughout the VC.

- **Export-oriented – High risk of food safety and quality (including fraud) and transparency issues:** Since both VCs are produced as cash crops that are relatively oriented to export (14 percent of dates and 51 percent of olive oil production was exported from NENA in 2020),[26] the supply chain needs to meet customers' demands. Depending on the requirement level, a high standard of food safety and quality and certifications are prerequisites for profitable markets. This will influence VC actors' decision to improve traceability and transparency.

- **Predominant smallholder producers – High risk of unfair value distribution**: For instance, 70 percent of date producers in Egypt are smallholder farmers,[27] and 72 percent of olive producers in Tunisia are small or medium-sized.[28] The level of organization of these producers will affect the cost of collecting the necessary information; its timeliness and reliability will thus impact the feasibility of traceability and transparency. The level of organization may also affect producers' bargaining power, and may lead to unfair value distribution.

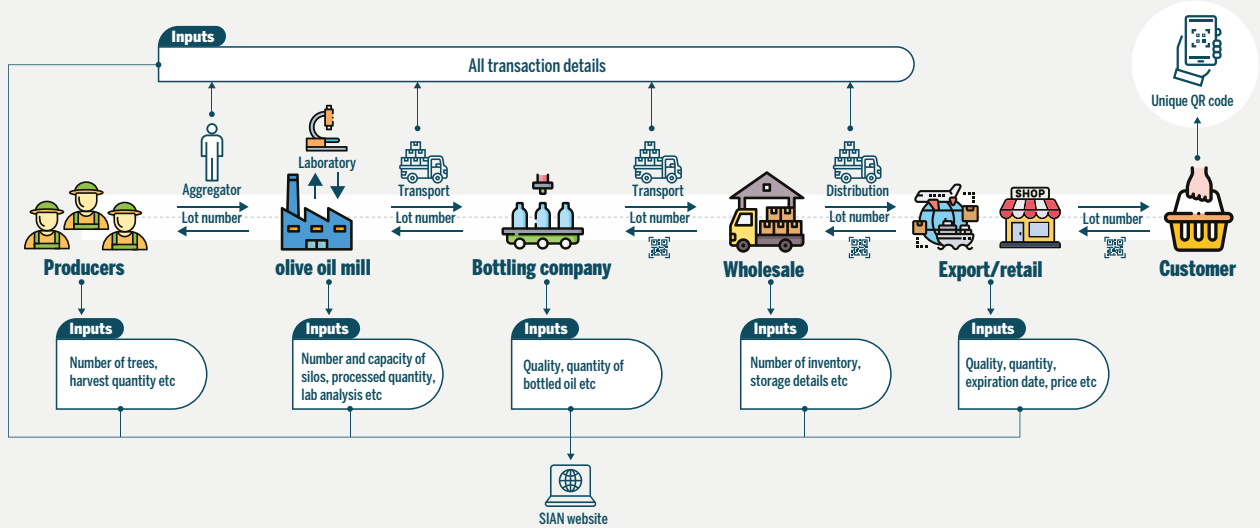
- **Perishability – Threat of food loss and loss of competitiveness:** Dates and olives require immediate post-harvest handling because they are highly perishable. Depending on the capacity of supply chain management, food losses and quality deterioration arise. This can negatively affect the profitability of business of all VC actors but particularly smallholder producers and SMEs who do not have sufficient capacity. The VC actors are motivated to reduce losses to increase profitability and in turn, demands for improving traceability and transparency will increase.

The traceability and transparency system can efficiently address the specific issues of the VC, as indicated above. Factors that stem from the nature of the VCs should be taken into account, so as to examine the feasibility of digital applications for traceability and transparency.

Existing model of digital traceability and transparency system

Figure 5 shows an example of the Italian Informative Agricultural System (SIAN), used as a supply chain traceability and transparency system in the Italian olive oil industry. Figure 5 illustrates how information flows as a system, who can access it, and the kind of information that should be collected. The study uses this model to extract the key benefits, barriers and drivers of adoption for a digital traceability and transparency system.

Figure 5: A simplified illustration of the Italian Informative Agricultural System: an olive oil supply chain showing the information recorded at each stage



Sources: Author's own elaboration adapted from the SIAN website: www.sian.it/portale-sian/home.jsp; European Commission. *Italian Informative Agricultural System* – AGEA (SIAN). https://joinup.ec.europa.eu/collection/egovernment/document/italian-informative-agricultural-system-agea-sian; and expert comments during key informant interviews.

There are **barriers** to adoption and implementation of SIAN: all actors must have access to the SIAN platform at any time with different access rights (*ICT infrastructure*);[29] coordination is required at each stage from production, aggregation, processing, wholesale to retail and export for data collection (*VC governance*);[30] collective input data provision needs to be reliable and trust level is high between actors (*social norms*);[31] nput data are standardized in line with requirements of certification and standards (*data management and standardization*);[32] data need to be correctly registered in accordance with an identification number that is assigned to each lot linked with a unique QR code on the final package, which is essential for customers so they can trace and confirm all information on food origin and processes (*digital skills*);[32] the government manages the registered data to protect and secure data quality (*regulatory framework*);[33] according to the study, adoption of new technology could also be affected by *perceived costs* of implementation,[35] and *cultural norms* such as risk aversion or future orientation (long-term or short-term oriented).[34]

Drivers of implementation: Stakeholders have used SIAN in Italy since 2014 because it is mandatory to register information with the government (*regulation*).[33] In other cases, private companies require initial investment costs and extension services as drivers (*access to finance* and *governmental support*).[35] Drivers are enabling factors that influence the rate of adoption of new technologies.

Benefits of implementation: Since incorporating the necessary devices and data management solutions into food supply chains generates new costs and risks, it is essential that the economic, social and environmental benefits for all actors involved are known so as to increase the motivation to engage in the traceability and transparency system (*benefits*). The incentives include all potential benefits from improved traceability and transparency such as *improving food safety and quality, meeting consumer confidence, increasing supply chain efficiency, contributing to sustainability, including reduction of food loss, and achieving fair value distribution*.[36]

Regarding the aforementioned features, the VC flow of Italian olive oil is similar to that of selected VCs in NENA, hence the paper uses these key factors (Table 3) in the following case studies, to identify the presence of clear benefits, and to what extent the VC addresses barriers and enables drivers to feasibly adopt a digital traceability and transparency system for VC actors, particularly small and medium-sized producers and SMEs.

Table 3: Key criteria for analysis

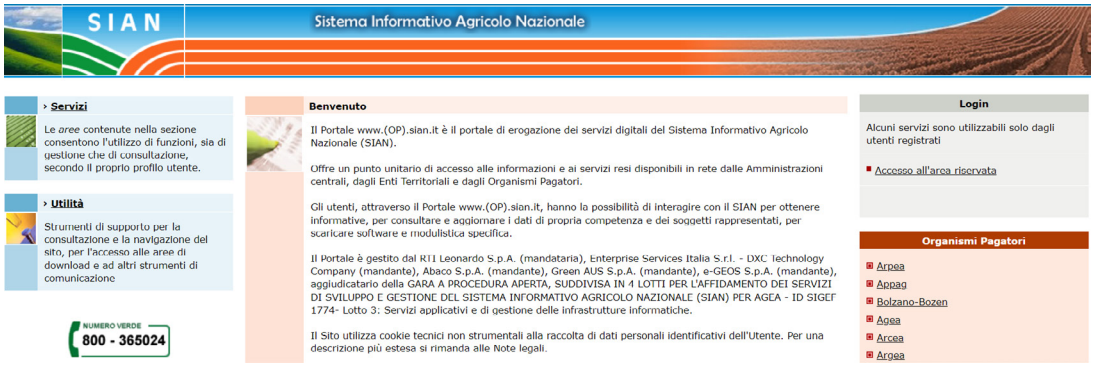
Category	Criteria	Rationale
Benefits	Food safety and quality (e.g. fraud prevention)	If markets demand many requirements for food safety and quality, VC actors have an incentive to improve traceability that can ensure food safety and quality by providing all information at any time. This helps prevent food fraud by ensuring that food products are accurately labelled and prevents the intentional misbranding of food products. This ultimately benefits smallholder producers in increasing marketability of their produce.
	Consumer confidence (e.g. certifications)	Consumers' confidence is an important factor to incentivize supply chain actors to improve transparency of food information because it can increase consumers' willingness to pay, and improves the marketability of products, by enabling certifications, particularly export-oriented VCs. This can result in higher incomes for the most vulnerable actors.
	Supply chain efficiency for competitiveness	If operational costs, caused by inefficient supply chain management, hamper the price competitiveness of a business, VC actors are incentivized to identify bottlenecks by applying the traceability system to address the issues.
	Sustainability (e.g. reducing food loss)	If huge food losses are recognized, caused by deterioration of quality as a result of poor supply chain management, VC actors such as SMEs are motivated to reduce losses to increase profitability. Improving traceability can contribute to identifying bottlenecks and addressing the issue of food loss.
	Fair value distribution (information symmetry)	Unfair value distribution occurs when timely and reliable market information is not accessible to all VC actors (low transparency). A particular group of actors with access can control or manipulate the price settings (the most vulnerable small and medium-sized actors have minimal bargaining power) and hence other VC actors have an incentive to access information at any time and increase their bargaining power.
Barriers to adoption	VC governance	If VC actors are not vertically integrated, sharing necessary information for products throughout the VC will be disturbed, thus negatively impacting the feasibility of traceability and transparency.
	Perceived costs	If VC actors perceive adoption of digital traceability and transparency systems as costly, or difficult to operationalize, motivation to adopt digital solutions will decrease.
	Social norms (e.g. organization, trust)	If producers are not well organized, and do not trust each other, the cost of collecting the necessary information will increase and timeliness and reliability of information will decrease, thus negatively impacting the feasibility of establishing the traceability and transparency system.
	Cultural norms	If VC actors are culturally risk adverse, or short-term oriented, they will resist adoption of digital technologies that could bring uncertain benefits and costs in the initial phase.
	ICT infrastructure	ICT infrastructure such as the mobile network, affordability, accessibility, availability and connectivity supports the uptake of digital technologies. It is also affected by the availability of existing digital solutions that can be used to improve traceability and transparency.
	Digital skills	Digital skills of VC actors support the uptake of digital technologies. If VC actors are unable to use the technologies, the adoption rate will decrease.
	Data management and standardization	Data collection, processing, analysis should ensure digital traceability and transparency systems are accurate and provide real-time information. Standardization of data collection, management, and analysis is crucial to ensuring consistency and compatibility across the supply chain.
Drivers	Regulatory framework/ government support	A supportive regulatory framework is important for protecting the privacy and security of data, as well as for ensuring that traceability and transparency systems are implemented consistently. Government support (e.g. policy/ministerial coordination/extension service) and/or regulation reduce(s) costs and/or risks and increases efficiency of implementation of digital solutions throughout the VC stages.
	Access to finance	Installing equipment and adding new activities to ensure traceability and transparency is an additional cost for VC actors, which can cause them to be hesitant about adopting technologies. Access to finance for VC actors will facilitate investment in digital solutions for traceability and transparency.

Sources: Karaa, M. & Morana, J. 2008. *L'utilisation de la traçabilité en Tunisie : le cas de la filière dattes et huile d'olive*. www.researchgate.net/publication/237419660_L%27utilisation_de_la_tracabilite_en_Tunisie_le_cas_de_la_filiere_dattes_et_huile_d%27olive;

Astill, *et al*. 2019. Transparency in food supply chains: A review of enabling technology solutions. *Trends in Food Science & Technology*. 91. 10.1016/j.tifs.2019.07.024;

GSMA. 2019. *E-commerce in agriculture: new business models for smallholders' inclusion into the formal economy*. Groupe Speciale Mobile Association. www.gsma.com/mobilefordevelopment/wp-content/uploads/2019/05/E-commerce_-in_agriculture_new_business_models_for_smallholders_inclusion_into_the_formal_economy.pdf; and Authors' own research.

Box 1. Examples of application of digital technology for traceability and transparency using the Italian Informative Agricultural System.



Sources: SIAN website (www.sian.it/portale-sian/home.jsp)

Introduction: SIAN is a public web-based traceability system where supply chain operators are required to access and enter data by law. It is a national public registry from farm to oil manufacturing firms across Italy to ensure traceability of food governed by the Ministry of Agricultural, Food and Forestry Policies. The SIAN started in 2014 as a mandatory traceability system, which took one year to be fully installed. The system requires users to have only the Internet and Wi-Fi to connect.

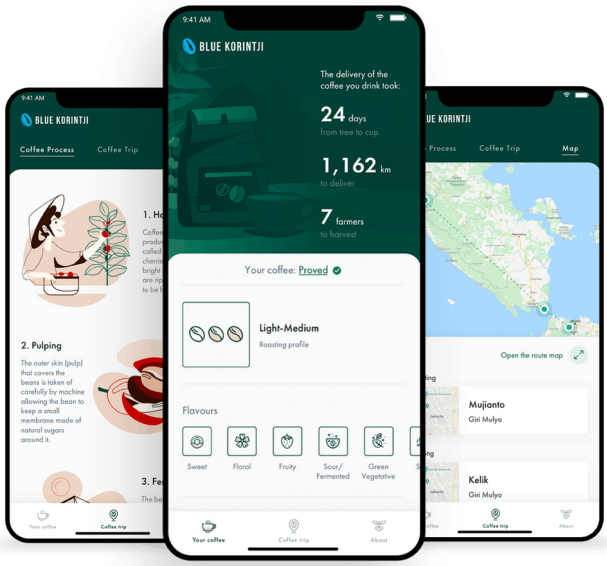
Purpose: The government's primary objective in using this invention was to prevent fraud. Before the SIAN, some olive oil manufacturers used to blend Italian olive oil with others from different countries, such as Tunisia, to reduce the cost of the product and gain a higher profit. As the government recognized the fraud, and how it negatively affected end-consumers, SIAN was developed. Today, the system is used for organic certification.

Operation: SIAN is user-friendly. Farmers, intermediaries, olive oil mill owners, bottling and exporting companies can visit the website, log in and register themselves. They need to input the required information such as the number of trees, harvest quantity, the number of silos and their capacity, quantity of bottled olive oil and price in accordance with an identification number that is assigned for each lot, which is linked to a unique QR code.

Cost and benefit: The estimated maintenance fee is USD 3 500 per year. There are many benefits for users such as certification and possible use of the information for marketing. All consumers can obtain information from farms, thus manufacturing companies can promote their brand and increase added value. Based on the key informant interview, the average price of olive oil before use of SIAN was EUR 3.50/kg, which has increased to EUR 5.00/kg because the issue of fraud has been addressed and there are value addition activities (Comments from key informant interviews).

Challenge: The only challenges are system maintenance and validation of data. Periodically, the government conducts audits to check all data have been entered correctly; although it is challenging to clear all input data as SIAN is a web-based, centralized barcode system.

Box 2. Example of application of digital technology for traceability and transparency: Blockchain-based traceability system for the coffee sector in Indonesia



Sources: EMURGO. Sales document for EMURGO Trace – Traceability and transparency software powered by blockchain technology.

Introduction: EMURGO Trace is a traceability and transparency solution combined with a "Target Facing App" and "Back Office App" developed by EMURGO, a global blockchain technology company. Back Office App is a web-based app that is available on mobile and desktop for all stakeholders to input relevant information.

Purpose: The technology was introduced to ALKO, a coffee cooperative in Indonesia to trace the origin of the bean's origin and increase its product value for export with support from a non-governmental organization (NGO).

Operation: Implementation involves farmers, collectors, processors and international buyers: farmers and collectors provide addresses and identities to verify information; a third party NGO assists with the processes; farmers take the coffee beans to registered collectors, then the collectors input price, weight and other information; the collectors process the registered batch and bring it with a QR code that has been generated by the system; ALKO scans the code with a mobile, registers the batch and generates a code for buyers.

Benefits: Blockchain has enabled stakeholders to provide and validate information along the value chain. It should satisfy consumers' interests for transparency and sustainable consumption. Eventually, consumers were willing to pay more as they had transparent information about the origin of the coffee, production and processing details.

Challenge: Farmers' behaviour is risk-adverse and sometimes farmers refuse to adopt new technologies. Thus farmers may require labour-intensive training.

Box 3. Example of application of digital technology for transparency: Electronic – National Market Agriculture (e-NAM), Indian digital marketplace for agriculture transparency

Sources: e-NAM government website: www.enam.gov.in

Introduction: e-NAM provides a Pan-India electronic trading portal that networks the existing *mandis* (agricultural markets) in India and has led to the creation of a unified national market for agricultural commodities. A total of 1000 markets in 18 states are connected to the e-NAM network, which gathers all information and services from e-Mandis.[a]

Purpose: e-NAM provides an integrated market on an electronic platform to facilitate the efficient flow of agricultural commodities, both at the state and national level. The platform also aims to improve the agricultural supply chain by reducing information distortion between farmers and traders, providing the real time commodity price to farmers and uniformity of procedures across the integrated market.

Operation: e-NAM software was developed by National Informatics Centre (NIC), Small Farmers' Agribusiness Consortium (SFAC) provide guidelines for setting up e-NAM at the national level and the State Agriculture Marketing Board implements e-NAM at the state level. The Board of Governors and Director of APMC monitors the implementation of e-NAM. The Ministry of Agriculture pays for the costs of integration, customization of software, training, etc. for local *mandis*. At every *mandi*, a lab will be established by the government to assess the quality of the commodity to be traded. The lab will provide a certificate and potential price of the commodity based on quality.[b]

Benefits: e-NAM is a platform where farmers can sell their produce at a competitive price. The central government provides Indian rupees (INR) 30 lakh (USD 36 670),[c] which is matched by the respective state governments to set up each e-NAM centre.

Challenge: Bottlenecks are related to the IT infrastructure, digital illiteracy, standardization of measurement, quality checks etc.

Sources:

a. Government of India. No date. e-NAM government website: www.enam.gov.in;

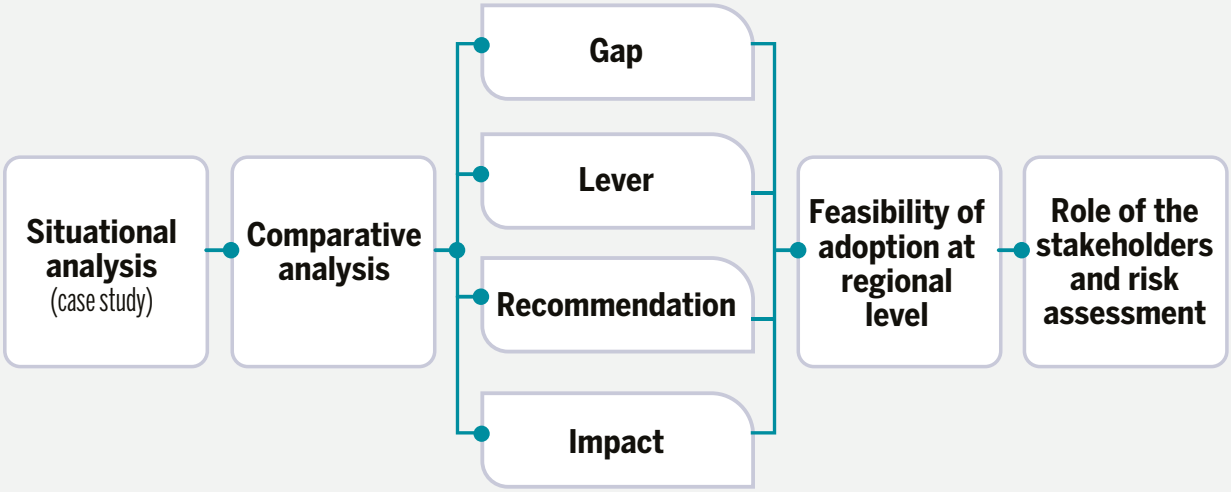
b. Mishra, G. & Bhatt, N. 2019. Evaluation of e-NAM Adoption: A Case of Jetalpur Mandi, Gujarat. 10.1007/978-981-13-7150-9_3. In: *Computing and Network Sustainability* (pp.21-29) www.researchgate.net/publication/332807260_Evaluation_of_e-NAM_Adoption_A_Case_of_Jetalpur_Mandi_Gujara;

c. Insights on India. Website. www.insightsonindia.com/social-justice/welfare-schemes/schemes-under-ministry-of-agriculture/e-nam-national-agriculture-market/ and Currency converter. Website. //www.xe.com/currencyconverter/convert/?Amount=3000000&From=INR&To=USD

Structure of the paper

This paper is organized as follows: based on the identified key criteria in three categories (benefits, barriers and drivers), Section *2. Situational analysis* presents case studies to demonstrate the situational analysis of the VC in each country regarding aspects of traceability and transparency. Section *3. Discussion*, summarizes the case studies and conducts a comparative analysis. Similarities and scalability of the diagnosis is also analysed to identify if the conclusion of the case studies will be able to represent the horticulture VC in the region. Finally, Section *4 . Conclusion* discuses the feasibility of traceability and transparency at the regional level, the role of stakeholders, and the support required from FAO and the risk assessment.

Figure 6: Illustrative flow of the study



1.6 Limitations of the study

The information and data presented in this study are a result of a comprehensive assessment of the available literature and consultation of known technologies. The collected information was not exhaustive, but nonetheless the evidence in this study can provide an accurate image of the status of the issues faced in the region and is sufficient for drawing informed conclusions and making practical recommendations concerning the feasibility of digital technologies within the scope of this study.

2. Situational analysis

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In this chapter, the situation of the date palm VC in Egypt and the UAE as well as olive oil the VC in Tunisia and Jordan is analysed to identify the challenges and opportunities to improve traceability and transparency using digital technologies. First, the study checks for a holistic overview of the VC at the macro level. Following are the diagnostics of the VC flow, focussing specifically on traceability and transparency-related challenges. Finally, the status of digital traceability and transparency development in the VC is assessed to evaluate the gaps that need to be filled to accelerate adoption.

2.1 Case Study 1: Date palm value chain

Egypt

Introduction

Date palm cultivation in Egypt has played a significant role in improving food security and nutrition as well as generating income in rural areas because of its large production capacity and high tolerance to arid conditions. The Ministry of Trade and Industry (MTI) stated, "date palm is a strategic crop, especially as Egypt is the world's top date producer with some 16 million palm trees, accounting for 18 and 24 percent of global and Arab production respectively."[37] Egypt is the largest producer of date palm with around 1.7 million tonnes of production per year, representing 17.8 percent of world production in 2020, followed by Saudi Arabia, Iran, Algeria and Iraq.[38] Over one million Egyptian families support the sector and 70 percent of those engaged in production are smallholder farmers.[37] The harvested area has increased by 25 percent in the last decade.[37]

Date palms are categorized as: soft (53 percent), semi-dry (17 percent) and dry (2 percent) (see Annex 3 for examples of Egyptian date varieties). The rest are unidentified varieties (28 percent), which have limited economic viability because of their low grade and production, and are processed into food ingredients to add value. Local consumers traditionally prefer to consume soft varieties of date palm such as Hayani. As dates are highly perishable, with high moisture content, dates are mostly marketed at local shops at a low price without specific information on production (lack of traceability). Thus, opportunities to add value are untapped and the volume of food loss during post-harvest handling through to retail is caused by the limited capacity of cold storage, which has become an issue. It is estimated that 30 to 40 percent of the soft varieties are consumed locally.[39] Experts have estimated that food loss could be over 60 percent of total production,[39] resulting in a significant reduction in profitability for the sector (inefficient supply chain management).

International markets have increased demand for the semi-dry variety of dates over others, which is the main reason why the export quantity of Egyptian dates was low, at around 30 000 tonnes, less than 2 percent of total production in 2020.[40] This figure is significantly low compared to other large date palm production countries such as UAE, Saudi Arabia and Iraq, exporting more than 200 000 tonnes with smaller production capacity. There is an opportunity for value addition as the average price for export is normally better than the average domestic retail price.

However, the proportion of exports to the European Union market, as a premium market, accounted for only 4 percent.[26] Inconsistent quality and quantity caused by shortages in cold chain facilities and poor packing weakens Egypt's export capacity. There is an opportunity where consumers in the European Union increasingly

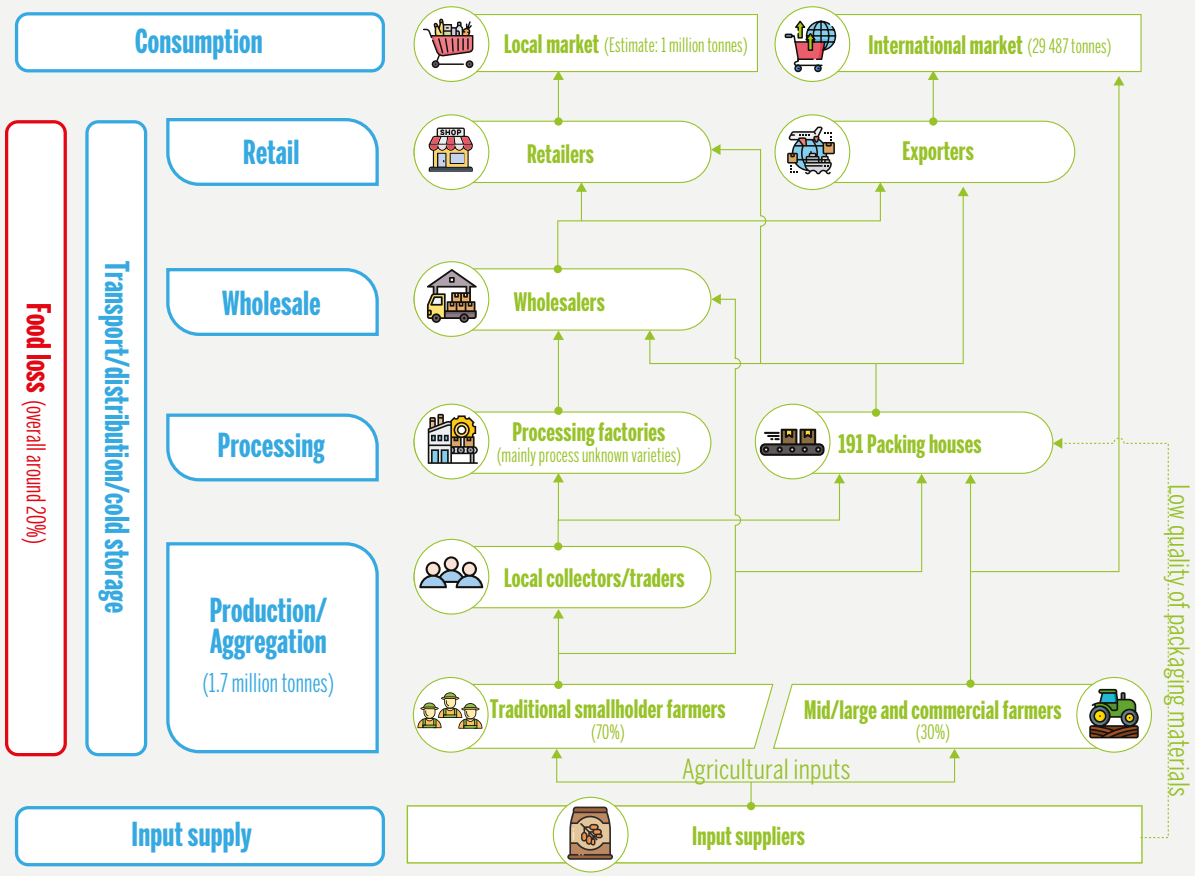
prefer organic products, but certification is uncommon in the Egyptian market. Moreover, food safety is one of the key issues in European food legislation thus acquiring international food safety certification is an export requirement (e.g. ISO22000, BRC Global Standard), another challenge is that few packing houses in Egypt comply with food safety management standards.[41]

However, it is noteworthy that huge efforts have been made in marketing of date palm exports, which has resulted in an increase in exported date palm. The National Date Palm Strategy was developed in 2016 during multi-stakeholder consultations. In response, a national project was launched in 2019 to plant 2.5 million date palm trees on 40 000 feddans in Upper Egypt.[42] During implementation of the project the supply chain in the newly planted area was improved. Recently more cold warehouses have been established for the storage of dates after harvest, and more refrigerated trucks are used for transportation. Yet, the expert said, government support for supply chain management is highly demanded.

Value chain flow

The date palm VC in Egypt is relatively long and comprises various key actors: input suppliers; producers; collectors/traders; packers; wholesalers; processors; retailers and exporters, see Figure 7.

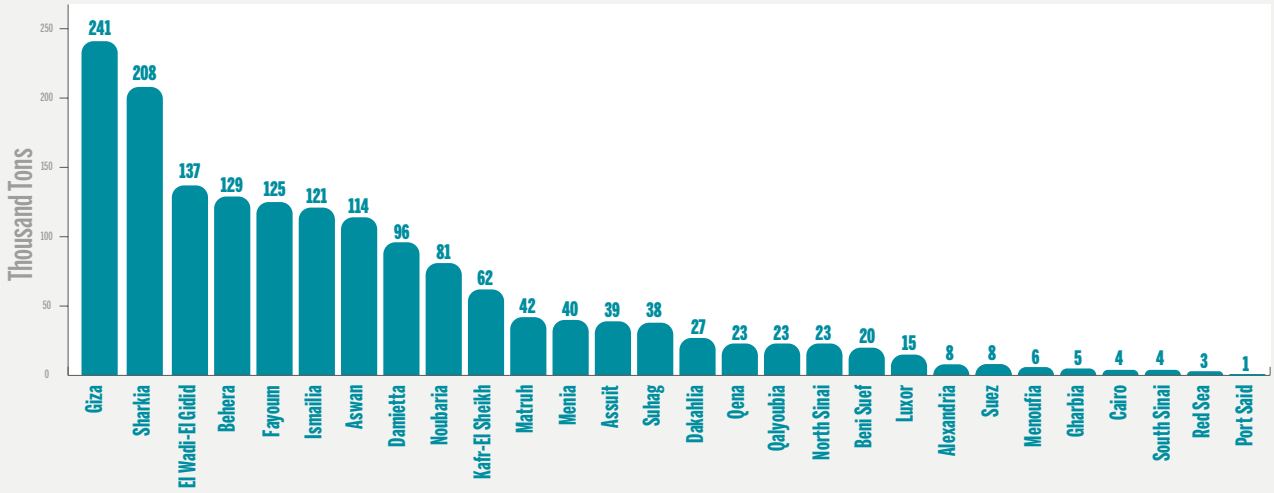
Figure 7: Egypt map of date palm value chain



Sources: UNIDO. 2021. *Gender sensitive analysis of the palm date sector in Fayoum and Giza governorates*. Vienna; FAO. 2019. *Palm dates value chain development in Egypt*. Rome, Food and Agriculture Organization of the United Nations. www.fao.*org/3/ca9013en/CA9013EN.pdf; and FAOSTAT.*

Starting with input supply, pests such as Red Palm Weevil (RPW) is a central issue, which may destroy the entire production of date palm; therefore pesticides are required, which are sometimes overused by farmers. Traditional smallholder farmers are predominant (70 percent) and are highly fragmented across the country[43] (Figure 8). The challenges faced by farmers include disorganized harvesting and limited access to marketing.

Figure 8: Date palm production across Egypt in 2018/2019 season (Unit: thousand tonnes)



Sources: Image from UNIDO, 2021. Original data are from the Central Agency for Public Mobilization and Statistics (CAPMAS) (Egypt).

Harvesting and post-harvest are the most important phases when maintaining the quality of dates, however, these phases are also the weakest links in the sector. Producers' poor harvesting skills make it difficult to maintain quality. Sorting entails getting rid of infected fruits and checking for ripeness, which is usually undertaken manually on farm by unskilled labourers who fail to provide proper attention and care. This results in inconsistent quality, which could be solved by using automated sorting machines.

Local collectors or traders may provide aggregation services, basic post-harvesting handling (drying, basic cleaning and storage of dates) before selling to either wholesalers, packers or directly to retailers. However, fragmented local farmers need to pay for transaction costs (unfair value distribution). Wholesalers buy dates from producers, often prior to harvest, packing and storing them in either open fields or cold storage depending on the type of date.

A total of 191 packing houses were built for collection and post-harvesting processes.[44] Normally, packing houses establish a direct sales contract with farmers to ensure there is a stable quantity of dates palm. Approximately 85 percent of farmers sell their dates directly to packers and 15 percent goes to collectors, traders or wholesalers. Most packing houses are traditional or semi-modern; few comply with food safety management system standards such as ISO 22000.[45] No clear mandatory quality standard is applied to the date palm sector in Egypt. Most unknown varieties, which are typically low quality and sold at a low price, are processed to add value and, for this reason, it is challenging to trace back for detailed food information.

Although most current Egyptian dates are categorized as a soft variety that require freezing, transport capacity is limited and the cold chain is not developed enough to cover all production and maintain a high quality after harvest.

The domestic retail market represents an instant selling point for producers with limited capacity to maintain quality. Currently, the most produced variety of date in Egypt is the soft variety, which is mainly sold cheap locally in rural areas as it is perishable. Semi-dry and dry varieties are preserved in cold chains and sold at supermarkets in urban areas at a higher price, although these are not the main products.

Generally, domestic consumers' interest in transparency of information and certification is minimal. On the other hand, the export market requires different types of documents on food safety. The National Food Safety Authority (NFSA) is the governing board for export clearance and requests and verifies documentation to ensure food safety. The Food Technology Centre (FTC) has developed a coding system for all exports to facilitate traceability and meet customers' demands but in reality, it is not recognized or implemented by VC actors in the private sector.[46]

Traceability and transparency-related issues

Benefit analysis:

- **High demand for food safety and quality:** Apart from the issue of variety, the VC actors all recognize that the constraints of value addition are mostly associated with food quality and safety issues throughout the VC and must be addressed by producers improving their harvest and post-harvest management; compliance with international sanitary and phytosanitary standards; food safety management system standards at packing houses, and acquisition of voluntary certificates.[27] In this regard, an improvement in traceability of information is requested so that bottlenecks in the VC can be identified and all data for certification collected. These actions can increase quality and, in turn, contribute to increasing producers' selling price.

- **Low consumer confidence:** As nearly 98 percent of dates are traded on the local market, consumer awareness of food transparency in the domestic market is not high, as consumers buy dates without considering the origin. Hence, general willingness to pay a premium for transparency in the local market is relatively low.

- **High demand for efficient supply chain management:** The relatively long value chain, with the various VC actors, results in inefficiency of supply chain management together with low capacity of logistics and cold storage.

- **High demand for addressing food loss and quality deterioration:** Sorting is manual by unskilled labour and the study found no standardized quality control system. A significant level of food loss occurs, resulting in a significant reduction in profitability for businesses involved. A traceability system would enable private sector actors, such as SMEs, to address food losses and increase profits.

- **High demand for fair value distribution:** A weak market information system is a challenge for all date palm VC actors, especially smallholder producers who have limited market access. Producers mostly rely on pricing set by buyers based on size and variety, as do packing houses and traders/collectors that are typically involved in negotiating price. Furthermore, there is a strong dependence on the nearest market, which means producers have minimal bargaining power. Hence, there is high demand from producers to explore market opportunities by improving transparency of information throughout the VC.

Barrier analysis:

- **High barrier to VC governance:** Vertical linkages do not work efficiently between VC actors, which results in the high level of food loss and deterioration in quality. The Union of Producers and Exporters of Horticultural Crops (UPEHC) is an apex organization that facilitates collaboration, members include small and medium-sized producers who have access to market information and training to improve their business capacity. The Union, however, does not fully facilitate coordination by the

private sector, which is partly because of land fragmentation. The Horticultural Export Improvement Association (HEIA) is active in the above-mentioned areas but mainly represents large-scale producers and exporters, not small and medium-sized producers or SMEs who are the majority of the actors in the date palm VC. Therefore, it is physically challenging to share information in a timely manner.

- **High barrier of perceived costs:** Findings from KIIs in the private sector revealed that installing a traceability system has a lower priority than physical quality control by machines or provision of cold chain storage because of the perceived costs. The rationale for this argument is that improvements in the quality or capacity of cold chain storage can bring immediate returns; a traceability system may require vertical integration that can only be accomplished by large commercial exporters; there is minimal awareness of the importance of transparency; and operationalization may require trust-based relationships among all stakeholders and require constant monitoring by the operator.

- **High barrier of social norms:** Production sites are scattered across the country and producers are not well organized. It is difficult to collect or share the right data at any time for traceability and transparency. Moreover, as contract farming is not commonly practiced, this implies that the level of trust among actors is low throughout the VC. This distrust could affect the reliability of recorded information.

- **High barrier of cultural norms:** The private sector focuses on short-term returns and there is lower priority for investment in digital traceability and transparency systems.

- **Moderate barrier of ICT infrastructure:** The fast-growing ICT sector is marked by 100 percent mobile ownership and a high penetration of the mobile network with nearly 100 percent coverage by 3G and 4G services.[47] The upgrade of infrastructure is mainly the result of the "Digital Egypt" strategy, where digital infrastructure is one of the three pillars.[48] A series of national projects was carried out by MCIT to strengthen connectivity and network speeds, including fixed broadband, mobile networks, fibre optics, which has resulted in Egypt having one of the best network speeds in the entire Africa region. Meanwhile, mobile phones are a pivotal tool for rural producers when obtaining advisory and information services, and online training, which can stimulate the market growth of e-commerce.

- **Moderate barrier of digital skills:** In 2022, 57 percent of the population had basic ICT skills.[47] However, the number of skilled and qualified workers is insufficient to meet the requirements of the new jobs in information technology sector. As with the date palm sector, the VC is supported by rural small and medium-sized producers and SMEs whose access to education is limited and digital literacy is potentially minimal.

- **High barrier of data management and standardization:** Data management and standardization have not been developed to capture accurate and timely information in date palm VCs in Egypt resulting in minimal application of digital traceability and transparency systems.

Driver analysis:

- **Weak driver of government support, regulatory framework:** The government attempted to introduce an automated traceability system.[46] However, the study did not find any centralized traceability and transparency system in place that can be practically used for the date palm sector and thus there is no regulatory framework.

- **Limited access to finance:** Predominant smallholder farmers in the date palm VC in Egypt have faced great challenges when accessing financial support, particularly from commercial banks. Lack of credit or other types of financial support may prevent them from investing in digital agriculture. Additionally, agriculture SMEs can only get 1 to 2 percent of the total credit provided.[49] This is a critical obstacle for those in the private sector who may be considering investments in digital traceability and transparency systems. However, Egypt is exploring ways to use digital solutions and agriculture fintech to help farmers and SMEs access credit. For example, the first agriculture fintech platform, Mozare3,[50] 60 targets smallholder farmers and provides them with access to embedded financial products that allow them to purchase inputs for production. Also, led by the Egyptian Credit Bureau, a web-based solution "I-SCORE" has been developed to conduct credit evaluation and risk assessment of farmers and SMEs to encourage financial institutions to increase lending.[49]

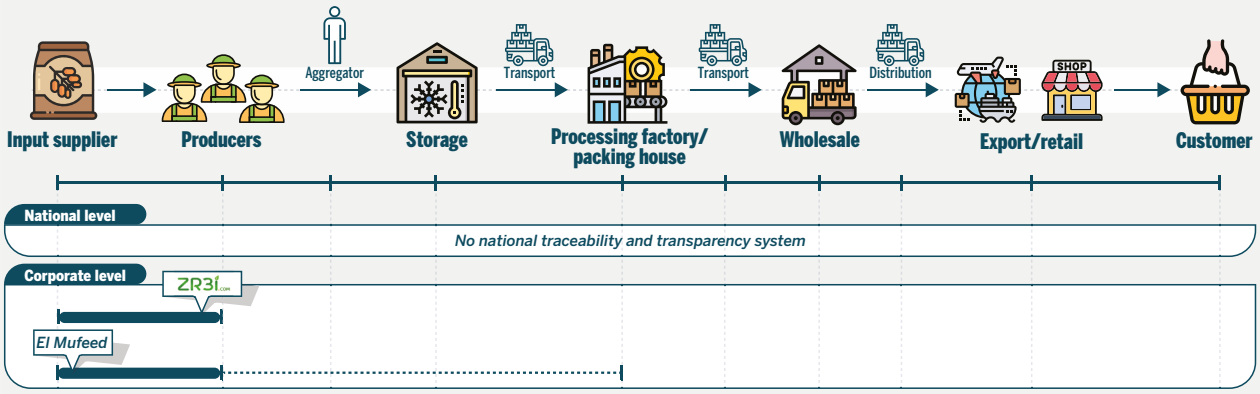
Technology application for traceability and transparency

The Government of Egypt started its traceability and transparency trial in 2004. The Egyptian Traceability Centre for Agro-Industrial Exports (ETRACE) was established with support from UNIDO. The centre is part of the technology centre network and helps VC actors meet international quality and traceability standards employing an automated traceability system.[46] However, because VC actors are fragmented, the system has not been mainstreamed.

Regarding the transparency of prices and market information, FAO supported Egypt in the establishment of an information network for smallholder farmers "HORTISUN".[51] This system supports the horticulture sector and includes a market module that provides precise market information, but it has not functioned since 2016. The mobile app "El Mufeed" has a specific function, to provide market prices for agriculture products, such as vegetables and fruits focussing on smallholder producers who tend to have limited access to extension services and market information. Although all information can be accessed, even without access to the Internet, the system is still in the process of being developed for scaling up.

The private sector is more active in exploring possible solutions. Taking ZR3i as an example, which is the first agriculture platform in Egypt, it is a software as a service platform, an information delivery system that deploys technologies such as big data analytics; artificial intelligence and machine learning; geographic information system (GIS); satellite imaging; mobile technology and cloud computing,[52] to improve data collection and ensure VC transparency and reduce the transaction costs for supporting smallholder producers. Through the app, producers can send real-time photos of their cultivation that can be saved as a QR code for traceability.[53] However, the system is not being used at the national level.

Figure 9: Egypt – Current situation of traceability and transparency system



Sources: Authors' own elaboration.

Egypt – Summary of the date palm value chain, a situational analysis

The study found no traceability and transparency system at the national level and a few digital apps only cover production information. Table 4, summarizes the findings of the analysis, and indicates that the condition of the VC for both traceability and transparency is not at a level that could benefit all stakeholders, particularly the fragmented small and medium-sized producers who are hardly able to share timely information. The overall condition for adoption of digital solutions is still underdeveloped in the date palm sector. Enablers, such as the regulatory framework and access to finance, do not fully alleviate the burden of adopting digital technologies.

Table 4: Egypt – Summary of situational analysis of date palm value chain

Criteria	Assessment
Current level of application of digital technologies for improved traceability and transparency	**Low**
Recognition of potential benefits	**High**
Food safety and quality	**High**
Consumer confidence	**Low**
Supply chain efficiency	**High**
Sustainability	**High**
Fair value distribution	**High**
Level of barriers	**High**
VC Governance	**High**
Perceived costs	**High**
Social norms (organization, trust in VCs)	**High**
Cultural norms	**High**
ICT infrastructure	**Mid**
Digital skills	**Mid**
Data management and standardization	**High**
Level of enabling drivers for adoption	**Low**
Regulatory framework / government support	**Low**
Access to finance	**Low**

Sources: Authors own elaboration.

United Arab Emirates

Introduction

The hot climate in the UAE causes date palms to flourish naturally. In 2021 dates accounted for 66 percent of the total crop cultivation area.[54] The UAE has the largest number of date palms of any country in the world with various commercially important cultivars such as Medjool, Khalass, Khenaizi, Fard, Lulu and Barhi.[55] Date palm is one of the strategically important crops as it contributes the most value to agricultural exports in UAE, which ranked tenth in world date palm production in 2020.[26]

The production of date palm in the UAE has increased over the last decade from around 240 000 tonnes in 2011 to around 330 000 tonnes in 2020, while the harvested area decreased from 41 159 to 38 422 ha in the same period, illustrating tremendous improvements in productivity of around 50 percent.[26] According to statistics issued by the UAE Government, production is highly concentrated in the Emirate of Abu Dhabi (ADE), over 75 percent of total quantity.[56] The UAE is also a major player in the international trade of dates, with 40 percent of the world's dates traded through the UAE.[57] Export is largely encouraged: more than 70 percent of total date palm production was for export in 2020 (240 652 tonnes) and the volume has stabilized, implying that the UAE has stable long-term clients. The main export partners are in Asia such as India and Bangladesh, aside from these, there are 98 other countries that are exporting partners.

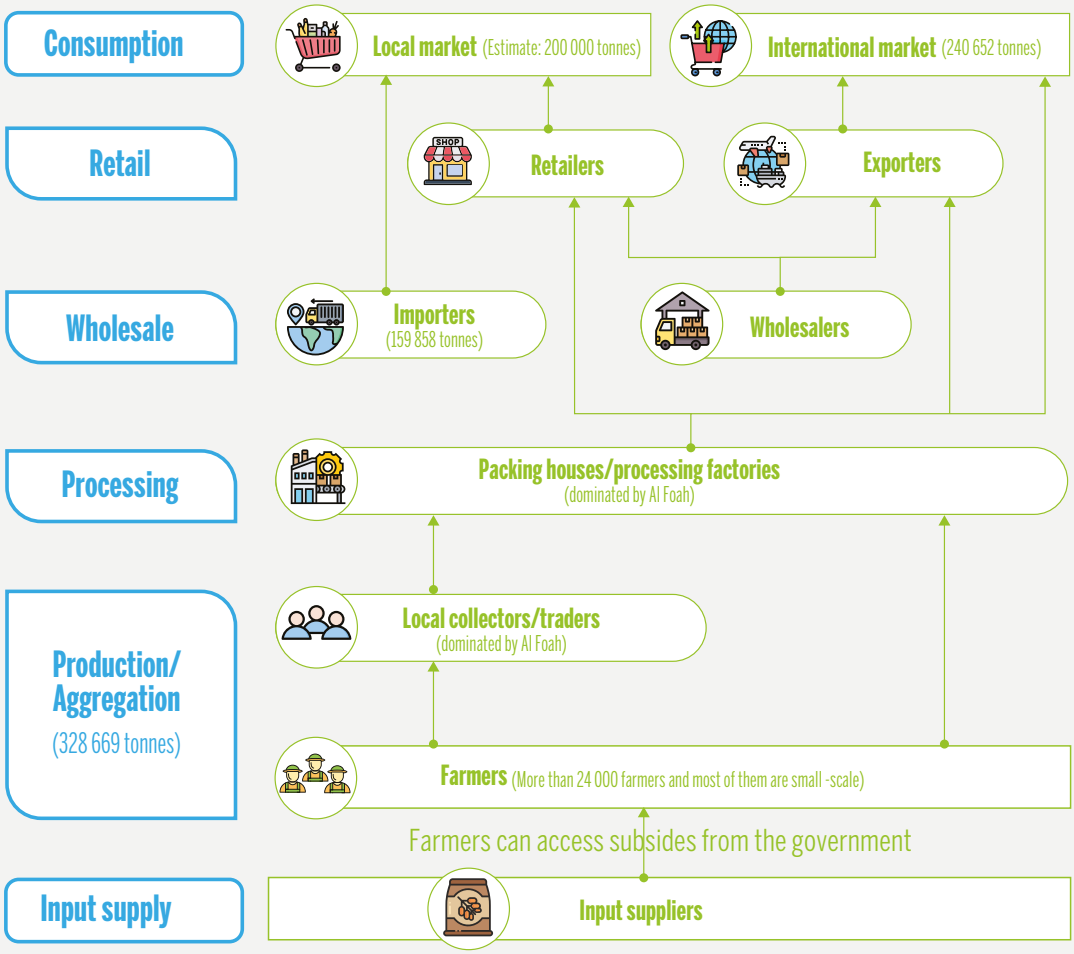
As the ADE contributes significantly to the national production of dates in UAE, the governance of the VC is highly advanced. According to the government's statistics report,[58] Al Foah, an ADE government-owned company, is dominant in this subsector, and produces and receives approximately one-third of total date production in the country and exports over 90 percent.[26] Al Foah has already acquired ISO22000 and other important certificates that enable the company to meet clients' demands concerning food safety and quality. In 2022, the Abu Dhabi Agriculture and Food Safety Authority (ADAFSA) introduced the Food Import and Export Management Information System (FIEMIS) that "supports food trade and import operations across Abu Dhabi's ports while ensuring food safety".[59] The system can incorporate requests for export food product certificates; disposal letters, and submits a customs declaration together with the exporting authority.

The research found that the UAE government and municipalities have developed food safety and quality systems. For instance, the Food Code 2020 was enforced in 2020 by the Food Safety Department in Dubai Municipality as a guideline to achieving a high level of compliance with food safety regulations.[60] In addition, in 2017 the Dubai Municipality launched "Food Watch", a digital platform for food safety and quality that enables residents to receive detailed information from farm to fork to attain a high standard of food safety.[61] In terms of transparency, the marketing avenues guarantee transparency of trade from farm to market and provide a healthy system of incentives so farmers can increase prices when quality improves.

The government has reinforced marketing for export. The annual Emirates International Date Palm Festival (EIDPF) has been held by Khalifa International Award for Date palm and Agricultural Innovation (KIAAI) every four years since 1998, and celebrates dates and date trees as an integral part of the history and cultural heritage of the UAE. In 2014, the festival attracted more than 175 exhibitors from over 15 countries, and approximately 25 000 visitors, including many tourists. The festival fosters international technical cooperation on different aspects of the date palm production chain.

Value chain flow

Figure 10: United Arab Emirates: Map of date palm value chain



Sources: FAOSTAT; Dhehibi, B., Mohamed Ben Salah & Aymen Frija. 2019. Date Palm Value Chain Analysis and Marketing Opportunities for the Gulf Cooperation Council (GCC) Countries. *Agricultural Economics - Current Issues*. IntechOpen. doi:10.5772/intechopen.82450; and author.

With all the available information, the study observed that, in most cases, the VC tends to be short because it is vertically integrated by the dominant players. Key actors include input suppliers, farmers, collectors and traders, wholesalers, packers, retailers and exporters. The most important feature of the VC is that Al Foah predominantly governs sales and marketing for both domestic and international markets although private actors are gaining relevance in the last few years: Al Barakah Date Factory located in Dubai is an example of a large collector, processor, importer, exporter, and retailer; Liwa Dates, although on a smaller scale, is also similar and has its own production sites. The high market concentration enables VC actors to easily coordinate and streamline the environment for producing high quality date palm such as Al Foah, extended its reach to most producers and streamlined logistics based on the operational needs at any time.

In the UAE, more than 24 000 farmers produce dates.[62] According to the Ministry of Economy, only 40 cooperatives are functional across all sectors, including agriculture,[63] implying that organizing cooperatives or associations is not a common practice. The best practices for post-harvest handling are provided farmers by ADAFSA to increase income and the quality of dates.[64] In addition, Al Foah defines the good and average quality so that most farmers can understand what is required for quality and can harvest carefully to receive a better income. In the UAE, a considerable share of date palm is directly traded to packing factories before export.[65] Since 73 percent of production was for export in 2020, and fragmented farmers in all production

areas tend to sell at the nearest markets, local intermediaries do not appear to have much power over the value chain.

Export takes around 70 percent of date palm directly from the farm; around 30 percent goes for animal feed, local wholesale markets do not have a significant presence in UAE. Al Foah has eight receiving centres across the country that collects date palm; 85 docking stations handle 60 000 truckloads per season. This allows the firm to fully control logistics and maintain a high quality of dates to ensure a high price.[66] The company has also invested in improvements to washing lines, production and packaging hence it complies with multiple European Standards including BRC, ISO22000 and is Kosher certified.[67]

Besides, concerning the recent development of its operation, since 2014 Al Foah is in partnership with a United States-based food safety company, RF Biocidics, to ensure the highest quality.[68] From production to export is a vertically integrated process, which is governed mostly by Al Foah. For value addition activities, Al Foah has a wide-range of product lines: date halva, syrup, paste, bars and plain dates. Its quality packaging and high quality dates allow it to attract suppliers from outside the UAE.

On export, ADAFSA, a local authority for food safety and security in ADE, controls and inspects imported and exported food including date palm. Al Foah appears to be the largest exporter, in collaboration with ADAFSA and other private exporters, which contribute to almost half of the exported amount. In cooperation with Al Foah, in 2022 ADAFSA launched eZad, an e-platform, as an alternative sales channel to trade dates and improve the transparency of market information for producers in ADE.

Traceability and transparency issues

Benefit analysis:

- **High recognition of food safety and quality:** The export market requires compliance with mandatory and voluntary quality standards and VC actors recognize the importance of food safety and quality to increase exports. Al Foah, plays a central role in the date sector, and has established a traceability system that fully controls the supply chain to ensure products meet the required standards. In addition, ADAFSA has provided guidance on good practices to small and medium-sized producers for post-harvest management.[63] The ADE state-owned company, Al Foah, has an extensive vertical network of 24 000 producers and provides standardized quality standards and invests heavily in improving post-harvest handling and management. Thus, the company has a reputation for high-quality date production in international markets and for providing incentives to smallholder producers to improve quality to receive a better income.[57]

- **High demand for transparency from end-customers:** Most dates are exported, meaning that the country fulfils requirements for information transparency in international markets. To ensure the required transparency, exporters in the UAE such as Al Foah have, in most cases, developed a direct relationship with farmers. The transparency of quality standards, prices and accessible support benefits producers, especially smallholders who are encouraged to sustainably engage in production and improve quality.

- **High demand for supply chain efficiency:** Supply chain infrastructure is developed and managed by Al Foah and ADAFSA to expand exports. To ensure the supply chain is efficient, and to fully control logistics, receiving centres have been set up across the country, with 85 docking stations that handle 60 000 truckloads. This sophisticated supply chain management can optimize operational activities and permit producers to sell dates in a timely manner.

- **High demand for reducing food loss and quality deterioration:** Reduction of food loss and quality deterioration is well considered in the UAE to increase the profitability of business. There is high demand for strengthening the traceability system to further improve the efficiency of the supply chain.

- **Moderate demand for fair value distribution:** Most farmers can sell their dates directly to the local market at prices set locally; they can market them to the packing factories at a pre-established price or use the e-platform to obtain a price in real time. In any case, farmers are informed of the price. Moreover, eZad and the Al Foah app are two e-services that can be accessed by date palm VC actors working with Al Foah, which provides an online trading platform and e-marketing services. Transparency of market information is already well developed in ADE, which produces most of the dates in the UAE, although the e-marketing services do not appear to cover all geographic areas in the UAE.

Barrier analysis:

- **Low barrier of VC governance:** Vertical linkages from farm to retail or export are very strong mainly because of the presence of Al Foah, which has led to effective information recording for traceability.

- **Low barrier of perceived costs:** The sector is highly governed by the ADE state-owned company; therefore investments in traceability and transparency are made by the public sector, making it easy for other VC actors to engage with the system.

- **Moderate barrier of social norms:** Farmers are fragmented in the VC. Independent farmers are not usually organized into cooperatives or associations. This is a potential disadvantage for the gathering and assurance of the quality of relevant data. However, Al Foah has arranged for receiving centres to address this challenge, although the entire production area in the UAE is not yet covered.

- **Low barrier of cultural norms:** The VC actors are oriented to long-term planning. For example, Al Foah stated its midterm strategy to enable producers and stakeholders to invest in date palm over the long term and to accept the immediate costs. Consequently, digitalization for traceability and transparency has been advanced.

- **Low barrier of ICT infrastructure:** The UAE is one of the most advanced countries in the NENA region for digital maturity, as it was ranked first for 23 indicators that include mobile broadband subscriptions; mobile broadband Internet subscriptions; mobile network coverage per capita; wireless broadband; etc.[69] Currently, the country has realized 100 percent mobile and Internet services that are affordably priced (below 1 percent of GNI),[46] which has generated a solid Internet infrastructure for establishing a digital UAE.

- **Low barrier of digital skills:** The latest data from ITU on digital skills shows that 89 percent of individuals have basic ICT skills, while 74 percent have standard skills, making the UAE a leading country in the region for level of digital literacy.[47] To equip the younger generation with the necessary ICT skills, the country has announced a number of strategies and policies, including the UAE National Innovation Strategy and the National Strategy for Advanced Innovation.

- **Low barrier of data management and standardization:** The UAE has made efforts to regulate its food traceability and transparency system. In 2008, the ADAFSA announced regulations for food traceability and recall, which clearly define the minimum information required for the business food operator. In 2020, the Abu Dhabi Good Agriculture Practice Standard Control Points and Compliance

Criteria further regulated the traceability system for each stage of the VC as well as aspects associated with traceability.

Driver analysis:

- **Strong government support and regulatory framework**: The government has invested in digitizing the supply chain. The AgriTech Sector Development Team was established in 2020 to establish policies and interventions and address the local production gap through the adoption of digital technologies. Besides, making the UAE the world's best in the Global Food Security Index by 2051, the National Strategy for Food Security emphasized development of a comprehensive national food system using modern technologies to enhance local production through traceability capabilities.[70] Moreover, the government has enhanced digital literacy and technologies such as AI, which has been integrated into the education system.

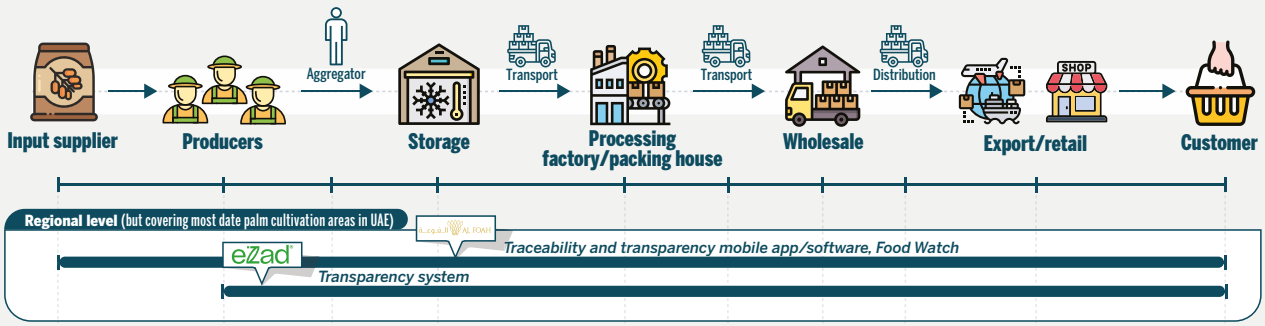
- **High level of access to finance:** Al Foah contributes to increasing access to finance. According to the report, in 2015 the company paid instalments of UAE dirham (AED) 427 million (USD 116 million) to over 18 000 farmers for marketing their dates.[68] The Khalifa Fund and the Agricultural Investment Fund are also financing institutions for farmers. Digital Payment has experienced tremendous growth, with an annual rate of over 9 percent between 2014 and 2019.[71] Farmers increasingly prefer the digital payments method and the easy access to credit.

Technology application for traceability and transparency

The UAE has the most integrated date palm VC and shows a high level of digitalization across the different stages. The ADE state-owned company Al Foah has its own traceability and transparency mobile app/software and full quality control throughout the supply chain that ensures its products fully meet European Standards.[72] Currently, the country is extending traceability to tissue culture before the production stage, which allows for traceability starting with the mother tree, labelling with the necessary DNA and other required information. Meanwhile, the auction function of eZad can help improve price transparency and ensure that date palms are less prone to price deterioration. A certification system helps farmers to list dates on eZad for grading to market standards and to contact buyers directly around the world.

Around ten traceability mobile apps and software are available in the UAE for individual or business users, which help to improve food traceability and ensure quality management. These apps include Food Watch, developed for the Dubai Municipality, which integrates the technologies of big data and the IoT along the food supply chain. Although the study was unable to find nationwide digital traceability and transparency systems, most cultivated areas of date palm in the UAE are covered by the above-mentioned technologies that are supported by governmental entities to ensure traceability and transparency.

Figure 11: United Arab Emirates – Current situation of traceability and transparency system



Sources: Authors' own elaboration.

Summary of the date palm value chain, a situational analysis

The UAE has demonstrated different scenarios for date palm development in other countries. The maturity and strength of UAE date palm is closely dependent on the ADE state-owned Al Foah and ADAFSA successes, while the study faced a scarcity of information on the private sector. As summarized in Table 5, needs for the traceability and transparency are at high level and the government has invested in meeting increasing demands from markets and smallholders' sustainable production of dates. The UAE does not perfectly satisfy all the required conditions for digital traceability and transparency systems, although the country has implemented countermeasures to reduce the risks of operational dysfunctions in the system.

Table 5: United Arab Emirates – Summary of situational analysis of date palm value chain

Criteria	Assessment
Current level of application of digital technologies for improved traceability and transparency	**High**
Recognition of potential benefits	**High**
Food safety and quality	**High**
Consumer confidence	**High**
Supply chain efficiency	**High**
Sustainability	**High**
Fair value distribution	**Mid**
Level of barriers	**Low**
VC Governance	**Low**
Perceived costs	**Low**
Social norms (organization, trust in VCs)	**Mid**
Cultural norms	**Low**
ICT infrastructure	**Low**
Digital skills	**Low**
Data management and standardization	**Low**
Level of enabling drivers for adoption	**High**
Regulatory framework / government support	**High**
Access to finance	**High**

Sources: Authors' own elaboration.

2.2 Case Study 2: Olive oil value chain

Tunisia

Introduction

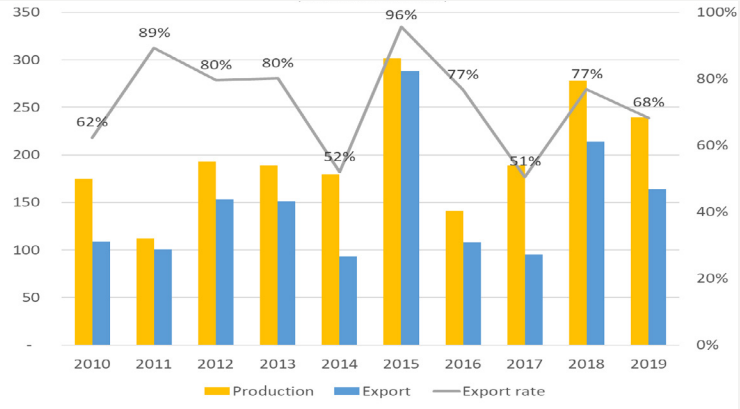
The olive oil industry is economically and socially pivotal in Tunisia. The VC largely contributes to the achievement of national goals for economic development, food security, employment, increased export earnings and preservation and enhancement of natural resources. The share of the value of olives (table and oil) for total agricultural products in Tunisia accounted for 17.5 percent in 2020 and olive oil exports comprised 58.4 percent of the total value of the export of crops and livestock products.[26] Tunisia ranked fourth after Spain, Italy and Greece as an olive oil producer in 2019, producing 7.7 percent of world production (around 240 000 tonnes). The trend of Tunisian olive oil production shows a positive increase by 60 percent between 2009 and 2019.[26]

Olive oil is the top of agricultural exports in Tunisia. In 2019, 68 percent of the total production of olive oil (around 160 000 tonnes) was for export, out of which 63 percent went to the European Union. The export volume shows a positive trend increasing by 15 percent between 2009 and 2019. According to the International Olive Council (IOC) (2017),[73] and an industry expert, 70 to 80 percent of Tunisian olive oil production is categorized as extra virgin olive oil (EVOO).[74] The biggest challenge for exporters is the low price bulk olive oil is sold. In fact, only 6.3 percent of exports were bottled olive oil and the average price for bottled olive oil was USD 5 000/tonne, while bulk olive oil was USD 3 500/tonne (70 percent of bottled) in 2012 although the data is out-dated.[75] Because of this challenge, the average unit value has not increased and has remained 50 to 60 percent lower than Italy's olive oil and 30 percent lower than Spain's.

Most high-quality olive oil went to countries in the European Union in bulk and was processed as bottled oil for sale to international markets. In other words, Tunisia is losing significant value to external markets. To address these issues, the government has applied subsidies to packaging and has encouraged exporters to export bottled olive oil, although packaging costs are still burdensome as Tunisia does not produce enough bottles and relies on imports from Italy and China. A cooperation agreement was signed by the European Union with Tunisia to export up to 56 700 tonnes of duty-free olive oil to EU Member States annually, resulting in increasing exports to the EU. New measures were introduced in 2022 to enhance the traceability of Tunisian olive oil products. As such, for exporters to obtain authorization for export, they need to provide detailed information on their requests, including importer partner data and a copy of the sales contract.[76]

An opportunity for producers is that the sector has strengthened exportation of organic olive oil. Despite organic olive oil accounting for 40 percent of total production, producers have not yet obtained organic certification, which results in minimal value addition to their selling price.[77] Tunisian organic olive oil accounts for only 12 percent of total exports but the price is 10 percent higher. The export market has a greater potential for higher profitability of the market owing to organic certification and the country has already succeeded in acquiring sustainable trade partners.

Figure 12: Olive oil production and export trend (2010-2019)

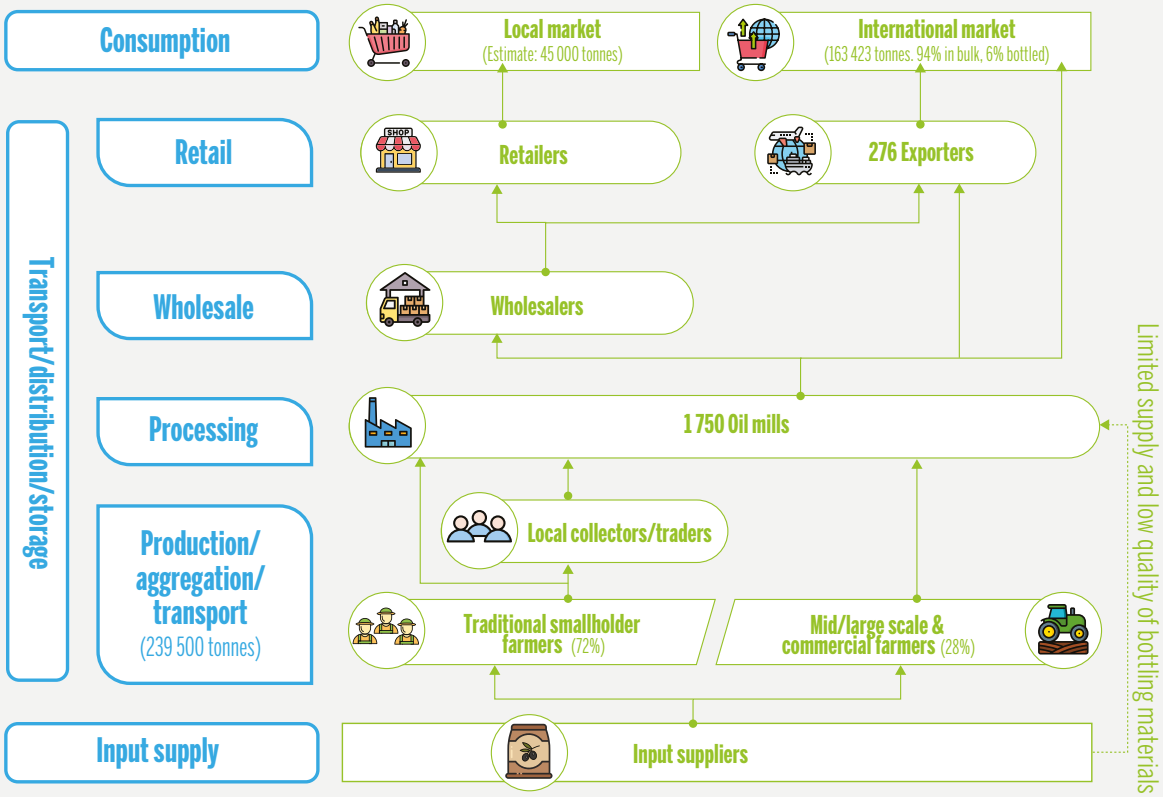


Sources: Authors' own elaboration, adapted from data in FAOSTAT, 2022.

Processing infrastructure in the olive oil sector has been modernized over the last decade. According to IOC (2017), the sector witnessed the introduction of modern oil mills. Currently, 65 percent are modern mills and 35 percent are traditional mills hence grinding capacity has risen from 8 000 tonnes/day in 1986 to 40 000 tonnes/day in recent years.[77] Modernization has led to higher quality of the final product and, recently, Tunisian olive oil producers have won prizes in an international competition, the New York International Olive Oil Competition (NYIOOC). Moreover, there is a sectoral demand for creating a national label to promote the high quality of Tunisian olive oil for added value because of the low awareness of Tunisian olive oil in foreign markets.[77]

Value chain flow

Figure 13: Tunisia – Map of olive oil value chain



Sources: Authors' own elaboration, adapted from data in FAOSTAT and FAO & EBRD. 2015. *Tunisia. Analysis of the olive sector*. Rome, FAO and London, the European Bank for Reconstruction and Development.

As Figure 13 illustrates, the Tunisian olive oil VC is comprised of several key stakeholders: input suppliers, producers, collectors and traders, processors, exporters, wholesalers and national retailers.

Once farmers produce olives, they take them to an oil mill for processing. They pay a fee to the processor and sell the olive oil directly to buyers such as the National Olive Oil Board (ONH) or private exporters.[39] Most importantly, after selling the olive oil, the buyers check the quality at the laboratory and pay the farmers based on the result. The average distance between farm and mill is about 75 km but not many farmers depend on local collectors or traders to sell.[28] The processing industry in Tunisia generally suffers from the regional disparity of mills and producers. Thus, transport from farm to mill takes time, and there is the risk of deterioration of the quality.

figure 14: geographic distribution of the olive production and oil mills

Region	South	Centre	North
Distribution of olive trees	25%	45%	30%
Olive production	50%	29%	21%
Olive oil Production	55%	27%	18%
Olive oil mills	16%	71%	13%

Sources: IOC. 2017. Jordan, Where olive trees grew long before the advent of civilization. *Official Journal of the International Olive Council*. Madrid, *International Olive Council.*

Storage and transport facilities are often in poor condition resulting in deterioration of the quality of the olive oil and reduced selling prices. Around 30 percent of olive oil produced goes to wholesalers before domestic retail or export. Then, ONH and private companies by most olive oil produced for export. There are 276 private exporters that sell olive oil; the private sector comprises around 70 percent of olive oil sales.

Traceability and transparency issues

Benefit analysis:

- **High demand for food safety and quality:** One of the main obstacles to added value in Tunisia is the difficulty of acquiring certifications such as an organic certificate. Tunisia needs to invest more in the differentiation of its olive oil through identification of the origins and qualities using traceable information from farm to fork to signal quality (certification/national quality label). In addition, as most olive oil is sold in bulk and destined for the EU markets, fraud and adulteration have threatened Tunisia's reputation in terms of authenticity and international recognition, particularly for EVOO.

- **High demand for transparency from consumers:** The export market of olive oil, particularly to the EU is highly aware of the importance of transparency. For instance, consumers in Italy require full traceability of the product and are likely to pay a premium for transparency, which can lead to a price increase for small and medium-sized producers who produce most of the olives in Tunisia.

- **Moderate efficiency in supply chain management:** The price of olive oil in Tunisia is more competitive than the major competitors because of the low cost of labour. However, since smallholders and labour are mostly unskilled, operational efficiency could be improved. The traceability system can identify the bottlenecks and provide opportunities to those who are unskilled if they can improve the relevant practices.

- **High demand for improving traceability to ensure sustainability:** The traditional model of handling, the long lead time to process olives, and insufficient management of the supply chain, including poor storage conditions and transport facilities can result in deterioration of the quality of the olive oil and loss of added value. The deterioration of quality reduces marketability and selling price, which can eventually negatively affect the income of smallholder producers.

- **Moderate demand for fair value distribution:** The study did not find an available market information system, or one that is used by smallholder producers to access timely reliable market information. The selling price is managed by the ONH; although farmers can obtain price information once they check the quality at the laboratory. Thus, establishing transparency of information could help farmers plan the best time to harvest and process olives into oil to secure a better price.

Barrier analysis:

- **Moderate barrier of VC governance:** The expert agreed that the VC is vertically integrated, from the viewpoint of olive growers who trade olives directly with oil mills despite land fragmentation. Moreover, ONH governs the VC activities and one-third of exporters have their own oil mills (vertical integration). These conditions ease collection of data for traceability throughout the VC.

- **Moderate barrier of perceived costs:** According to KIIs, leading private companies are motivated to develop their own digital traceability and transparency system. On the other hand, because of the lack of knowledge of digitalization, most private companies believe that the cost of initiation and maintenance of the system, and training of employees, would extensively exceed the potential benefits.

- **High barrier of social norms:** 72 percent of farmers are small or medium-scale and are highly fragmented, as few producers are grouped into cooperatives. This situation makes it difficult to install a traceability system because of the high cost of data collection.

- **Moderate barrier of cultural norms:** One indicator of trust among VC actors is the practice of contract farming. However, this is not a common practice for the olive oil VC in Tunisia, therefore, sharing correct information in a timely manner (transparency) could be challenging. On the other hand, since the Tunisian olive oil sector is shifting to organic production, actors could be oriented to long-term thinking, to encourage them to invest to obtain long-term benefits, such as transparency, and not for immediate low income.

- **Moderate barrier of ICT infrastructure:** The mobile Internet development in Tunisia is robust with nearly 100 percent of the population covered by a mobile cellular network. With the rapid adoption of mobile phones and services, quality and speed of the mobile network performs better than broadband. As of 2021, the high penetration of mobile phones has led to 128 mobile cellular subscriptions per 100 inhabitants.[47] 3G and 4G services are both available and reached 99 percent and 96 percent of the population respectively. In general, Internet access is affordable, but the digital divide still exists between urban and rural areas for the Internet and service coverage; around 33 percent of rural areas are still offline. With the current infrastructure, there would be the risk that small and medium-sized producers in rural areas, who are the key players in the VC, will not benefit from digital technologies.

- **High barrier of digital skills:** The overall literacy level reached 96 percent in 2014 (UNESCO, 2022)[78] while the digital literacy level remains quite low. According to the ITU's latest data, only 21 percent of individuals have basic ICT skills and the percentage is below 20 percent for standard and advanced skills. It is essential that there are the fundamental skills for adoption of digital technologies; however, there is not much training or many available or accessible courses, which contributes to inequality in the labour market.

- **High barrier of data management and standardization to ensure traceability and transparency:** The absence of a national traceability and transparency system for olive oil continues to pose challenges for data management and standardization.

Driver analysis:

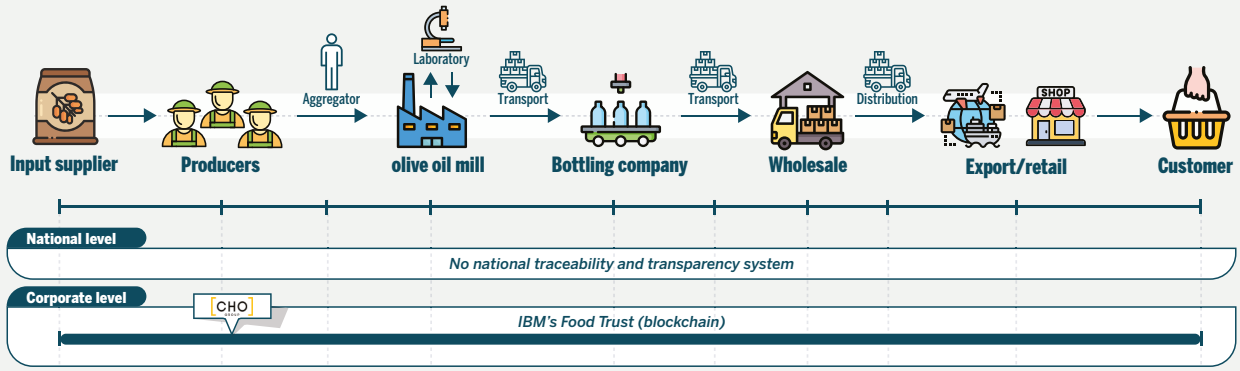
- **Moderate government support, regulatory framework**: Tunisia has developed a national plan "Digital Tunisia" to achieve digital transformation and to create a better regulatory environment. The Digital Strategy 2021 to 2025 aims to mainstream digitalization through eight axes including the legal framework.[79] However, application of digitalization has not yet benefitted VC actors.

- **Limited access to finance:** Accessibility to bank loan for olive oil producers is only 7 percent.[28] Cooperatives and SMEs also have limited access to credit, as compared to large companies. With this situation, producers and SMEs are not encouraged to invest or participate in activities to enhance traceability and transparency.

Technology application for traceability and transparency

The private sector plays an important role in the olive oil sector in Tunisia, as it applies emerging technologies to improve traceability and transparency. Blockchain technology has been piloted and technologies such as IoT, remote sensing, etc. are being applied but are not yet widely used in the sector. One of the biggest producer companies CHO decided to use IBM's Food Trust (blockchain) to monitor the production of its Terra Delyssa EVOO across eight quality assurance checkpoints (improving traceability). The monitoring starts with the field image and provides consumers a QR code[80] on the bottle so they can visualize the entire production process. The new technology, applied by CHO, will further enhance the quality of the products and its traceability system, which will benefit distributors and consumers around the world with transparency. However, the digital system for traceability and transparency has been developed at the corporate and not at the national level.

Figure 15: Tunisia – Current situation of traceability and transparency system



Sources: Authors' own elaboration.

Tunisia – Summary of the olive oil value chain, a situational analysis

The Tunisian olive oil VC shows a high demand for traceability and transparency, which is driven by untapped export opportunities. The government has supported improvement through several means, however the technology has not been mainstreamed, as the national system has not been developed, and the fragmentation and disorganization of producers has delayed further investment. As such, only large private companies, such as CHO, which has full control of the VC, leads the introduction of digitalization of traceability and transparency.

Table 6: Tunisia – summary of situational analysis of the olive oil value chain

Criteria	Assessment
Current level of application of digital technologies for improved traceability and transparency	**Mid**
Recognition of potential benefits	**High**
Food safety and quality	**High**
Consumer confidence	**High**
Supply chain efficiency	**Mid**
Sustainability	**High**
Fair value distribution	**Mid**
Level of barriers	**Mid**
VC Governance	**Mid**
Perceived costs	**Mid**
Social norms (organization, trust in VCs)	**High**
Cultural norms	**Mid**
ICT infrastructure	**Mid**
Digital skills	**High**
Data management and standardization	**High**
Level of enabling drivers for adoption	**Mid**
Regulatory framework / government support	**Mid**
Access to finance	**Low**

Sources: Authors' own elaboration.

Jordan

Introduction

The olive oil industry is the most important agribusiness activity in Jordan, with a value of over USD140million.[26] Olive farms comprise over 30 percent of the total planted area, and over 70 percent of the area with fruit trees.[26] Olive oil is the main source of income for 80 000 families engaged in the olive sector. The government has endorsed the National Strategy for Agriculture for 2020 to 2025 requesting an increase in the harvested area to around 700 000 ha, and production to 225 000 tonnes, and an increase in olive oil exports to 2 200 tonnes at an estimated value of USD 6.5 million by 2025. Jordanian olive oil production was ranked fourteenth in the world, accounting for 25 500 tonnes in 2019, which showed an increase of 19 percent from 2009; although production fluctuates as a result of adverse climatic conditions and the natural oscillation of the production of olive trees.

Production is supported primarily by small and medium-scale producers who produce on average around 2.5 tonnes of olives per ha, almost the same as other major production countries such as Italy and Spain. Rainfed production prevails on 62 percent of the planted area.[81] Olives are cultivated in two main regions, on the uplands of the Western mountains, by small-scale farmers, which is rainfed representing 77 percent of the total area planted with olive trees and the North Eastern desert region, which is mostly irrigated,[82] with larger-scale farmers and higher productivity.

In the Jordanian olive oil sector, there is a lack of skilled labour, which is a significant challenge to production and leads to higher costs per unit, eventually reducing competitiveness in the international market. Labourers are mainly local and, men and women, working for an in-kind payment system. Workers are paid with a share of the harvested olives (one-quarter to one-third), and hence attention is focused on quantity of production rather than quality. Harvesting, by traditional farmers is manual and the olives are collected in plastic or jute sacks for transportation that may take a couple of days. Little consideration is given to proper storage until harvesting is finished. The quality of the olives may deteriorate which can threaten food safety.

As a result of the above-mentioned situation, the VC is focused on meeting domestic demand, which accounts for 95 percent of total production.[83] The volume of exports is significantly small displaying high price volatility, as compared to other production countries in NENA, such as Tunisia.[26] The export rate was on average 4 percent in recent years. The import ban on all olives and olive oil, since 2015, has supported vulnerable producers, as it prevents international competition, because the domestic production cost is significantly high.

The high price of olive oil on the domestic market has driven local customers to purchase directly from olive oil mills to be assured of the best quality, although the olive oil is mostly kept in 16 kg metallic cans without concern for international quality standards and is rarely labelled. The olive oil purchased at mills is not tested, therefore fraud may take place in the local market. Thus, there is a strong need for food safety measures, which could be achieved by establishing a traceability system that would detect and address issues of fraud as well as a transparency system so consumers can be assured of quality, although the informal sales system makes it difficult to enforce any measures along the VC.

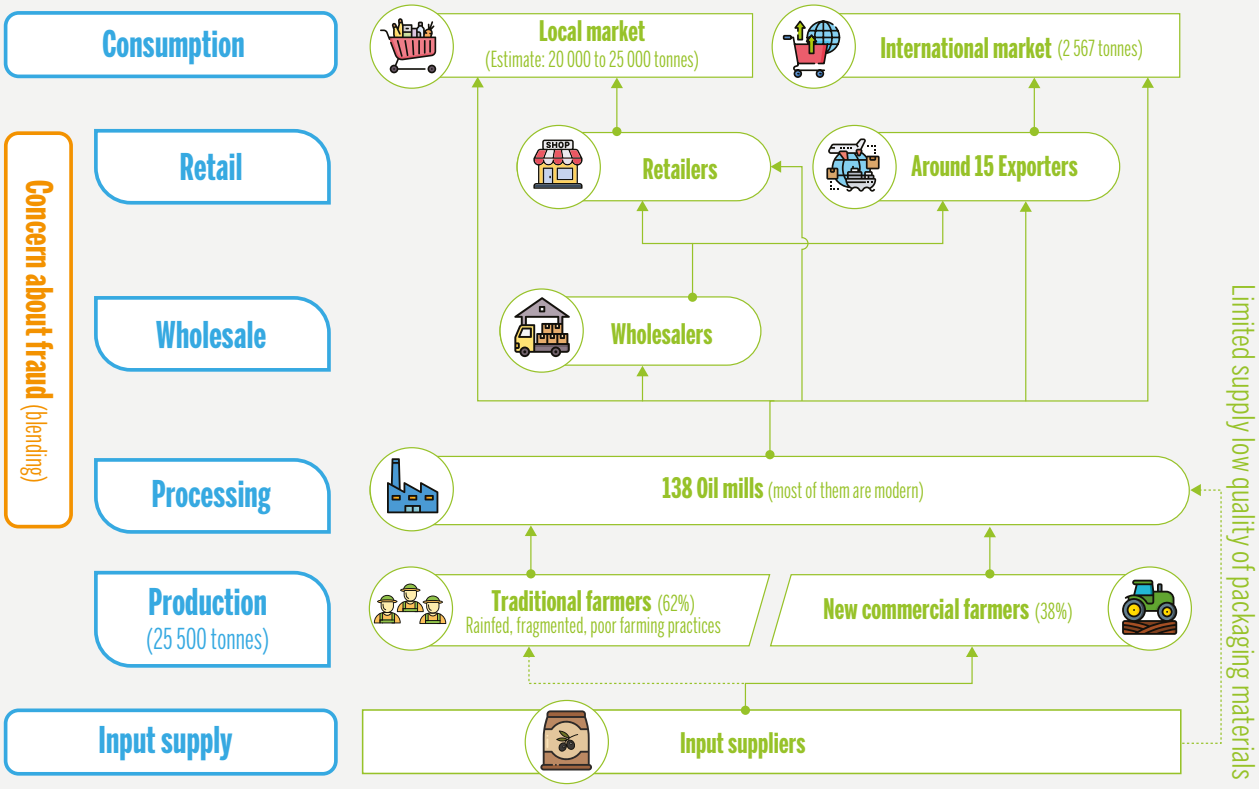
In 2020, Jordan exported olive oil to the Gulf States: Saudi Arabia (44 percent), UAE (22 percent) and Kuwait (16 percent). The average export price was around USD 2.0 per kg in 2020, the local market is preferred for

a higher income, since the price of locally produced olive oil is between USD 5.3/kg and USD 9.9/kg.[84] One means to increase the export price would be to sell organic olive oil, although organic farming is not common in Jordan. Another way to increase the export price is to improve the quality, but exporters do not have any incentive to do so because the export market is not attractive.

The olive oil processing industry has undergone extensive modernization in recent years. In 2022 there were 138 olive mills in Jordan, 134 of which were modern with a total of 305 lines. As for marketing efforts, in 2022 the MoA established the IOC and organizes trade shows to promote olive oil. The first time to win was at the NYIOOC World Olive Oil Competition in 2021, with four awards for extra virgin olive oil. Quality is gradually improving and gaining recognition on international markets.

Value chain flow

Figure 16: Jordan – Map of olive oil value chain



Sources: Authors' own elaboration, adapted from data in FAOSTAT; IOC. 2019. *Jordan olive oil industry report*. Madrid, International Oil Council.

In general, the olive oil VC is short, particularly because most transactions take place between farmers, processors at the mill and consumers. Most producers are small-scale and unskilled. Once olives are harvested, it is a common practice that farmers take the olives directly to an olive oil mill and are paid, although quality tests are not properly enacted. This raises concern about fraud, blending olive oil with other oil to make a higher profit.[85][95] There are a number of shortcomings in packing and transportation of picked olives because of the lack of pre-cooling facilities, which causes natural decomposition resulting in lower quality olives and olive oil.[86] In addition, there is a lack of coordination between farmers and mills hence, during the peak season, access to the mill is delayed and the quality of the olives deteriorates.[86] As a result, only 15 to 20 percent of olive oil production is EVOO, a high-quality product.[86]

During processing, even though olive oil mills are extensively modernized, only 25 mills out of 138 (18 percent) have Hazard Analysis and Critical Control Point (HACCP) and ISO certificates.

The functionality of wholesale and retail in the Jordanian olive oil VC is generally not appreciated because of the risks of fraud and thus there are few wholesalers and retailers. There are approximately 15 export companies in Jordan which that vertically integrate the VC from farm to export to control the quality of the olive oil quality.[86] Exporters demand bulk shipments of low-quality olive oil for an undefined market.

Traceability and transparency issues

Benefit analysis:

- **High demand for food safety and quality:** Food safety and quality is at risk in the VC. Local consumers are aware of, and concerned about the risk of fraud when purchasing Jordanian olive oil. In addition, olive oil is stored without compliance with international quality standards and is rarely labelled with information. Only 25 mills out of 138 have HACCP and ISO certificates. Quality tests are not usually undertaken and thus safety and quality of the olive oil cannot be guaranteed.

- **Moderate demand for transparency from consumers:** The main market is the local market where customers are concerned about possible fraud (blending olive oil with other oils). To avoid this issue, local consumers purchase olive oil directly from oil mills and check the quality themselves. In this regard, consumers exhibit a moderate demand for transparency and tracing information is already in place as a countermeasure to ensure the oil has not been blended.

- **High demand for sufficient supply chain management**: The Jordanian olive oil sector has high production costs, as operations are inefficient because of unskilled labour and manual operations. There is a strong demand to tackle this issue because it affects exports to high value markets.

- **Low incentive to address quality deterioration or food loss issues:** The most commonly applied approach to post-harvest and transport, mainly by traditional farmers, is to fill plastic or jute sacks with olives for transport to the mills. This practice results in injured, bruised and deteriorated fruit that may display hydrolytic and oxidative deterioration characteristics. Therefore the oil produced will score a lower quality grade. Because of the import ban, and minimal interest in the export markets, most VC actors do not have the incentive to address these issues or produce higher quality olive oil.

- **Low appetite for addressing unfair value distribution:** The study did not find widely available market information or a transparency system in the VC, as the price is controlled annually and maintained by the government entity to avoid price fluctuations and protect national producers. Under these conditions, producers do not have a strong appetite to access timely market information, as they already obtain a reasonable price with a margin to cover productions costs.

Barrier analysis:

- **High barrier of VC governance:** The VC is vertically integrated since direct trade between producers and consumers is common practice. Yet, governance is still weak, as the quality control system is not functional, which has caused the entire VC to be affected by the problem of possible fraud.

- **High barrier of perceived costs:** Since the sector faces high costs of production and does not have the incentive to pay additional costs to increase the price, the costs for digital traceability and transparency system are perceived as too high.

- **High barrier of social norms:** 80 000 Jordanian families are fragmented olive producers. This fragmentation has led to higher costs and risks of not obtaining timely and reliable information from producers for traceability.

- **High barrier of cultural norms:** An indicator of cultural norms is trust, which affects the reliability of information. In this VC, producers and consumers do not trust wholesalers or retailers as they suspect fraud. In addition, long-term thinking is difficult in this VC because of the fear of removing the import ban, which currently protects VC actors. Therefore, investment in a digital traceability and transparency system is a low priority.

- **Low barrier of ICT infrastructure:** Jordan has a high penetration of mobile networks, with 100 percent of the population covered by a mobile cellular network and both 3G and 4G services are available nationwide. According to the Ministry of Investment, ICT is one of the fastest-growing sectors in Jordan, contributing to about 12 percent of GDP,[87] with 84 000 jobs in the wider economy. Compared to the mobile network, Internet coverage remains low; as of 2018, about 65 percent of individuals use the Internet. The consumption of mobile data and voice, and the mobile broadband basket takes account of 4.2 and 3.7 percent respectively as of 2021, and the fixed broadband basket is as high as 11 percent,[46] which creates barriers to the adoption of mobile-based services.

- **Low barrier of digital skills:** As of 2018, the overall rate of literacy is 98.2 percent. In terms of digital literacy, Jordan pays particular attention to digital skills and entrepreneurship and is a leading country in modernizing the education system. The "IT in education" initiatives carried out by the Ministry of Digital Economy and Entrepreneurship have improved the digital skills of both students and teachers in public schools, resulting in an average of 43 000 ICT graduates, with 51 percent being female.[88] In 2019, Jordan passed the Vocational and Technical Skills Development Law to develop a skilled workforce.[89] Jordan has more than 900 active tech companies, which account for two-thirds of the regional total, making Jordan a regional leader regarding entrepreneurship initiatives.[89]

- **High barrier of data management and standardization:** Currently no national traceability and transparency system has been established for the olive oil sector in Jordan, while the government collects data by running laboratories with tasting panels, in line with IOC guidance to ensure food safety and quality.

Driver analysis:

- **Weak government support and regulatory framework:** Two to three olive oil mills, with support from MoA, have introduced a QR code system to facilitate traceability, but the system has not been scaled up as a regulatory framework.

- **Limited access to finance:** The Agricultural Credit Corporation (ACC) has provided a variety of loans to farmers and millers for investment in facilities to improve production and quality. However, few can access the loans because of the short repayment period. It is therefore challenging for farmers and millers to invest in digital technologies to improve traceability and transparency, as the costs are perceived as high, and it is uncertain they can earn enough money to repay the loan in such a short period.

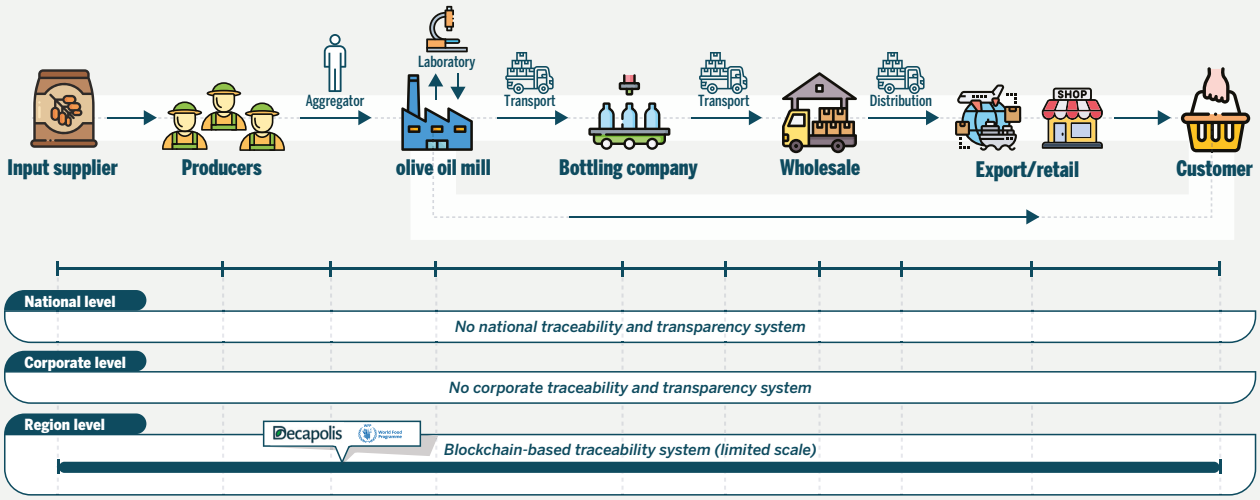
Technology application for traceability and transparency

A national traceability system has not been established for the olive oil sector. The most critical challenge is insufficient financial resources and lack of incentive due to the high cost of production. To meet the international standard, Jordan has provided institutional support in terms of lab tests and certification for national and private brands. However, the volume of exported EVOO is still quite small, representing only 15 to 20 percent of the total quantity exported.

Some private companies have already started the first trial to put a QR code on their product with basic information on farms and mills, as well as the entities that provide testing results. As most private companies have their own farms tracing the supply chain is easier. Still, the existing QR code system does not have enough detailed information, indicating that there is still missing information when tracing back to some stages of the VC.

The leading companies have made one step forward in the traceability of olive oil. A Jordanian company Decapolis is a leading start-up in developing solutions to establish a digital traceability system. With the World Food Programme (WFP) Jordan Innovation Hub, a blockchain-based traceability system (BBTS) (Decapolis platform/Decapolis Food Guard) was designed to track food products through the entire supply chain. Using the platform, smallholder farmers can improve product quality to meet local and international food safety standards; even consumers can easily access certifications at each stage of the value chain.[90] In terms of information transparency in agriculture, Jordan has established the National Agricultural Information System (NAIS), which is a platform for information dissemination and knowledge sharing. This information system will help monitor and assess production and development in the agriculture sector. The platform is not well commercialized and utilized by relevant VC actors because of the limited financial benefits.

Figure 17: Jordan – Current situation of traceability and transparency system



Sources: Authors' own elaboration.

Jordan – Summary of the olive oil value chain, a situational analysis

The Jordanian olive oil VC has distinctive features. There is a prevailing image of fraud occurring at wholesalers and retailers, where traceability is highly demanded to assure food safety and quality. In addition, it is recognized that producers do not have the incentive to introduce transparency because the government protects national producers by enforcing the import ban. The current condition is not favourable to actualizing digital technologies to improve traceability and transparency because of the lack of incentives for the private sector.

Table 7: Jordan – summary of the situational analysis of the olive oil value chain

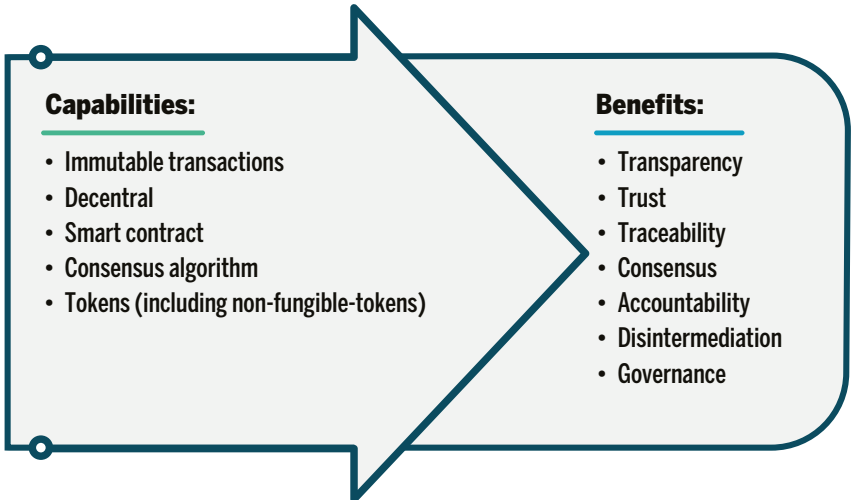
Criteria	Assessment
Current level of application of digital technologies for improved traceability and transparency	**Low**
Recognition of potential benefits	**Mid**
Food safety and quality	**High**
Consumer confidence	**Mid**
Supply chain efficiency	**High**
Sustainability	**Low**
Fair value distribution	**Low**
Level of barriers	**High**
VC Governance	**High**
Perceived costs	**High**
Social norms (organization, trust in VCs)	**High**
Cultural norms	**High**
ICT infrastructure	**Low**
Digital skills	**Low**
Data management and standardization	**High**
Level of enabling drivers for adoption	**Low**
Regulatory framework / government support	**Low**
Access to finance	**Low**

Sources: Authors' own elaboration.

Box 4. Blockchain positioning

Blockchain is mentioned throughout this document as a promising technology. The paper uses enterprise architecture constructs, such as capabilities and benefits,[a] to spell out blockchain as such:

Figure 18: Blockchain capabilities and benefits



Sources: Authors' own elaboration.

This paper is deliberately not positioned as blockchain centric because it should not dominate the discussion. Blockchain can be used as a metaphor for a *digital backbone*, rather than prescribing blockchain. New distributed ledger paradigms are coming up such as Directed Acyclic Graphs as implemented, for example, by Hedera HashGraph.[b] Another digital backbone direction could be the Inter Planetary File System (IPFS).[c] Within blockchain, there is the difference between public and private blockchains.

It is likely that the digital backbone should have a public character but, as a matter of fact, many digital agriculture service providers use a private blockchain. Blockchain can be the metaphor for the required digital backbone for traceability and transparency. The discussion about how to implement the digital backbone becomes, then, almost only an issue of implementation. A possible implementation choice could be to indeed use blockchain for this specific role. Blockchain is used in the olive oil sector to track and trace each lot number from the olive oil manufacturer to the consumer. The limitation of this approach is that it ensures only the traceability of the bottle but not the contents.

Notes:

a. van de Wetering, R., Kurnia, Sh. & Kotusev, S. 2020. The Effect of Enterprise Architecture Deployment Practices on Organizational Benefits: A Dynamic Capability Perspective. *Sustainability*. 12. 1-21. 10.3390/su12218902;

b. Hedera. No date. Home Page. *The open source public ledger for enterprises*. Homepage: https://hedera.com/;

c. "PFS is a distributed storage system that does everything that central servers do but without relying on a central system. This makes it resilient to downtimes, censorship, and attacks while enabling it to lay the foundation for a decentralized Internet." (Ledger Academy, 2022). What is InterPlanetary File System (IPFS)? www.ledger.com/academy/what-is-ipfs#:~:text=%E2%80%94%20InterPlanetary%20File%20System%20or%20IPFS%20is%20a,to%20lay%20the%20foundation%20for%20a%20decentralized%20internet

3. Discussion

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This chapter examines the feasibility of adoption of digital solutions for traceability and transparency for all case studies by conducting a comparative analysis to consolidate the facts in the situational analysis, identify the recommendable solutions, required actions and impacts on sustainability. The section also discusses commonalities and scalability of the case studies to come to an overall conclusion concerning the feasibility of implementation of digital technologies for the horticulture VC in the NENA region.

3.1 Commonalities

Two horticulture VCs were analysed in four countries with a different status. Regardless of the current economic, social and environmental conditions, all VCs in each of the countries have the desired benefits for the market and consumers to improve traceability and transparency for different reasons. As assumed in the section *Conceptual framework*, the date palm and olive oil VCs do not have distinctive differences that would significantly affect the adoption rate of digital traceability and transparency systems. Therefore the study observes major commonalities as follows:

- **Relatively long structure of VC mapping**: All VCs in the four countries have a similar structure with key actors that include input suppliers, farmers, local collectors and traders, wholesalers, processors, national retailers and exporters, making the VCs relatively longer as compared to other subsectors. The situation causes information asymmetry where only VC actors, who are closer to the end-market, manage to receive price information. To access a high value market such as export, small and medium-sized producers are excluded from price negotiations and can only access local markets at a lower price. Moreover, transaction costs are generally high, although farmers' behaviour of occasionally cutting intermediaries is recognized to lower costs. Mainstreaming a traceability system will ensure transparency of all information and support fair value distribution for small and medium-sized producers.

- **Predominant small and medium-sized producers**: All four countries have geographically fragmented small and medium-sized producers. They rarely practice collective action or organize themselves into cooperatives or associations partly because of social norms. This can increase the barrier to collecting and sharing the right data from the farm for traceability and transparency.

- **Weak VC governance and linkages leading to weak flow of information and low level of data collection capacity**: Both date palm and olive oil VCs traditionally work in silos and consumers are not well informed about the products. With digital capabilities, this can be changed completely, provided there is a clear vision of the required digital ecosystem. In the olive oil VC, although farmers mostly take olives directly to the mill to extract oil and sell to private firms, they do not share strict quality standards or coordinate to improve quality. Similarly, in the date palm VC, farmers take dates directly to packers but further collaboration throughout the supply chain to improve quality is barely recognized by VC actors.

- **Limited capacity in supply chain management**: The biggest weakness in the two VCs is supply chain management. This is demonstrated by the high rate of food loss or quality deterioration. As mentioned in the introduction to this paper, the NENA region's average logistics performance is significantly lower than other regions with limited cold chain and storage capacity. This directly and indirectly stems from low market concentration, fragmentation of producers and weak linkages among VC actors.

Based on the commonalities found in the two VCs, the study anticipates that these common conditions can be applied to most other horticulture VCs in NENA, with some exceptions typically in Gulf Cooperation Council (GCC) countries that have well-established supply chains and strong VC governance by the governmental entity.

3.2 Comparative analysis

Understanding the commonalities of the two VCs, the study compares all four case studies to identify non VC-specific, but country-specific, gaps for adoption of digital technologies for traceability and transparency. Table 8 is a summary of case studies.

Table 8: Summary table of the case studies

Value chain	Country	Current level of application	Benefits	Barriers	Drivers	Identified features
Date palm	Egypt	Low	High	High	Low	Perceived costs are very high causing VC actors to be hesitant about investing in traceability and transparency. Since the export rate is lower, benefits are not highly appreciated and therefore the role of export associations is limited.
	UAE	High	High	Low	High	The government's initiatives enable adoption of digital traceability and transparency systems.
Olive oil	Tunisia	Mid	High	Mid	Mid	Adoption is led by leading firms in the private sector while the government indirectly facilitates adoption by paying relevant subsidies.
	Jordan	Low	Mid	High	Low	Incentives for adoption of digital traceability and transparency are limited because of underdevelopment of the VC.

Sources: Authors' own elaboration.

From the case studies, the paper confirms the assumption that if benefits are highly realized, barriers are lowered, and drivers work effectively, the adoption rate of digital technologies to improve traceability and transparency can increase (e.g. UAE). The following indicates the identified gaps and levers that affect adoption of the digital traceability and transparency system.

Benefits

Competitiveness is a key factor that is associated with the motivation to adopt digital solutions. In Jordan, as the olive oil VC is not export-oriented and the domestic market is saturated at a high price, ensuring traceability and transparency will not produce economic benefits and hence the current level of adoption, or implementation of digital traceability and transparency systems, is low. Therefore, whether digital traceability and transparency produces ***competitiveness*** is a key variable for adoption.

Barriers

Overall, the ***ICT infrastructure*** is mature, and the level of ***digital skills*** is around low to middle among the four countries. Therefore, these two factors do not significantly affect the introduction of digital technologies in NENA. ***Data collection*** barely occurs after the farmgate because of limited coordination (low level of ***VC governance***) between VC actors. ***Social and cultural norms***, such as lack of trust, disorganization of VC actors or short-term thinking, which negatively influences the adoption of digital traceability and transparency. ***Perceived costs*** are significantly high in most cases, leading to uncertain benefits that cause VC actors to be hesitant about trying new technologies.

Looking at each country: In Jordan, ***VC governance*** is underdeveloped creating an opportunity for fraud. This increases consumers' distrust of VC actors (***social norms***). However, the cost of addressing food safety with digital technologies is perceived as being high. Therefore, consumers shorten the VC flow by purchasing directly from the oil mill to ensure quality, instead of developing traceability and transparency systems. In Egypt, according to the KII comments, ***perceived costs*** exceed the perceived economic benefits. In relation to this, risk aversion, short-term thinking and lack of trust between VC actors (***social and cultural norms***, linked with ***VC governance***) contribute to uncertainty about using new technologies. In Tunisia, ***VC governance*** and ***perceived costs*** are critical for accelerating adoption. For instance, the leading private company, CHO, succeeds in using digital solutions by integrating the VC and demonstrating the advantage of economy of scale for digital traceability and transparency systems. In the UAE, ***VC governance*** is well maintained by Al Foah to increase exports, which has resulted in low ***perceived costs*** when adopting new technologies. The country, however, appears to be able to strengthen the organization of producers (***social norms***) at the national level, so as to provide technologies more efficiently and inclusively.

Drivers

The promoters of new technologies differ across countries. In the UAE and Tunisia there are Al Foah and ONH, which are both state-owned entities (***the government support, regulatory framework***) and play a major role in the market (strong driver). There are no state-owned entities in Egypt and Jordan playing such a role (weak driver). Private sector export associations mostly lead exports from these countries; hence coordination and data standardization is weak. Since digital access to finance is limited in all countries, mostly private companies lead the introduction of technologies for traceability and transparency. The study emphasizes the significant ***influence of the government*** regarding the feasibility of application of digital technologies.

Overall

It is crucial that all key criteria listed in Table 3 are interlinked and attributed to the level digital technologies have been adopted to improve traceability and transparency. It is noteworthy that a combination of a few of these key factors can determine the readiness of VC actors to accept traceability and transparency technologies, especially small and medium-sized producers.

3.3 Recommendations

Based on the findings in the analysis, the paper first proposes general recommendations on data and digital technology, followed by possible digital solutions for each case. Required actions are identified, and the possible impacts on the three dimensions of sustainability, and concludes with the feasibility of adoption of digital technologies to improve traceability and transparency.

General recommendations for data and digital technology

This document reveals a generic theme of the importance of data standards, data governance and data interoperability.[91] The FAO report, on the future of food and agriculture,[92] lists four data governance frameworks that can be examples of how the NENA region could develop data governance frameworks for the horticulture VC at the regional or national level. Data governance provides consistency and the foundation for brand development, premiums, food safety, data quality, transparency, traceability and bonding with customers. The region could also collaborate with the Digital Integration of Agricultural Supply Chains Alliance (DIASCA)[93] initiative that addresses the topic of digital interoperability of supply chains. DIASCA is also useful in the context of upcoming due diligence legislation.[94]

This present document uncovers new digital technologies (see Annex 5 and Annex 9 for examples of enabling technologies) for date palm and olive oil, which lead to general recommendations. First, the date palm and olive oil sector can continuously research, test and pilot the latest digital technologies. Second, any new digital technology will greatly benefit from the above-mentioned data governance and data interoperability performed in the context of data palm and olive oil.

Date palm value chain

Egypt and the UAE have shown very different scenarios in the development of the date palm sector. The UAE has high digital maturity, a high level of demand and the conditions for digital traceability and transparency. The country has already developed digital tools with cutting-edge technologies for food safety and quality (e.g. FIEMIS) and fair value distribution for small and medium-sized producers (e.g. eZad). On the other hand, Egypt perceives moderate potential benefits, comparatively high barriers and low uptake of digital solutions in the date palm sector, thus technologies have not been mainstreamed at the national level and adoption depends on individual efforts.

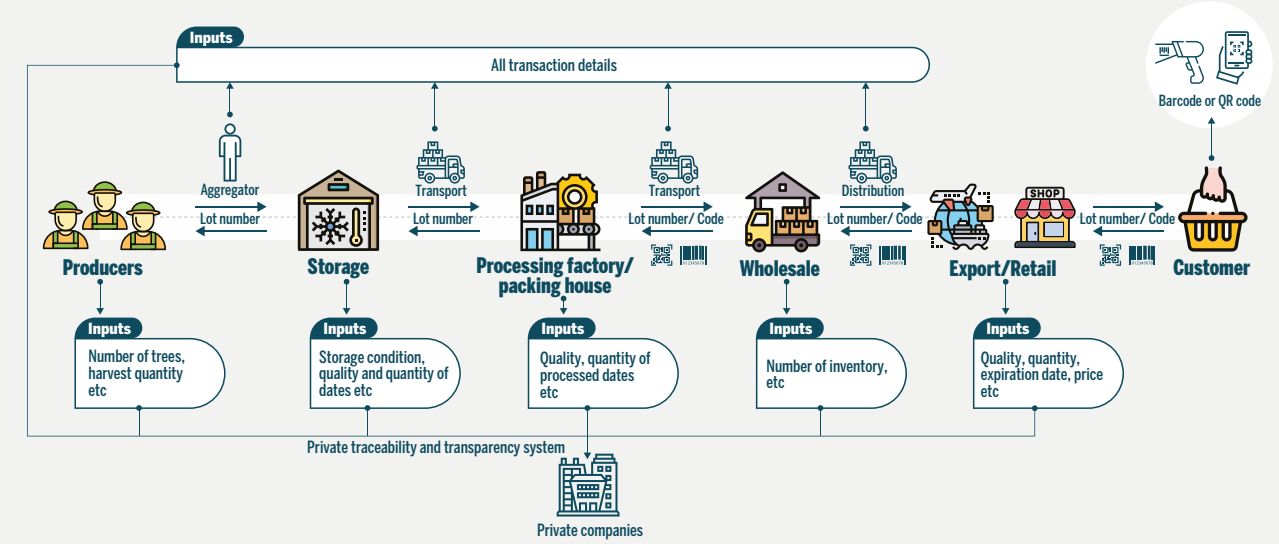
Egypt – Recommendations

This paper concludes that Egypt is currently in a position to feasibly introduce **a low-tech system or a low-risk pilot for both traceability and transparency (possibly led by the private sector)** because of the high barriers and low drivers. As the perceived costs are high, and social and cultural norms strongly influence decision-making, it may be better to pilot low cost digital solutions to identify actual benefits. Needless to say, private companies could conduct a cost-benefit analysis in advance to check if the system would be beneficial or not, depending on the scale of business. The possible digital solutions are described following. These can improve the traceability and transparency of the date palm VC within the existing conditions. This list is not exhaustive but rather provides possible orientations.

Various scenarios can help demonstrate the recommended digital solutions for Egypt

- **Private traceability and transparency system (short-term):** Companies involved in the supply chain are willing to improve competitiveness with traceability. They could apply food traceability and quality control tools such as cloud-based or software (e.g. Enterprise Resource Planning system), depending on the functions needed in compliance with regulations for export. The use of web or mobile-based software can help them better trace each stage of the supply chain, which can be combined with a barcode/QR code system that includes the necessary transparency information for the end consumers. Information transparency would benefit small and medium-sized producers when accessing timely market information and would increase their bargaining power. A simple economic model for this potential short-term low-tech solution suggests that it could be financially feasible even for SMEs to pay off the initial costs and create a profit after a couple of years (Annex 14).

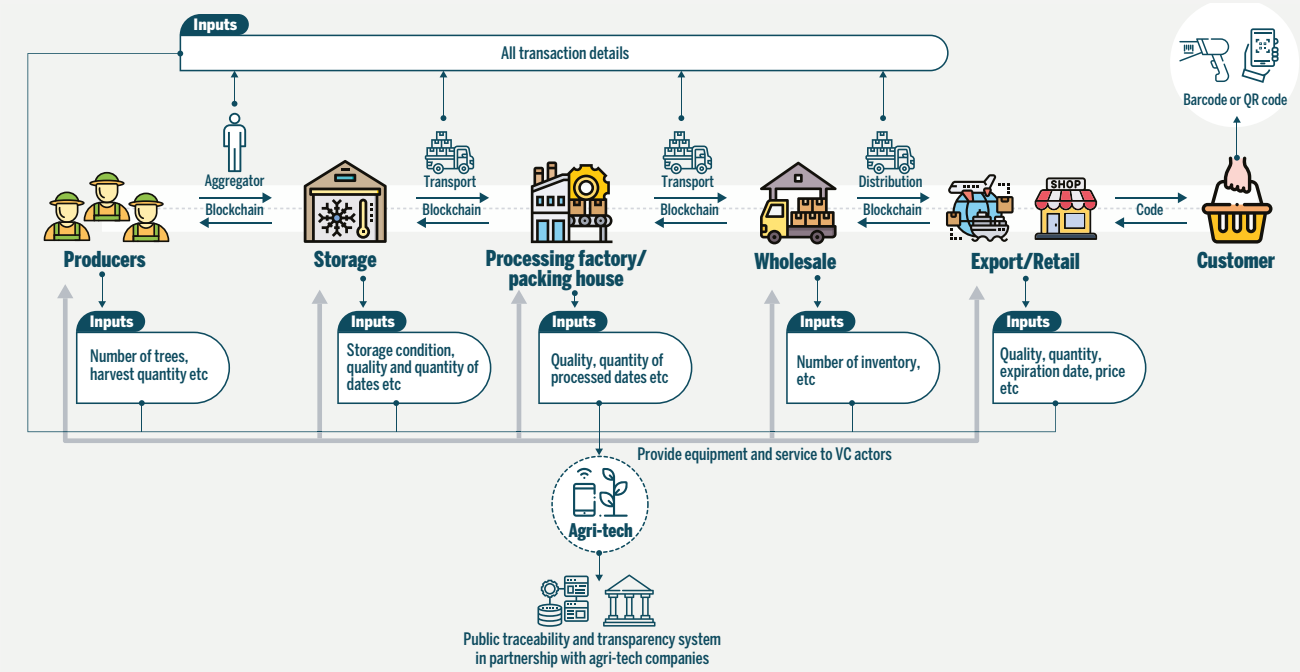
Figure 19: Private traceability and transparency system



Sources: Authors' own elaboration.

- **Partnerships with agritech (mid-term):** In collaboration with agritech companies or start-ups (e.g. an IoT company, AI company, etc.) to share risks, more advanced technologies could be extended to the date palm sector through pilot testing, such as blockchain, installing sensors, using AI, drones or satellite image, etc. to ensure data traceability at the farm level.[95] This would require training for VC actors so they could have more advanced ICT infrastructure and digital skills. The technologies could be further extended to cold storage, warehouses, and packing houses established by the government over the long-term to comprehensively integrate the system and standardize data to ensure food safety and quality; efficient supply chain management; improve marketability of products and fair value distribution, which would benefit small and medium-sized actors more efficiently. Data could be accessed jointly, which would facilitate the establishment of a national market information and transparency system at a later stage.

Figure 20: Partnership with agritech



Sources: Authors' own elaboration.

Required actions

To achieve the above-mentioned solutions, some general recommendations are proposed to lower the barriers to, and drive adoption of, digital technologies for traceability and transparency:

- **Awareness-raising:** help VC actors understand the demands of international markets and the priority of increasing date palm exports; explains why traceability and transparency are important factors and how they can be beneficial for exports.
- **Supply chain management:** maximizes benefits from the digital traceability and transparency systems; improve operational capability of supply chain especially for SMEs by facilitating investments in cold chain facilities and coordination among actors.
- **Producer integration:** group producers could form associations, cooperatives or producer organizations, which would help them to easily gather data collectively; access services, information and the market; prevent price manipulation by intermediaries and improve logistics; and better link farmers directly to buyers for transparent setting of price.
- **Digital skill development:** provide the end-users (e.g. smallholder producers, SMEs, other private companies) with the relevant training or instruction to share correct data in a timely manner and manage the use and adoption of technologies; provide VC actors with agribusiness training so they can better manage their farm business and maximize profits.
- **Government support, regulatory framework:** develop clear regulatory frameworks for the collection, storage, and use of data and the adoption of digital traceability and transparency solutions; improve inter-ministerial collaboration in drafting digital standards, policies and cyber-security regulations; scale up the existing digital extension services. It can be costly to implement and maintain digital traceability and transparency solutions, as they require significant financial investment in technology and equipment, data management systems, training and support.

- **Access to finance:** improve access to loans or credit to increase investments in quality improvement or procurement of the necessary tools or machines; increase financial support to SMEs and agritech start-ups focused on innovations to upgrade to better technologies; provide producers financial incentives to engage in the required activities in the new digital system.

United Arab Emirates – Recommendations

The paper confirmed that the UAE has unique sectorial development and has established a mature digital traceability and transparency system. The existing digital solutions, including Al Foah app, eZad and Food Watch, have demonstrated a high level of functionality in traceability and transparency, although the system at the national level was not identified in this study. In addition, fragmented producers could be a factor that constrains the efficiency of the system. Therefore, recommendations focus on **required actions for further potential improvement in scale-up and system efficiency**.

Required actions

- **Awareness-raising:** help all VC actors across the country understand the demands of international markets to promote similar technologies to support smallholder producers who have not accessed existing digital solutions; explain why traceability and transparency are important factors and how they can be beneficial for exports.
- **Producer integration:** group producers into associations, cooperatives or producer organizations and help them collect data easily in a timely manner and assist the private sector, including SMEs, to provide services for wider coverage of the digital traceability and transparency system by reducing operational costs.
- **Mid-segment value chain integration and public infrastructure:** for full transparency from farm to fork, integration of national authorities and producer organizations, and put in place interoperability mechanisms to improve data flow and the efficiency of the cross-sectorial system.

Olive oil value chain

Tunisia and Jordan employ different incentives to improve traceability and transparency. The Tunisian olive oil sector aims to increase exports by improving food safety, quality and transparency, incentivizing a few leading companies to introduce advanced technologies. On the other hand, the olive oil sector in Jordan has high demand for addressing food safety issues (i.e. fraud) in the local market. The greatest distinction between the two countries is VC governance and government support, which provide favourable conditions to VC stakeholders in Tunisia for the adoption of digital technologies for traceability and transparency.[96]

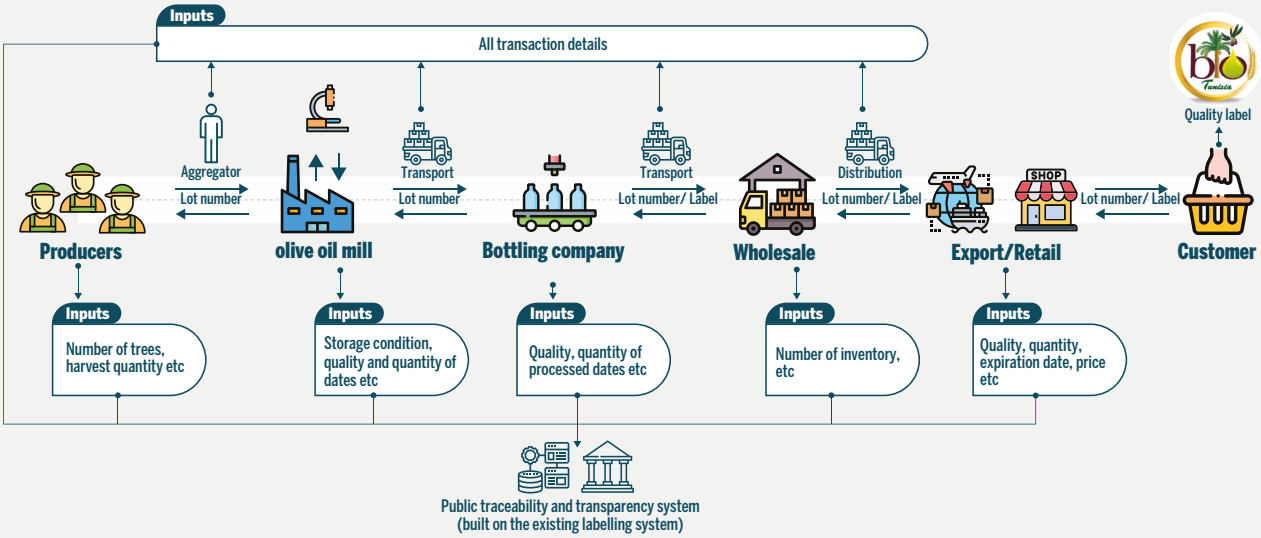
Tunisia – recommendations

In Tunisia, the export rate of olive oil is high resulting in high potential benefits and awareness among VC actors of traceability and transparency. Three distinctive points affect possible solutions: a state-owned institution ONH with the capability of governing the olive oil market; the fact that certification systems are introduced by the private sector; and the fact that the leading company, CHO, has already implemented a blockchain solution.

A basic scenario would be to strengthen **data management and standardization as well as** the **regulatory framework. This could be achieved by ONH using the existing platform and assisting the private sector to introduce a low-tech traceability and transparency system**.

- **Public traceability and transparency system** (short-term)**:** This would build on the existing public label and promotion plan (web-based) to establish a national digital traceability and transparency system that integrates label certifications for EVOO and organic olive oil. This will help track through labels and prioritize the products with local labels for exports and will not require producers to have sophisticated digital skills or large investments from the private sector. It could also combine with necessary certifications integrated in the system. The ONH could play an important role in both governance of the system and support smallholder farmers by providing market information, directly purchasing olive oil and alerting of the detection of bad quality olive oil. With the streamlined transparency system, the added value from the improved quality and certifications would increase the incomes of small and medium-sized producers. The extended system would benefit SMEs that have recently faced challenges to investing in a traceability and transparency systems.

Figure 21: Public traceability and transparency system

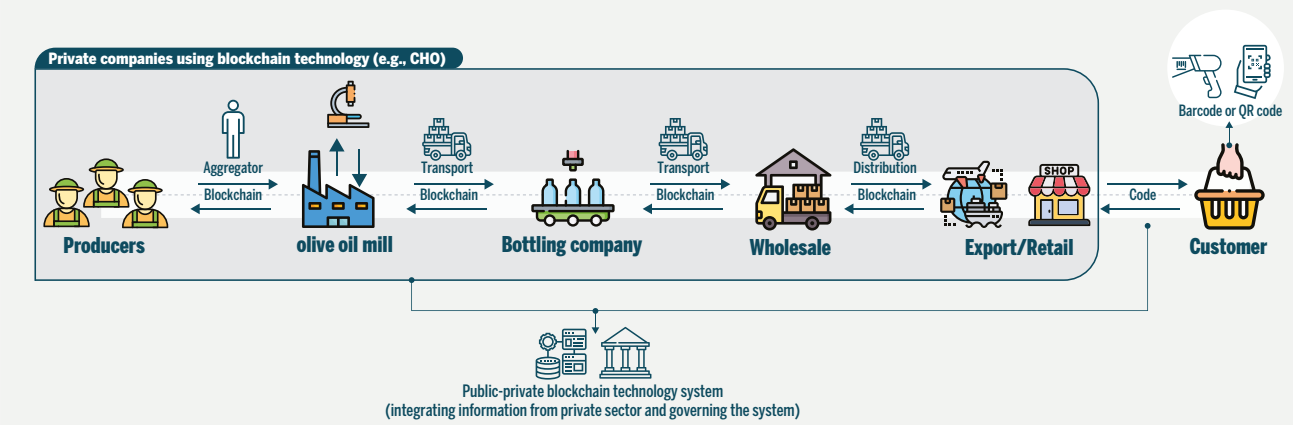


Sources:: Authors' own elaboration. The bio logo image is from IOC, 2017.

Another scenario is to accelerate the **high-tech traceability and transparency system by not only strengthening the governance of data and regulatory frameworks but also increasing access to finance** for private companies to set up digitalization in traceability and transparency (reduce barriers and increase drivers). This should be considered as a mid-term solution, given that the public sector would need to make a large investment and develop capacity based on a simple economic model (Annex 15).

- **Public – private blockchain technology system** (mid-term)**:** Leading companies (the CHO model) use IBM Food Trust or other blockchain technologies to achieve full traceability of the supply chain. The large-sized private companies aim to secure data privacy and transparency of suppliers to increase exportability, while the public system will financially support and integrate information from the private sector with importers and customers. This system would benefit small and medium-sized actors by improving access to better services for traceability and transparency and would increase their profits.

Figure 22: Public and private blockchain technology system



Sources: Authors' own elaboration.

Required actions

- **Awareness-raising:** Need to the raise awareness of all actors along the VC so they understand international market demand, also provide information on the most applicable technologies in the country that could help VC actors improve transparency of information at all stages.

- **Producer integration:** Group producers into associations, cooperatives or producer organizations to improve access to services, equipment and subsidies; expand and strengthen existing cooperatives for olive oil farmers to reduce the costs of data collection and improve data reliability; promote contract farming with embedded services and transparent price setting; enhance the extension service function provided by ONH to improve the capacity of producers so they can use the technologies.

- **Digital skills development:** the end-users (farmers, SMEs, companies) as well as the government entities need to receive relevant training or instruction to collect and share the right data and manage the utilization and adoption of technologies; VC actors need to be trained in agribusiness so they can better manage their farm business and maximize profits.

- **Data management and standardization:** A standardized information management system needs to be established by ONH to improve interoperability and mainstream the traceability and transparency system at the national level.

- **Government support, regulatory framework:** Improve inter-ministerial collaboration in drafting digital standards, policies and cyber security regulations; scale up the existing digital extension services; support training and financial investments of small and medium-sized actors when adopting and engaging in the new digital traceability and transparency system.

- **Access to finance:** Improve access to loans or credit to increase investments for the private sector for development and promotion of the digital traceability and transparency system; provide financial incentives to producers so they can engage in the required activities in the new digital system.

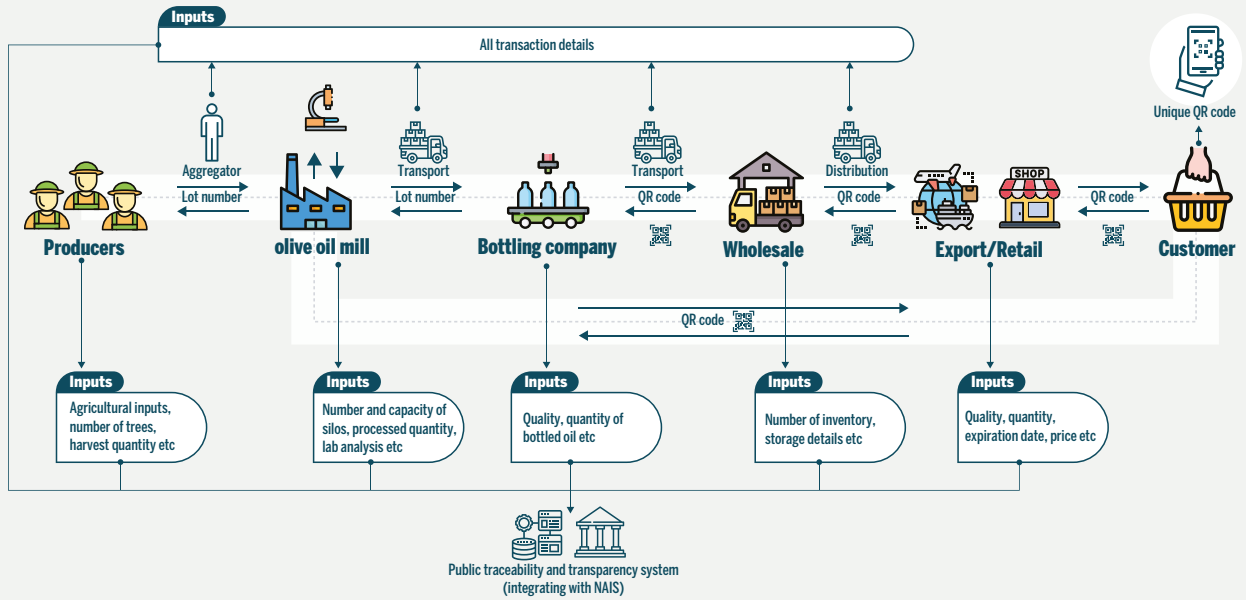
Jordan – Recommendations

The study showed that the Jordan olive oil subsector has huge domestic consumption and faces the threat of food fraud. Domestic customers are aware of the food quality and safety issues. However, the domestic price of Jordanian olive oil is already priced higher than for the international, therefore VC actors understand that improvement in traceability and transparency barely brings a premium price in the markets. Moreover, producers may have little interests in transparency of market information as the government protects them with an import ban. In this regard, the proposed solutions are basically built on the existing system, which can be improved by the public sector at minimal additional cost (low-tech adoption):

- **Public traceability system based on the existing QR-code system (short-term):** The existing QR-code system in Jordan needs to be further improved and regulated. Relevant ministries need to develop data standards for the QR-code system including the provision of detailed information and involving actors, so that the code can cover all stages of the VC and provide consumers with reliable and necessary information for tracking and to help producers increase marketability of their produce. In addition, the system needs to incorporate necessary tests and certifications to ensure the final products in the market meet adequate quality and safety standards. The system could function to prevent fraud and facilitate the acquisition of certifications by providing information.

- **Public sector develops a real-time information system for transparency (mid-term):** Building on the existing NAIS, for the olive oil subsector, it would be possible to design a real-time information system that provides reliable information including supply chain and market information to stakeholders to help with decision-making. The traceability component could be integrated to better monitor development in the sector. However, as the VC focuses mostly on the domestic market, prices are fixed by the governmental entity, the system could be developed at a later stage.

Figure 23: Public traceability system based on the QR-code system



Sources: Authors' own elaboration.

Required actions

- **Awareness-raising:** To help VC actors understand the need for a traceability and transparency mechanism to ensure food safety and quality in domestic markets and fair value distribution among VC actors.
- **VC governance:** Should be strengthened to improve the flow of information. It is also recommended that a quality control system be set up at each stage to reduce the risk of fraud.
- **Digital skills development:** Existing technologies could be taught that could help VC actors improve their adoption of technologies.
- **Data management and standardization:** A standardized information management system could be established built on NAIS, which would improve interoperability and mainstream the traceability and transparency system at the national level.
- **Government support, regulatory framework:** Develop a clear regulatory framework for the collection, storage, and use of data. To accelerate adoption of digital traceability and transparency solutions, producers should be trained to engage with the system.
- **Access to finance:** Improve access to loans or credit to increase investments in the improvement of quality or the procurement of necessary tools or machinery.

3.4 Potential impact on sustainability of the horticulture value chain and scalability

Based on the recommended solutions for both the date palm and olive oil VCs, this section will examine the potential impacts on sustainability (economic, social and environmental) so as to ensure the solutions will positively contribute to the sustainable development of the VCs.

Economic impacts of digital technologies for improved traceability and transparency in the horticulture VC will depend on a variety of factors, including the specific technologies used, the context in which they are adopted, and the policies and regulations in place to address potential negative impacts. In general:

- The benefits of digital traceability and transparency technologies are likely to outweigh the costs over the long-term, as they can improve supply chain efficiency, reduce food loss, and increase consumer trust and demand for products leading to increased sales and revenue for not only large private companies but also SMEs (refer to Annex 14).
- The introduction of digital technologies for traceability and transparency can lead to improved efficiency in the supply chain; reduce the use of energy and thus costs. By having a real-time view of the entire VC including production, processing and distribution, stakeholders can make informed decisions that drive costs down.

- The use of digital technologies can also enhance food safety and quality, leading to improved marketability, increased demand and can improve the incomes of producers, processors, wholesalers, retailers and exporters. Digital technologies will ultimately benefit the most vulnerable in the market including small and medium-sized producers and SMEs who will obtain a fair price for their products.

- The adoption of these technologies may create new job opportunities in the development and implementation of digital systems.

- By providing reliable information about the origin, quality, and authenticity of horticultural products, these technologies can support the growth of new markets, particularly in the NENA region where consumers are increasingly interested in sustainable, high-quality products.

The social impacts of adopting digital technologies for improved traceability and transparency in horticulture VC are as follows:

- By providing accurate and transparent information about the journey of food products, digital traceability and transparency solutions can help reduce the risk of foodborne diseases and outbreaks.

- Digital traceability systems can help improve food safety and quality and prevent food fraud by allowing for the tracking of food from farm to table, ensuring that products are safe for consumers to eat.

- These systems can provide valuable information to small and medium-sized producers, helping them to improve their production processes and better understand consumer preferences. This can lead to increased income and better livelihoods for producers.

- The private sector can be motivated to train rural small and medium-sized producers (major producers) in production so as to address the digital divide.

- Digital traceability and transparency can support local communities by increasing the availability of high-quality horticultural products, support the growth of local economies, which will lead to better nutrition and job creation.

- Unfair value distribution will be addressed by providing transparent information throughout the supply chain and increasing consumer awareness.

- Prevailing digital solutions can enhance inclusion of youth and capacity-building can reduce the youth digital divide.

- Promotion of digital systems can enable small and medium-sized actors such as SMEs to have equal access to services and strengthen their business model.

- Increased transparency can help address issues such as child labour and exploitation in the supply chain, promote fair labour practices and improve working conditions for workers.

Environmental impacts of applying digital traceability and transparency systems in the horticulture VC are as follows:

- Digital technologies can help promote sustainable agriculture practices by providing data on crop yields, water use and fertilizer applications. This information can be used to optimize the use of resources and reduce food loss, reducing the environmental impact.
- Digital traceability and transparency systems can help combat deforestation and habitat destruction by providing information on the source of raw materials and ensuring they are sourced from sustainably managed sources. For instance, the systems can support the growth of certification schemes to promote environmentally friendly and sustainable practices.
- The use of digital technologies can reduce the carbon footprint of the supply chain by optimizing the use of energy in processing and logistics, transportation routes and reducing the need for manual labour.

By applying the digital traceability and transparency systems, the study suggests it will benefit all three sustainable dimensions (economic, social and environmental), particularly for small and medium-sized producers as well as SMEs.

Scalability: Based on the commonalities discussed above, the approach employed by the study could be applicable to horticulture VCs in NENA, as long as the commonalities are strongly identified. The approach includes several steps: study of the VC; assessment of the key criteria and data availability on VC actors; identification of possible digital solutions and the required actions to fill gaps; and assessment of the impacts on sustainability. It is recommended that interviews be conducted with key VC actors and agritech companies so as to gain a comprehensive understanding of the VC landscape.

4. Conclusions

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4.1 Feasibility

Based on the findings of the case studies on date palm and olive oil VCs, and the identified similarities between them, the study concludes that is feasible to apply digital technologies to horticulture VCs in NENA so as to improve traceability and transparency. The potential impacts on economic, social and environmental sustainability are all positive and will ensure inclusive, competitive and sustainable development of the horticulture VCs. Three main levers have been identified as key to the adoption of digital technologies, in particular for small and medium-sized producers:

- Raising awareness of the benefits and capacity-development to apply digital solutions for all VC actors including producers, processors, wholesalers, retailers and exporters. The benefits include ensuring food safety and quality, consumer confidence, supply chain efficiency, sustainable practices and fair value distribution, ultimately benefitting small and medium-sized actors.
- Mitigating risks of not capturing the possible benefits because of misconduct, and lowering barriers to the adoption of new technologies for traceability and transparency. Benefits can be achieved by thoroughly assessing and identifying the countermeasures for the following points: VC governance, perceived costs, social and cultural norms, ICT infrastructure, digital skills, data management and standardization.
- Promoting an enabling environment, such as establishing a regulatory framework and financial support from the government would smooth application of technologies.

Addressing the gaps to maximize the impact of these levers to increase the feasibility of adoption includes strengthening VC governance; gathering producers into organizations; promoting risk-adverse solutions; developing ICT infrastructure; enhancing policies and regulatory frameworks; providing training in digital literacy; developing a data management and standardization system; establishing a regulatory framework; and facilitating access to finance.

Potential impacts of applying digital traceability and transparency systems for economic, social and environmental sustainability are positive and will contribute to addressing digital-related challenges such as the digital divide for smallholder producers and SMEs in rural areas. Aligning with the FAO mandate, areas of work and priorities, facilitation of the use of digital technologies to improve traceability and transparency systems in NENA would be a key factor in the success of sustainable development of the horticulture VCs.

4.2 Possible solutions

Based on the analysis of the three levers in the horticulture VCs, approach to application, level of uptake and extent of impacts on sustainability of digital technologies for improved traceability and transparency will vary. It is noteworthy that no one single component can determine the entire approach and a combination of key factors will define the possible solutions. For instance, even though the level of ICT infrastructure is high, this does not mean adoption of high-tech is necessarily the most effective and viable strategy. The case studies suggests possible solutions as follows:

- **Egypt:** In the short-term, private traceability and transparency system using low-tech is recommended because the cost of applying the technology exceeds the return on investment. In the mid-term, a viable option would be to introduce high-tech in partnership with agritech companies so as to improve service quality, efficiency and data coverage, based on the moderate level of ICT infrastructure and digital skills.

- **UAE:** The country has already developed and implemented the digital traceability and transparency system that covers most production areas. To leverage the existing technologies, it is proposed that the organization of producers be strengthened, and provision of services across the country extended.

- **Tunisia:** In the short-term, a public traceability and transparency system with low-tech is proposed because of the substantial presence of the governmental entity ONH and the current level of ICT infrastructure and digital skills. In the mid-term, a public-private blockchain technology system is suggested because leading companies have already started to apply the high-tech system such as blockchain to increase added value.

- **Jordan:** The low-tech public traceability and transparency system is recommended for the short-term since the perceived potential benefits for the private sector, particularly producers, are expected to be limited due to the existence of the protective policy towards volatility of the market price. At the same time, a public real-time agriculture information system is proposed as a short-term solution because there is an existing system NAIS that can be utilized and ICT infrastructure is moderately developed. The mid-term solution is not proposed as the decision would depend on the enabling environment (e.g. the import ban or the price strategy, which currently does not provide an incentive to invest in high-tech solutions).

Needless to say, the possible recommended solutions are not exhaustive with all available technologies concerned but reflect the reality of the country and the context of the VC, which may entail simply prioritizing the approach.

In summary, and expanding the findings to the broader horticulture VCs, solutions vary depending on two elements: **ownership** (public or private sector-led development) and the **level of the technologies applied**. Where the government plays an important role in regulations and standardization in a VC, a public system is highly recommended to smooth mainstreaming and vice versa. Moreover, if benefits are not highly realized, or there are high barriers that hamper adoption of digital traceability and transparency system, low-cost low-tech solutions are likely to be proposed and vice versa. A follow-up study is suggested to make further recommendations on scalability and to develop an in-depth study of implementation.

4.3 Role of the stakeholders

A diverse landscape of stakeholders involved in agrifood value chains and in shaping digital ecosystems places the importance of coordination at the centre of applying digital technologies. Clarity on the roles and responsibilities of the actors can facilitate the process of co-creation and design of digital pathways to benefit communities and contribute to the development agenda of governments.

Government

Public sector and governments are key actors in creating a conducive, enabling environment to facilitate adoption and deployment of digital technology by small and medium-sized agrifood producers. Their role and responsibilities span the following points:

- Raise awareness of small and medium-sized actors on the benefits of using suitable digital solutions for improved traceability and transparency as a vehicle for better productivity, better quality and better profits. Pilot or demonstration projects could be designed to sensitize actors about the impacts of the uptake of digital solutions.
- Establish standards and guidelines for the use of digital traceability and transparency systems, taking into account the impact on sustainability and inclusion.
- Provide tax incentives and subsidies to companies and organizations that invest in such digital technologies to benefit small and medium-sized actors.
- Facilitate development of comprehensive data management system that can capture and track all relevant information throughout the value chain.
- Facilitate and establish robust security measures to protect the confidentiality and integrity of sensitive data.
- Develop and mainstream a quality control system to capture the potential benefits of adoption of traceability and transparency technologies.
- Fund research projects, supporting R&D initiatives, and collaborate with research institutions to advance the state of the art technologies in the field of digital traceability and transparency.
- Establish public–private partnerships to support the development and implementation of digital technologies in the AVCs.
- Promote the use of these technologies in the public procurement of horticultural products. Work with industry associations to encourage wider adoption of digital technologies for traceability and transparency.
- Organize fragmented smallholders, individual collectors and traders into cooperatives, associations, etc. to assist them to integrate into the VC, which would be useful for supply chain management and tracking information.
- Enhance the basic ICT infrastructure to permit the uptake of emerging technologies such as blockchain for more efficient use.
- Enhance digital capacity-development through programmes or projects, and encourage young graduates to become involved in the agriculture sector through the generation of more digital relevant job opportunities.
- Provide an attractive business environment for the private sector, in particular SMEs and agritech start-ups, to attract more investments in digital innovations in traceability and transparency.
- Enhance ministerial and multistakeholder collaborations to improve leverage of resources and expertise to crosscut obstacles.

Other stakeholders

Private sector

Value chains are comprised of multiple private sector actors whose actions and decisions determine the way the food is produced, consumed and flows along the chain. They play a key role in increasing competitiveness of value chains and in improving social and environmental co-benefits that are generated for all actors. The following factors could guide the sector in enhancing its contribution in the design and deployment of digital technologies in an inclusive and sustainable manner:

- Invest in the development and implementation of new platforms,[97] for instance remote sensing, blockchain (see Box 4 *Blockchain positioning*) and applications, also invest in cloud based infrastructure for a higher return on investment.
- Form consortiums and joint ventures to develop digital solutions and services of traceability and transparency as well as partner with research institutions to support R&D initiatives.
- Work with partners in the VC to develop, test and pilot the platforms (e.g. cloud-based infrastructure, remote sensing and blockchain) and traceability and transparency applications, and use the results of these pilots to promote wider adoption of these digital technologies, particularly for SMEs that have financial constraints hence the high barrier of costs.
- Invest in capacity-building and provision of technologies to small and medium-sized producers to fully utilize the technologies.
- Help producers become better informed about market information and consumer insights concerning high-value produce and thus improved profitability.
- The prominent companies in the sector can play a leading role in driving technological applications in the VCs. Also, agritech startups and SMEs should be given more support by the government, private sector and international development agencies in terms of knowledge, awareness and innovation capacity.
- The private sector in horticulture VCs needs to create a long-term plan to meet increasing food quality requirements and sustainably capture value addition opportunities in export markets. In addition, the choice of digital technologies should be in line with the actual capacity of the companies.
- Form a community or network for the sector such as associations (e.g. HEIA in Egypt) to improve collaboration with the government when developing policies and guidance to improve the enabling business environment.

International development agencies

International development agencies, including FAO, which has a mandate to achieve food security and nutrition for all through transformation to more efficient, inclusive, resilient and sustainable agrifood systems by effective collaboration with all the stakeholders in maximizing public benefits and ensuring equal access, can play an important role in improving and introducing digital technologies for traceability and transparency in AVCs in several ways:

- International development agencies can provide technical assistance to governments and other stakeholders to help them understand the benefits and implementation of digital traceability and transparency systems. This can include training programmes, workshops, and other capacity-development initiatives.

- International development agencies can work with governments, other stakeholders to promote international cooperation and coordination in the implementation of digital traceability and transparency systems. This can help to ensure these systems are implemented in a consistent and harmonized manner across different countries and the NENA region.

- International development agencies can provide funding and support for research and development of new technologies and approaches to traceability and transparency. This can help ensure these systems are continually improved and adapted to meet changing needs in the agrifood value chains.

- International development agencies can facilitate partnerships between governments, the private sector companies, and other stakeholders to promote the implementation of digital traceability and transparency systems. These partnerships can help ensure systems are designed and implemented in a way that meets the needs of all stakeholders.

- International development agencies can advocate for policies and regulations that support the implementation of digital traceability and transparency systems in the agrifood value chains. This can include supporting the development of national and regional standards for traceability and transparency, data governance, systems interoperability, and advocating for their adoption by governments and other stakeholders.

- International development agencies can take responsibility for equal access and proper use of the digital technologies for sustainable development of agrifood VCs and focus on addressing the digital divide, especially for small and medium-sized producers in rural areas who do not usually have regular access to new technologies. This includes effective facilitation of a coordinated mechanism set up among stakeholders to sustainably operate digital technologies.

As a specialized international organization in food and agriculture promoting digital technologies for equal access for the most vulnerable such as small and medium-sized producers and SMEs, FAO can support the region and its Member States in:

- Sustainably upgrading AVCs by addressing critical challenges along the chain that affects food safety and quality to improve quality, nutrition and achieve higher value addition.

- Linking local farmers with the private sector (especially SMEs) to build a traceability and transparency system, through contract farming, etc. to better improve food quality and access market opportunities.

- Develop the conceptual framework for the digital ecosystem to support sustainable food systems for date palm and olive oil production.

4.4 Risk assessment

The case studies have demonstrated a few similarities and differences among the countries in the region. Therefore, the proposed digital solutions for improved traceability and transparency along the VCs could be replicated in relevant sectors or referred to. It is, however, important to note that digital technologies are tools that can effectively facilitate the achievement of national priorities and goals in the development of the agrifood sector, and should remain flexible and adjustable based on the actual context of a country, a company or an individual actor. Therefore, it is essential to assess the possible impacts and risks that may cause failure or unsustainable results.

Unwillingness of participants to cooperate

Regarding the proposed solutions, blockchain is considered the most advanced technology for building decentralized traceability and improving the transparency system. Yet, to apply blockchain, the precondition is the current high level of ICT infrastructure and relevant standards or policies that can enable implementation. Clear standards need to be established and methodologies that can ensure sustainable and traceable sustainability claims (to register for example in blockchain) such as on minimum wage, food safety, climate footprint, deforestation and labour conditions.

Siloed and inefficient data standardization

The integration of financial services through related transactions is challenging because of the risk of lack of interoperability,[98] which may lead to the scalability issue of private blockchains being run as isolated solutions. As a result, the existing blockchain solutions in the studied countries are often led by the private sector, in collaboration with global leading companies (e.g. IBM Food Trust) with mature solutions. It is inevitable that when using different platforms, the lack of standardization may create challenges. Blockchain is not the only means to realize decentralization or a digital ecosystem for sustainable agrifood systems. The regulation of data standards, governance and interoperability should be developed to address this challenge.

Date privacy and data sovereignty

When producers of horticulture crop can rely on platforms from digital agriculture service providers, it is important to understand how well the offered platforms respect the data privacy of its users. In addition, these digital platforms often require the producers to hand over a lot of farm level data and the data sovereignty of the data owners (the horticulture crop producers) may not be respected.

System vulnerability

Most companies may adopt the QR code system. However, KII interviews revealed that, in certain cases, QR codes can provide only limited information so control of the information largely depends on the companies themselves. Also, QR codes are susceptible to containing unreliable or inaccurate data, and records on movement may be incomplete. When consumers have a high awareness of private data security they may be reluctant to scan code. Therefore, there should be relevant regulations and policies to build standards for QR code traceability. Companies that install such a system should improve their technological solutions to address the above-mentioned issues.

When establishing a national food traceability and transparency system, the biggest challenge is lack of records, particularly for long and complicated VCs where a large number of actors are involved. Meanwhile, human error may occur during data entry and recording, leading to inaccuracy of the uploaded information. Apart from the solutions themselves, the value of governance of the VC is of particular importance for any type of digital traceability and transparency system. The digital traceability and transparency system is an integrated system that requires institutional support, stakeholder involvement, qualified and skilled employees, as well as the capacity to use the relevant tools (mobile, web, software, etc.) of the relevant suppliers. Therefore, awareness-raising, and capacity-building should be considered so as to enable the system to actually be implemented and used.

Risk of widening the divide

Another risk is the exclusion of a group of actors, such as women, because they lack access to assets and resources and fall into the digital literacy gap. According to ITU (2017) the Arab region has the highest gender digital divide in the world.[99] Digital services require users to be able to access and use the Internet, however, but Internet penetration rates are higher for men than women in the region. Globally, women are 12 percent less likely to have mobile phones than men.[100] Illiteracy is also an obstacle to online access. In the Near East and North Africa region, gender disparity in literacy is still a challenge as the literacy rate is 86 percent for men and 73 percent for women.[77] In terms of financial access, women have fewer opportunities to finance investment in digital technologies. For instance, women's start-ups in the digital sector obtain 23 percent less funding than men's.[101] To ensure digital inclusion, especially for women, requires improved access to the Internet and devices, capacity-building for digital literacy and facilitation of access to finance.

Annex 1. **Scoring the target value chains**

Steps: Three steps to narrow down value chains and countries.

- **Step1:** Longlisting value chains (from 29 horticulture crops to 8)
- **Step2:** Country selection for each value chain
- **Step3:** Shortlisting value chains (from 8 candidates to 2)

Approach:

- **Step1:** Screening horticulture VCs and quantitative information mainly comprising macro-economic factors (production size, share in total world production, export rate, annual growth rate of export and production cost) are used as criteria for longlisting.
- **Step2:** Country-specific quantitative information on macro-digital readiness is added, including number of digital start-ups, digital access, use and skills as well as the government commitment.
- **Step3:** Country-specific qualitative information on social and environmental aspects is added.
- The weight for each criterion is allocated based on priority at each stage.

Results of Step (1) **longlisting value chains**

- **Results:** Eight value chains are selected from 29 horticultural value chains produced in NENA in 2020, namely; olives/olive oil, tomatoes, onions, oranges, watermelons, grapes, dates and pumpkins.

#	Item	Data from FAOSTAT					Score (0-5 points)					
		Production quantity (tonnes) (2020)	% in Total world production (2020)	Export rate (%) (2020)	Annual growth rate of export quantity worldwide (2011-2020)	Producer price advantage (%) (2020)	Production quantity (tonnes) (2020)	% in Total world production (2020)	Export rate (%) (2020)	Annual growth rate of export quantity worldwide (2011-2020)	Producer price advantage (%) (2020)	Final scoring
1	Olives	7,084,086	30%	0%	18%	40%	5	5	-	5	5	4.75
2	Dates	7,203,689	76%	14%	8%	13%	5	5	4	4	5	4.75
3	Watermelons	6,833,283	7%	5%	3%	9%	5	2	2	2	5	3.80
4	Tomatoes	15,493,274	8%	6%	1%	49%	5	2	2	1	5	3.60
5	Oranges	6,712,536	9%	26%	2%	1%	5	2	5	1	4	3.55
6	Onions, dry	8,765,905	8%	6%	2%	-14%	5	2	2	1	3	3.20
7	Pumpkins, squash and gourds	1,480,369	5%	4%	13%	32%	2	2	1	5	5	3.15
8	Grapes	3,738,944	5%	6%	3%	3%	3	2	2	2	5	3.00
9	Mangoes, mangosteens, guavas	2,543,345	5%	2%	6%	8%	2	2	1	3	5	2.75
10	Onions, shallots, green	510,158	11%	15%	5%	50%	1	3	5	3	5	2.70
11	Sweet potatoes	727,818	1%	10%	19%	72%	1	1	3	5	5	2.70
12	Apricots	562,216	15%	2%	8%	25%	1	3	1	4	5	2.70
13	Chillies and peppers, green	2,809,095	8%	7%	4%	40%	2	2	2	2	5	2.60
14	Figs	557,785	44%	3%	8%	-12%	1	5	1	4	3	2.60
15	Carrots and turnips	1,481,196	4%	4%	4%	30%	2	2	1	2	5	2.55
16	Eggplants (aubergines)	2,319,608	4%	1%	3%	45%	2	2	-	2	5	2.50
17	Lemons and limes	1,429,359	7%	15%	5%	-2%	2	2	4	2	4	2.50
18	Melons, other (inc.cantaloupes)	1,455,741	5%	7%	1%	33%	2	2	2	1	5	2.40
19	Artichokes	517,346	34%	2%	2%	68%	1	5	1	1	5	2.40
20	Cucumbers and gherkins	2,267,135	2%	3%	3%	18%	2	1	1	2	5	2.40
21	Tangerines, mandarins, clementi	2,391,692	6%	29%	2%	-4%	2	2	5	1	4	2.35
22	Cabbages and other brassicas	1,008,544	1%	4%	5%	31%	1	1	1	3	5	2.20
23	Garlic	632,189	2%	17%	3%	16%	1	1	5	2	5	2.20
24	Almonds, with shell	459,237	11%	2%	4%	0%	1	3	1	2	4	2.10
25	Cauliflowers and broccoli	608,294	2%	5%	3%	48%	1	1	2	2	5	2.05
26	Peaches and nectarines	1,050,330	4%	10%	2%	20%	1	2	3	1	5	2.05
27	Strawberries	781,942	9%	7%	1%	62%	1	2	2	1	5	2.00
28	Apples	2,854,238	3%	5%	0%	-17%	2	2	2	1	3	2.00
29	Grapefruit (inc. pomelos)	443,349	5%	8%	0%	0%	1	2	2	1	4	1.80

- **Criteria, weight and scale:** Weight is calculated as below and scale ranges from 0 to 5 points based on deviation of actual figures for each value chain.

Category	Indicator	Weight
Economic sustainability	Production size (tonnes, 2020)	40%
	Share in the world production (%, 2020)	15%
	Export rate (%, 2020)	5%
	Annual growth rate of export (%, between 2010-2020)	20%
	Production cost - difference from world average (USD per ton, 2020)	20%

Results of Step (2) **Country selection for each value chain**

- **Results:** One country with the highest score is selected for each eight value chains as follows:

Value chain	Olive oil	Dates	Tomatoes	Oranges	Onions	Watermelons	Grapes	Pumpkins
Country (Main)	**Tunisia**	**Egypt**	**Egypt**	**Egypt**	**Egypt**	**Egypt**	**Egypt**	**Egypt**

- **Criteria, weight and scale:** Weight is calculated as below and scale ranges from 0 to 5 points based on deviation of actual figures for each value chain.

Category	Indicator	Weight
Economic sustainability (70%)	Production size (tonnes, 2020)	30%
	Share in the world production (%, 2020)	10%
	Export rate (%, 2020)	5%
	Annual growth rate of export (%, between 2010-2020)	5%
	Production cost - difference from world average (USD per tonne, 2020)	20%
Basic conditions for digitalization (30%)	Number of digital start-ups (2022)	10%
	Digital access index (2017)	5%
	Digital use index (2017)	3%
	Skills index (2017)	2%
	Government support	10%

Results of Step (3) **Shortlisting value chains**

- **Results:** Two value chains are selected namely, olive oil (Tunisia) and dates (Egypt). Countries for comparative analysis are selected namely Jordan and UAE for each VC.

Scoring		Olive oil	Dates	Watermelons	Tomatoes	Oranges	Onions	Pumpkins, squash and gourds	Grapes
		Tunisia	**Egypt**	**Egypt**	**Egypt**	**Egypt**	**Egypt**	**Egypt**	**Egypt**
Economic	Production quantity (tonnes)	0	2	2	5	3	3	1	2
	Percentage of total world production	4	5	1	2	2	2	1	1
	Export rate (%)	5	1	1	1	5	2	1	2
	Provision of support services	4	4	0	2	5	2	2	2
	Annual growth rate of export quantity (%)	3	2	1	3	3	0	2	5
	Producer price advantage (%)	1	5	0	4	3	1	4	2
Social	Small and medium-sized producer participation	4	2	4	4	2	4	4	2
	Participation of women	5	4	1	5	1	5	3	1
	Participation of the rural poor	4	4	5	4	3	4	4	5
	Participation of youth	4	4	3	4	4	3	3	4
	Employment	4	4	2	4	2	4	2	2
Environmental	Improved efficiency of water use	5	5	3	3	5	3	3	3
	Better water productivity	4	5	1	1	5	1	1	3
	Energy efficiency	4	5	4	2	2	2	4	2
	Impacts on climate	5	5	3	2	3	2	3	3
Digital	Percentage of digital startups	0	3	3	3	3	3	3	3
	ITU access index	0	3	3	3	3	3	3	3
	ITU use index	5	2	2	2	2	2	2	2
	ITU skill index	5	2	2	2	2	2	2	2
	Government support	3	3	3	3	3	3	3	3
Final score		**2.88**	**2.66**	1.55	2.60	2.34	1.94	2.01	2.13

- **Criteria, weight and scale:** At this stage, qualitative information is collected to holistically evaluate the suitability for adoption of digitalization. Hence, not only economic and digital readiness factors but also social and environmental information is taken into account as below. Weight is calculated as below and scale ranges from 0 to 5 points based on deviation of actual figures for each value chain.

Category	Indicator	Weight
Economic sustainability (35%)	Production size (tonnes, 2020)	7%
	Share in world production (% 2020)	7%
	Export rate (% 2020)	2%
	Support service provision level	5%
	Annual growth rate of export (Percentage between 2010-2020)	7%
	Production cost (USD per tonne, 2020)	7%
Social sustainability (25%)	Social inclusiveness: Small-scale farmers participation	9%
	Social inclusiveness: Women participation	4%
	Social inclusiveness: Rural poor participation	4%
	Social inclusiveness: Youth participation	4%
	Employment	4%
Environmental sustainability (10%)	Improved water use efficiency	3%
	Better water productivity	2%
	Energy efficiency	2%
	Impacts on climate	3%
Basic conditions for digitalization (30%)	Number of digital start-ups (2022)	7%
	Digital access index (2017)	5%
	Digital use index (2017)	5%
	Skills index (2017)	5%
	Government support	8%

Details of the indicators used

Category		Indicator	Source	Rationale
Economic sustainability	Established value chains	Production size (tonnes, 2020)	FAOSTAT	A larger size of production can potentially bring more opportunities to scale up business use and larger impacts on improvement in efficiency by digitalization.
		Share in the world production (% 2020)	FAOSTAT	Digitalization in midstream of AVC can potentially maximize production surplus resulting from increased efficiency throughout value chains. An existing larger share/presence in the world production can ease marketability for the surplus.
		Export rate (%, 2020)	FAOSTAT	Digitalization in midstream of AVC can potentially improve food safety and quality, triggering additional export opportunities. An established export market is foundation to capture the opportunities.
		Support service provision	Literature review	Well-organized support service provision is important to benefit from digitalization.
	Market demand	Annual growth rate of export (% between 2010-2020)	FAOSTAT	A higher growth rate indicates the possibility of higher return for digitalization investments.
	Competitive advantage	Production cost (USD per tonne 2020)	FAOSTAT	To market production surplus, cost advantage is key to enter new markets or compete in existing markets with competitors.
Social and environmental sustainability		Social inclusiveness	Literature review*	FAO mandate is to not leave anyone behind, especially those who are vulnerable including small-scale farmers, women, the rural and youth. They tend to be excluded from the value chain and this leads to inefficiency of value chains.
		Employment		Target value chains in target countries must highly contribute to creation of employment to improve social inclusiveness for the vulnerable.
		Improved water use efficiency		Typically the NENA region faces issues related to water scarcity, thus water use efficiency and water productivity are indicators of resilience to this environmental challenge.
		Better water productivity		
		Energy efficiency		One of the FAO strategic frameworks is better environment and digital transformation should ensure positive contribution to this mandate.
		Impacts on climate		
Basic conditions for digitalization		Number of digital start-ups (2022)	Briter Bridges	A larger number of established digital start-ups indicate the feasibility of implementation/adoption of recommended digital technologies is higher.
		Digital access index (2017	ITU	The access index comprises fixed-telephone subscriptions, mobile-cellular telephone subscriptions, international Internet bandwidth per Internet user, households with a computer, and households with Internet access. This indicates level of feasibility for beneficiaries to benefit from digital technologies.
		Digital use index (2017)	ITU	The use index comprises individuals using the Internet, fixed-broadband subscriptions and mobile-broadband subscriptions.
		Skills index (2017)	ITU	The skills index consists of three proxy indicators: mean years of schooling, gross secondary enrolment, and gross tertiary enrolment. It can indicate a level of appreciation of digital technologies and possibility of their adoption.
		Government support in digital initiative	FAO	The region promotes digitalization/e-agriculture strategy through FAO programmes with governments. The participation indicates their understanding of and commitment to digitalization.

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Annex 2. **List of interviewees in key informant interviews**

Country	Name	Institution
Egypt	Khaled El-Hagan	Agricultural Export Council (AEC), Haggan Group
	Amgad El-Kady	Food and Agro-Industries Technology Center
	Mohammed Nasser	Afro Egypt
	Ahmed Amer	EMURGO Egypt
Jordan	Ruba Daghmish Fayyad El Ziuod	Jordan Olive Oil Products Exporters Association (JOPEA)
Tunisia	Hamed Daly	National Olive Oil Board (ONH)

Annex 3. **Egypt: Examples of different varieties and prices of date palm**

Varieties of dates	Grade	Average pices per kilogram in EGP		
		At producer	At wholesaler	At retailer
Soft varieties				
Barhi	Unified	15	20	25
Zahloul	Unified	4	6	8
Hayani	Unified	4	6	10
Samani	Unified	3	5	7
Amhat	Unified	2	3	5
Semi-dry varieties				
Seidy	Large, medium	12	16	25
	Small	10	14	20
Siwi	Soft	15	20	25
	Large, medium	10	14	22
	Small	8	12	20
Medjool	Jumbo	60	75	120
	Large	45	60	90
	Medium	35	50	75
	Small	20	30	40
Melkabi Semi-dry	Large	40	60	75
	Medium	30	45	60
	Small	20	25	35
Dry varieties				
Dry Melkabi	Large, medium	25	30	40
	Small	15	20	30
Bertmoda	Large, medium	12	15	20
	Small	6	10	15
Sakuti	Large, medium	12	15	22
	Small	7	12	18
Unknown soft varieties	Unified	3	5	7
Unknown dry varieties	Unified	2	4	10

Sources: UNIDO. 2021. Gender sensitive analysis of the palm date sector in Fayoum and Giza governorates.

Annex 4. **Egypt: Institutions involved in the date palm value chain**

Institution	Role
National Food Safety Authority (NFSA)	It issues export authorization certificates as requested by the importing country's pertinent authority or the importer. In such cases, the Egyptian exporter ensures compliance with the importers' requirements and submits a request to the NFSA along with the information and documents required and the fees. The NFSA has the right to ensure compliance of the shipment.
Higher Council for Date palm	The Council's mandate is the development of the date palm sector on a national level across different stages of the value chain, such as production, processing, exporting, branding, food safety and quality, employment, cultivation, etc.
Food Technology Center (FTC)	It was established by the Ministry of Industry in 2001 to provide technical assistance to the food processing sector in Egypt
Chamber of Food Industries (CFI)	It includes more than 3000 enterprises in the food and beverage sector and is the main representative of the private sector before the Government.
Food Export Council (FEC)	One of the sectoral export councils established by the Ministry of Trade and Industry to enhance Egyptian exports in these sectors. It is responsible for processed food export.
Agricultural Export Council (AEC)	The official representative of agro-exporters with the Government of Egypt. It aims to increase Egyptian agro exports of fresh food and penetrate new markets. It has developed the integrated coding system from farm to export in order to ensure export of a safe Egyptian product that conforms to the requirements of importing countries in collaboration with Egyptian Quarantine General Organization for Import and Export Control.
Central Laboratory for Date Palm Research and Development (CLDPRD)	Established in 1993 to improve the quality of Egyptian palms nationally and regionally and enhance its economic, social, and environmental impact through research and training programs
Food Technology Research Institute (FTRI)	Established in 1991 concerned with applied research in food processing and preservation.
Horticultural Export Improvement Association (HEIA)	Established in 1996, HEIA expanded in a very short time to reach a large group of members who represent producers, exporters, suppliers of horticultural products, and companies working in agricultural equipment and packaging material supply. HEIA encompasses a group of highly qualified and recognized agricultural specialists and experts as well as offers a wide range of services.
Khalifa International Award for Date palm and Agricultural Innovation (KIAAI)	The UAE Government, within the framework of its development plans, has placed the establishment of a date production industry as one of its important priorities. The mission is to encourage innovators such as researchers, growers or exporters, whether individuals or institutions, engaged in the agricultural and date palm sector and to honour influential figures in agricultural and date palm innovation at the local, regional and international levels. They also organize exhibitions in Egypt.

Annex 5: **Technologies in the date palm value chain**

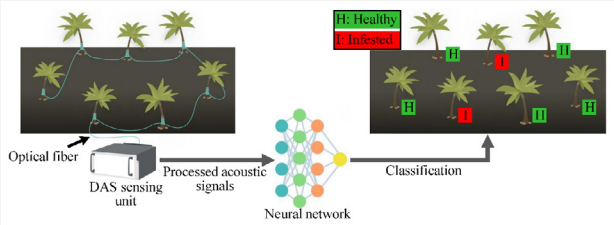
Red Palm Weevil

Red Palm Weevils (RPW) is the most destructive pest of palm trees across the globe and causes considerable damage to various palm species. In 2022, FAO signed a letter of agreement with KFU in KSA in order to promote scientific research and innovation for long-term solutions and sustainable control of the RPW, within the framework of the FAO programme to eradicate RPW from the NENA.[102]

Red Palm Weevil detection - acoustic sensing

A field experiment reports on the use of Distributed Acoustic Sensors (DAS) in combination with machine learning (an artificial intelligence technique). See Figure A.5.1 for the experiment setup.

Figure A.5.1: Overall approach for RPW detection using an optical fibre DAS and machine learning



Sources: Ashry *et al*., 2022. CNN-based detection of red palm weevil using optical-fibre-distributed acoustic sensing. 57. 10.1117/12.2609308

The experiment reports an accuracy of ~97 percent for classifying invested and healthy trees, of which the invested trees report ~20 percent of false alarms. The best performance of the system is obtained when wind speeds are less than 9 mph.

Another study combines DAS with the injection of fungal isolates. The larval activity is measured through the rate of impulse bursts with an acoustic sensor. Two months after fungal injection, the RPW sound signal declined, while the RPW sound signal increased in the control date palms (water injection). The mean rates of bursts produced decreased to zero. The fungals used are *Beauveria bassiana* and *Metarhizium anisopliae*.[103]

Red Palm Weevil detection – normal imagery

The RPW early identification through an accurate technique for the identification, localization and classification is challenging. Deep learning (a machine learning artificial intelligence technique) can help to identify and discriminate between the RPW and other insects living in palm tree habitats, this was not applied before. A convolutional neural network (R-CNN) algorithm was used to detect the location of the RPW in an image by building bounding boxes around the image. The model can be scaled up for efficient, low-cost RPW detection and classification technology for palm trees.[104]

Alsanea *et al*. (2022)[104] described a method that would work well with high-resolution images collected through on the ground sensors like mobile phone like cameras. The imagery would need to capture literally the RPW insect. It is not clear how to monitor large fields with on the ground-collected imagery. Imagery from remote sensors like satellite or drones are lower in resolution and it is unlikely that RPW insects would be detectable there.

An experiment (analysing over 100 000 aerial and street images) shows another way of RPW detection. The use of public available imagery can map palm trees at large scale and detect ones that are potentially invested. The method can revolutionize RPW management through its cost effective and efficient monitoring.

The method can be instantly deployed to any scale of need and every geographic location where public street level imagery is available.[105]

Red Palm Weevil detection – remote sensing

Research indicates that remote sensing can recognize and monitor RPW, using a using a combination of vegetation indices, object detection and semantic segmentation techniques. The method demonstrates excellent potential for individual date palm tree recognition and multi class monitoring of growing status using satellite imagery. This could help to precisely manage plantation and efficiently deal with infected date palm trees. Future work will develop a more effective generalized date palm tree detection method.[104]

Remote sensing and date palm

The body of knowledge of remote sensing for data palm management is small. High resolution remote sensing can assess various health aspects and plant management of date palm plantations, adding to its precision agriculture techniques.[106]

There is a remote sensing method through satellite imagery to estimate the carbon stock of date palm plantations. It makes use of the correlation between spectral reflectance and different vegetation indices on one side, and aboveground biomass derived from ground measurements on the other side. For the medium and young age classes, the correlation was not significant. The carbon stock represented 53.87 percent of the total above ground biomass.[107]

Date palm needs sufficient water to reach its potential yield and a study estimates the daily, monthly and annual actual evapotranspiration (ETa) for date palm, comparing also computed ETa and the actual water applied in the field. The Surface Energy Balance Algorithm for Land (SEBAL) supported by climate data was used to calculate the ETa. The SEBAL model outputs were validated using the FAO Penman-Monteith method coupled with field observation and measurements. The study concludes that the ETa calculated from the satellite data and the SEBAL model is useful for guiding the daily operation of date palm water management at the farm scale. Also, this information is essential for water planners and policymakers to formulate strategies and make decisions for managing water resources over large agricultural areas. The spatial distribution of the agro-hydrological processes and total water use patterns needs further investigation. On-farm validation measures need to be improved to monitor soil salinity, soil moisture, water table and irrigation uniformity. Reducing the total water use may lead to sustainable agricultural water management.[108]

An oil palm perspective shows that oil palm phenology has many advantages in managing the sustainability of oil palm plantations. One of the recently developed methods of oil palm phenology involves the use of remote sensing technology based on sensors, biophysical tree parameters, and classification techniques based on wavelength, biophysical tree parameters, and the type of regression model. There is a lot of potential in combining multisensor approaches, suitable classification methods, and regression models for oil palm phenology. For future studies on oil palm phenology, integrating machine learning with oil palm biophysical parameters based on multisensor remote sensing technologies is recommended. The identification and mapping of oil palm phenology can be conducted based on sensors, including passive sensors with the accuracy levels varying from 90-98 percent (depending on the area). Multisensor remote sensing technologies and convoluted neural networks machine learning can be further developed for classification and regression models with a large number of parameters.[109] Another study confirms the power of remote sensing for oil palm planting, showing the capability of distinguishing between young and mature trees.[110] The oil palm perspective can be inspirational for developing a data palm remote sensing methodology.

Ultrasound date sugar extraction

Refined sugar can lead to various health problems such as diabetes, obesity, cancer, hypertension, and others. A healthier substitute for refined sugar can come from date palm. An ultrasound technique can extract highly nutritious date sugar from date powder. The extract contains fructose, glucose, and sucrose with good thermal stability. The method is efficient and cost-effective.[111]

Annex 6. **United Arab Emirates: Al Foah subsidy scheme in the date palm value chain**

Subsidy for small, medium-scale farmers		Good quality (Dirham/kg)		Average quality (Dirham/kg)	
	Dates variety	**2021**	**2022**	**2021**	**2022**
High commercial value	Farad, Lolo, Khenaizy, Barhi, Medjool	15.50	15.50	7.00	7.00
Medium commercial value	Khalas	13.25	11.50	5.75	5.00
	Maktomy	12.50	11.50	5.75	5.00
	Bumann	12.50	11.50	5.75	5.00
	Shishi	11.75	11.50	5.25	5.00
	Raziz	11.75	11.50	5.25	5.00
	Anbra Almadina	11.50	11.50	5.00	5.00
	Sukkary	11.50	11.50	5.00	5.00
	Dabas	11.50	11.50	5.00	5.00
	Segae	11.50	11.50	5.00	5.00
Acceptable commercial value	Naghal	7.75	6.00	3.75	2.75
	Sultana, Nabtef-seif, Jabri	6.00	6.00	2.75	2.75
Low commercial value	Other varieties	-	-	-	-

Subsidy for large-scale farmers		Good quality (Dirham/kg)		Average quality (Dirham/kg)	
	Dates variety	**2021**	**2022**	**2021**	**2022**
High commercial value	Farad, Lolo, Khenaizy, Barhi, Medjool	11.50	11.50	5.25	5.25
Medium commercial value	Dabas, Khalas, Segae, Bumann, Raziz, Sukkary, Shishi, Anbra Almadina, Maktomy	8.50	8.50	3.75	3.75
Acceptable commercial value	Sultana, Nabtef-seif, Jabri, Naghal	4.50	4.50	2.00	2.00
Low commercial value	Other varieties	-	-	-	-

Sources: Al Foah. Updated date marketing policy (2018-2022).

Annex 7. **United Arab Emirates: food safety and quality standards**

Dates classification	Insect infestation	Mould	Phenotypic defects
Good quality	<6%	<1%	<10%
Average quality	>6%, <20%	>1%, <2%	>10%, <20%
Rejected quality	>20%	>2%	>20%

Quality standards

	Item	Good quality		Average quality		Rejected quality
		Weight of 50 pcs of dates is				
		Equal or greater than	Less than	Equal or greater than	Less than	
High commercial value	Farad	350	350	238	238	
	Lolo	350	350	238	238	
	Khenaizy	350	350	238	238	
	Barhi	368	368	238	238	
	Medjool	900	900	238	238	
Medium commercial value	Khalas	373	373	238	238	
	Bumann	403	403	238	238	
	Raziz	350	350	238	238	
	Anbra Almadina	641	641	238	238	
	Dabas	300	300	200	200	
	Segae	641	641	238	238	
	Sukkary	481	481	238	238	
	Shishi	463	463	238	238	
	Maktomy	385	385	238	238	
Acceptable commercial value	Jabri	391	391	238	238	
	Nabtef-Seif	581	581	238	238	
	Sultana	581	581	238	238	
	Naghal	350	350	238	238	
Low commercial value	Other varieties	300	300	238	238	

Sources: Al Foah. Updated dates marketing policy (2018-2022).

Annex 8. **United Arab Emirates: Institutions in the date palm value chain**

Institution	Role
Ministry of Climate Change and Environment (MOCCAE)	The mission is to foster the integrated management of natural resources to ensure sustainability.
Abu Dhabi Agriculture and food safety authority (ADAFSA)	To control and inspect the Emirate's food and agriculture establishments, farms, agricultural inputs, imported and exported food and agricultural items or those produced in the country and circulated in the UAE, to ensure the access of safe food to the community
Date Palm Research and Development Programme of the UAE University in Al Ain	Plays an important role in improving the living conditions of rural communities, protecting the environment and the sustainable management of natural resources.
The United Arab Emirates Agricultural Research Centres	Transfers research results and successful technologies through close cooperation with the national extension service.
Al Foah	An ADE government-owned company producing, collects, processes and exports dates. Aims to lead the global date market by producing innovative products.

Annex 9. **Digital technologies for data collection in the olive oil value chain**

Ultrasound

The *Olive Sound* project developed the high-flow oil extraction plant called the Sono-Heat-Exchanger for producing Extra Virgin Olive Oil (EVOO). It combines ultrasound and heat exchange, which improves the health quality of the product by enhancing its polyphenols content without causing undesired sensorial defects, thus placing it in a higher production range. The project reports that it breaks the historical paradigm between yield and quality of traditionally produced EVOO.[112] The ultrasound-assisted extraction of EVOO improves the efficiency and the quality of the product. But the introduction of ultrasounds for EVOO also brings up the topic of *Willingness-To-Pay* (WTP). The consumer's acceptance of this innovation on the traditional character of the product is not easily predictable. In blind conditions, consumers did not find significant sensory differences among the EVOO extracted consumers among the EVOO extracted through ultrasounds and the other control products. The costs of using ultrasound over traditional methods should be carefully analysed and compared. The WTP may be the same for EVOO produced through ultrasounds. There is no support yet for the hypothesis that there is a WTP for an ultrasound EVOO based premium.[113]

Near-Infrared Spectroscopy and Artificial Intelligence

Avoiding off-flavours and aromas related to rancidity is one of the major problems for EVOO business during production, packaging, transport, and storage. There is a new way of assessing the level of rancidity, aromas and off-flavours for EVOO, through Near-Infrared (NIR) Spectroscopy. This allows for amore predictive production to secure EVOO quality and acceptability. The NIR sensor feeds Artificial Intelligence (AI) models (using Machine Learning) with data. Using AI with low-cost sensors can significantly contribute to the EVOO sector and its predictive capabilities are useful during the pre-packaging stage. The predictions are valuable product positioning and maintaining quality and preference among consumers.[114]

Other literature also refers to this by the abbreviation NIRS (Near-infrared spectroscopy) and links it to its capability of *nutritional labelling* of olive oil (predicting fat, total saturated fatty acids, monounsaturated fatty acids, and polyunsaturated fatty acids in olive oils). The International Olive Council (IOC) can play an important role to the standardization and acceptance or nutritional labelling methods.

Spectroscopy is also relevant to detect fraud (see also next section), since EVOO is frequently blended with inferior vegetable oils. LED-induced Spectroscopy through ultra-violet (UV) can detect soybean oil and peanut oil. Handhold instruments can be built to deploy this in the field to measure the adulteration level of EVOO. More work is needed to improve the algorithms for edible oil adulteration detection.[115] (Zhang *et al*., 2022).

Fraud

Extra Virgin Olive Oil (EVOO) the top VOO category that remains one of the most highly targeted by fraudsters. There is a need to improve checks, harmonize the VOO classifications and better monitoring to be one-step ahead of fraudsters. The International Olive Council (IOC) and other regulatory bodies can work together to combine sensory and instrumental data. The data can be harmonized and the proficiency and alignment of the panels by a mutual calibration achievable e.g. by finding the same sensory reproducible reference

materials on the market. The EU OLEUM databank is under development to mature the used for quality and authenticity references. This would improve the quality of the data on volumes produced, possibly including also geolocation. The next fraud countermeasure could be blockchain.[116]

The authenticity of olive oil has become a major problem for producers, consumers, and legislators. There are analytical techniques to detect fraud, such as comprised spectroscopic, spectrometric methodology and analyse separation techniques such as liquid chromatography and gas chromatography. Then there are protein-based biomolecular techniques and analytical approaches like metabolomic, hyperspectral imaging and chemometrics.[117]

There is a strong economic interest in blending pure VOO with other lower quality vegetable oils. Acidity and lipid change during storage are major quality criterions of olive oil. Related analytical methods in the authenticity field are time-consuming and complex. There is a need for rapid analyses methods with minimal sample preparation and online controls.[118]

One rapid analyses method could be a *portable hyphenated photonics sensor* to test authenticity of EVOO. In combination with high-level data fusion (combining classification results from individual sensors), one class classification and tuned decision thresholds, it delivers better screening results than individual sensors.[119]

Digital transformation

One way to think of digital transformation is for applying it for olive oil production now or in the near future. However, it can also be used to preserve the past (heritage management), through Historic Building Information Modelling (HBIM). A study in Spain identified substantial differences between sixteenth century and eighteenth century mills.[120]

A study in Tunisia suggests that organizations that have their personnel trained in ICTs have better economic results. Other impacting factors are the existence of plans and budget for ICT adoption. Only a small number of Tunisian olive-growing entities can be considered efficient. Digital transformation is a decisive competitive factor in guaranteeing the survival and profitability of the organization. The study recommends to use ICT in the company for efficiency, planning and to have the human capital trained.[121]

Annex 10. **Classification of different types of olive oil**

According to the International Olive Council (IOC) classification, there 8 types of olive oil namely: EVOO, virgin olive oil, ordinary virgin olive oil, virgin olive oil not fit for consumption, refined olive oil, olive oil, olive pomace.

- Extra virgin olive oil: virgin oil with a free acidity, expressed as oleic acid, not exceeding 0.8g per 100g
- Virgin olive oil: virgin oil with a free acidity, expressed as oleic acid, not exceeding 2g per 100g
- Ordinary virgin olive oil: virgin oil with a free acidity, expressed as oleic acid, not exceeding 3.3 g per 100 g
- Virgin olive oil not fit for consumption: The oil that satisfies the taste standards for virgin olive oil but scores a higher percentage of free fatty acids (more than 3.3 g per 100 g). This kind of olive oil is either refined or used for industrial purposes.
- Regular olive oil: A blend of odourless and flavourless refined olive oil and virgin olive oil. This is the most common one on store shelves.
- Refined olive oil: Refined olive oil is the olive oil obtained from virgin olive oils by refining methods that do not lead to alterations in the initial glyceride structure. It has a free acidity, expressed as oleic acid, of not more than 0.3 grams per 100 grams and its other characteristics correspond to those fixed for this category in the IOC standard.
- Olive oil: Olive oil is the oil consisting of a blend of refined olive oil and virgin olive oils fit for consumption as they are. It has a free acidity, expressed as oleic acid, of not more than 1 gram per 100 grams.
- Olive pomace: Olive pomace oil is the oil obtained by treating olive pomace with solvents or other physical treatments, to the exclusion of oils obtained by re esterification processes and of any mixture with oils of other kinds.

Annex 11. **Tunisia: Government support in the olive oil industry**

Beneficiaries	Institution	Subsides (%)	Loans (%)
Olive Growers/Processors			
Replanting, rejuvenation	DGFIOP	5	-
Creation of olive-growing area	DGFIOP	25	
Mechanization, chemical treatment	DGFIOP	25	65
Purchase of tractors, inputs	DGFIOP	25	65
Transport costs	ONH	until	65
Agricultural equipment	APIA	25	
Irrigation systems	APIA	40-50-60	
Diesel financing	APIA		
Organic olive growing			
Certification costs (1,000 to 2,000 dinars) over 5 years	ATM	up to 70	
Processors, grinders and exporters		N/A	N/A
Exporters			
Category A investments (less than 60,000 dinars)	APIA	2	
Category B investments (between 60,000 and 225,000 dinars)	APIA	20	
Category C investments (above 225,000 dinars)	APIA	7	
Promoting the value chain or business opportunities (FOPRODEX)	CEPEX	30	50
Cost of carrying out an export marketing plan up to 10,000 dinars (FAMEX) 1	CEPEX	up to 70	

Sources: FAO & EBRD. 2015. *Tunisia. Analysis of the olive sector*. Rome, FAO & London, European Bank for Reconstruction and Development.

Annex 12. **Tunisia: Institutions in the olive oil value chain**

Institution	Role
National Olive Oil Board (ONH)	Founded in 1962 as a public industrial and trade body. It is responsible for providing guidance and support for olive growers, encourage promotion of olive oil quality and trade, ensure development and promotion of exports, regulate the domestic market, coordinate the various participants at all levels in olive oil sector.
The Technical Center for Organic Agriculture (CTAB)	Established under the Ministry of Agriculture. It plays a key role in supervision, assistance and promotion of organic farming by implementation of research and training.
Agricultural Investment Promotion Agency (APIA)	A non-administrative public establishment created in 1983. Its mission is to promote private investment in agriculture, fisheries and primary processing activities.
The Export Promotion Center (CEPEX)	A public institution operating under the Ministry of trade and Export Development. It supports and guides the exporting companies in the international markets.
Technical Center for Packaging (PACKTEC)	A governmental entity whose mission is to diagnose quality and assist modernization and upgrading of the packaging.
Institution of Agricultural Research and Higher Education (IRESA)	A research institute whose mission is to develop national research programmes and establish the budgets for implementation.
Olive Tree Institute	It undertakes research, studies and experiments to develop and promote olive oil and fruit tree sector.
Tunisian Union of Agriculture and fisheries (UTAP)	UTAP represents the professionals of the primary sector of the country. The objectives include (1) represent and defend interests of farmers and fishers, (2) improve their economic situation, and (3) contribute to training and awareness raising activities.
Tunisian Union of Industry, Commerce and Handicrafts (UTICA)	An organization of employers representing industrial, trade and craft sectors. Its mission is to support, promote and revitalize the private sector.

Annex 13. **Jordan: Institutions in the olive oil value chain**

Institution	Role
Jordan Enterprise Development Corporation (JEDCO)	An arm of the Ministry of Industry, Trade and Supply (MoITS) which focuses on trade promotion, export development and enterprise development.
Syndicate of Olive Mill Owners and Producers	The syndicate is licensed by the Ministry of Labour. Its mandate is to provide millers with advice on issues such as exporting, inspect mills to help the government in licensing new mills and changes to existing mills and support the government in preventing illegal imports of olive oil (FAO, 2022)
Jordan Olive Oil Products Exporters Association (JOPEA)	A non-profit organization established to support the olive and olive oil producers and exporters. The mission is to initiate activities and assist its members in enhancing the product's quality, exploring new markets and applying good manufacturing practices.
Jordan Standards and Metrology Organization (JSMO)	The national quality infrastructure in Jordan. The JSMO operates in cooperation with other public and private organizations in the fields of standardization, metrology (industrial and legal), accreditation and conformity assessment services (inspection, testing and product and system certification).
Jordan Food and Drug Administration (JFDA)	An independent public sector regulatory institution established in 2003 to inspect food, pharmaceuticals and manufacturing facilities.
National Agricultural Research Centre (NARC)	NARC is the only specialized governmental agricultural research institution at the national level, to constitute a national umbrella for applied agricultural research and governmental agricultural consultations (FAO, 2022).
General Directorate of Civil Defence	Responsible for inspecting all commercial and industrial facilities, to make sure that they abide by national occupational safety regulations.
Agricultural Credit Corporation (ACC)	The governmental financial institution missioned to support farmers and all other agribusinesses to enhance agricultural development.

Annex 14. **Egypt: Economic model of possible digital solution**

The paper looks into investment benefits versus costs to analyse two points: (1) whether the recommended technology can benefit or not, and (2) if financially beneficial, who can make investments. To be practical, we use a simple business model to judge if this system can work for small medium enterprises (SMEs) that FAO can support.

The target is the private exporters as they are priority beneficiaries to use the barcode/QR code system for increasing the value of dates by exports. First, costs should be identified. According to the KIIs with a private company in date palm VC, the barcode/QR code system in Egypt may cost around USD 20 000 for developing the system plus annual subscription fee each year (simply we put 10 percent of the development costs). The company should pay its producers as an incentive to participate in the new system undertaking new extra activities. Hence, according to the expert, the paper assumes for the SME to provide 10 percent bonus added to its buying price to producers. Expected benefits are reduction of operational cost by 25 percent and a selling price increase by 20 percent when the system is fully utilised by the company with internal stakeholders.[122] The paper took the figures as benchmarks for the economic model focusing on cash flow. In addition, the study sets an average SME business model where a company buys dates directly from farmers and sells in total 150 tonnes of low quality Siwi at USD 0.9/kg with the cost of goods at USD 0.4/kg, operational costs at USD 0.2/kg and other costs at USD 0.1/kg.[123] Its profitability is overall 22 percent. We define this company is a small to medium-scale exporter as the company's market share for export only is 0.5 percent.[124] The followings are assumptions to make a simple economic model.

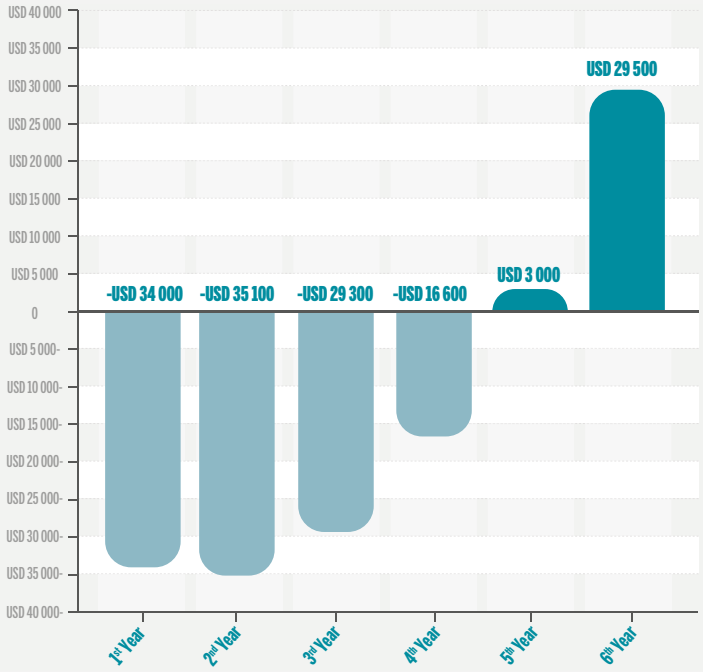
Assumptions

Target	The model is targeting an SME exporting 150 tonnes of date palm per year. The company should make profits in five years from the investment otherwise it will not invest.
Business model	The company's export quantity is fixed. The development cost of the barcode/QR code system is USD 20 000 only for the first year and USD 2 000 for its maintenance costs each year. The unit selling price increase by 20 percent when the system is fully utilised. The company can gradually benefit from the Barcode/QR code system in five years (a linear increase) as introduction of new technology takes users a certain period before adoption. The company provides 10% bonus added to its purchase price for producers as an incentive to participate in the system. In the first year, operational costs increase by 20% for training and monitoring.

With all the above, as shown in Figure A.14.1, this SME can pay off the initial costs and make a profit from the fifth year. Despite the fact that many variables that can potentially affect the level of adoption and the effectiveness of the technology have been put aside, the study concludes that, based on all the assumptions, a private traceability system using the Barcode/QR code could work for SMEs with the condition that a company could financially survive for more than four years to reach the breakeven point. Note that, before

applying this model to actual conditions with intense competition, a thorough analysis should be undertaken to reflect the more realistic environment, as this is a simplified economic model that has not taken into consideration any externalities.

Figure A.14.1: Trend of accumulative profit and loss in a model for small and medium enterprises (unit: USD)



Sources: Author's own elaboration.

Annex 15. **Tunisia: Economic model for a possible digital solution**

To consider introducing the high-tech traceability and transparency system such as using BBTS by private sector in Tunisia, evidential support exists as proof of concept: CHO, one of the largest Tunisian private olive oil exporters (CHO produces about 50 percent of the total Tunisian packaged olive oil exports), (Ledger Insights, 2020) started using BBTS in collaboration with IBM in 2017, whilst no publicly available information on cost and benefit for this application is found. Therefore, the paper analyses its financial benefit by establishing a simplified SME economic model focusing on cash flow and check a breakeven point based on multiple assumptions.

First, costs need to be identified. According to Goparakrishnan, *et al*. (2020),[125] the simplified model of low-cost permissionless blockchain costs approximately USD 80 000 for development cost of BBTS, and annual costs for maintenance by a third party are modelled at around USD 20 000 in the USA. Though costs should vary from one country to another depending on various factors, the paper takes this as a benchmark. Additionally, the paper assumes that the SME will pay extra 5 percent of its profits as an incentive to producers to participate in BBTS and operational costs for capacity building and monitoring operations are assumed to decrease profitability by 10 percent only for the first year.

Second, benefits must be calculated based on a potential increase of price and a potential reduction of operational costs. In CHO case: the firm "observed a spike in demand since implementing traceability features in olive oil bottles earlier this year. Through a consumer traceability app, the company anticipated the growing demand, which rose by 30 percent during the pandemic."[126] However, the data of benefits on cost reduction were not found. According to the expert, the average profitability of selling EVOO as an SME could be around 15 percent in a normal business model. Based on the fact in the Situational analysis part, the paper estimates that CHO exports at an average price of USD 5 000/tonne.

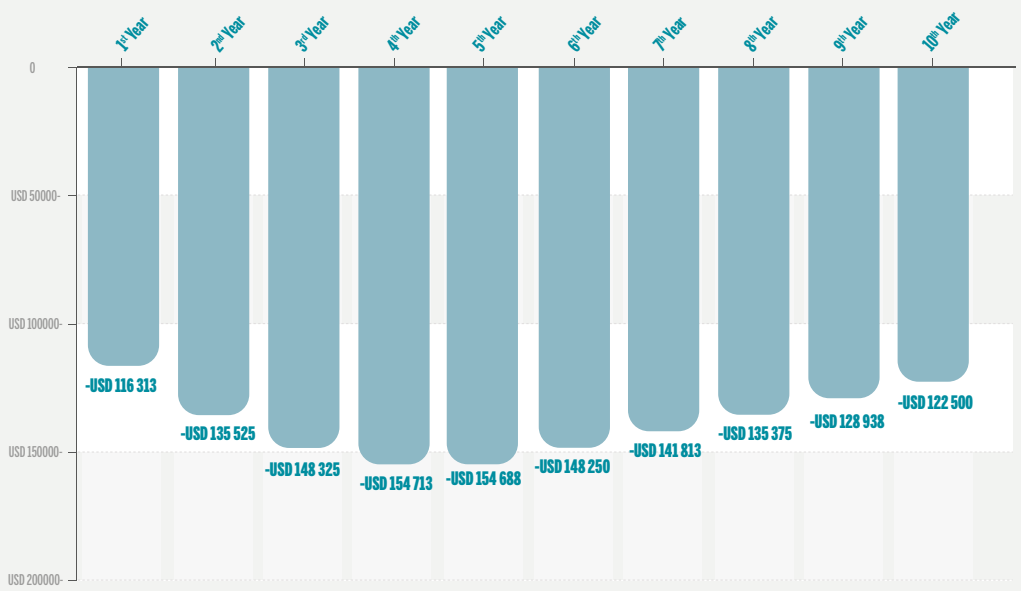
Considering all the above-mentioned facts, the study made assumptions for the SME economic model as follows:

Assumptions

Target	The model targets an SME exporting bottled olive oil. An SME is defined as a company having less than 1% of the market share in bottled EVOO (in this case, the study defines the SME with sales of 230 tonnes of EVOO). The SME needs to make profits in five years from the first investment otherwise it will not invest. Benefits are recognized by end-customers and are made from bottled EVOO.
Business model	The company's export quantity is fixed. The company can gradually benefit from the new digital solution in five years (a linear increase) as an introduction of a new technology takes a certain adoption period for users. The profitability is 15% and the selling price of bottled EVOO is USD 5 000/tonne. The unit selling price increase by 30 percent when the system is fully utilised. BBTS development costs are USD 80 000 only for the first year and USD 20 000 for its maintenance costs incur each year (the model does not consider depreciation period). The company pays extra 5% of its profits as an incentive to producers to participate in the system. In the first year, operational costs for training and monitoring incur and they decrease the profitability by 10%.

The figure below is the consequence that heavy initial costs to commence BBTS make the SME model difficult to pay off the costs within the set five years. Therefore, to make the model work, a company will have to export approximately 1100 tonnes of bottled olive oil to gain more benefits from the first year. It evidenced that this BBTS model can be applied to a large-scale company such as CHO at this moment or require subsidies or access to finance for investments to SMEs.

Figure A.15.1: Trend of accumulative profit and loss of batch/block tracking system for an SME model (Unit: USD)



Sources: Author's own elaboration.

It is necessary to note that to apply in the real condition with high competitions, thorough analyses should be undertaken to reflect the more realistic environment as this is a simplified economic model without consideration of externalities.

Notes

1. Introduction

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3. Discussion

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[95] This study reveals that remote sensing (using satellite imagery) for data palm planting is relatively underdeveloped. The recommendation is to start research streams, or innovation hubs, to develop remote sensing models. Remote sensing models benefit from ground data, which helps the "machine" to learn how to classify date palm features. The remote sensing models can result in advisory services for planting for palm oil and detection and monitoring of Red Palm Weevil (RPW). FAO runs an initiative called WaPOR (https://www.fao.org/in-action/remote-sensing-for-water-productivity/en/), a remote sensing platform for water productivity. Analysis can be carried out to understand at what level WaPOR is already useful as an advisory service for date palm plantation. This study also reveals promising results for Distributed Audio Sensors (DAS) for RPW detection and monitoring. The recommendation is to combine the on the ground DAS methodology with remote sensing, offering a cohesive set of digital agriculture services to the planters. The sugar extraction from dates through ultrasound described in this study is an interesting novelty. The recommendation is to test its return on investment and scalability aspects.

[96] Several technologies can be applied in the olive VC for traceability and transparency, including: i) Blockchain technology: Blockchain technology provides a secure and transparent way to track the flow of goods and information in the VC. This can be used to track the origin, quality, and authenticity of olive products and to ensure that consumers have access to reliable information about the products they purchase. ii) QR codes and barcodes: QR codes and barcodes can be used to identify and track products in the olive value chain. Consumers can use a smartphone to scan the codes and access information about the product, including its origin, quality, and authenticity. iii) Sensors and Internet of Things (IoT) devices: Sensors and IoT devices can be used to monitor various aspects of olive production, including temperature, humidity, and soil moisture. This information can be used to support better decision-making and to improve the sustainability of the value chain. iv) Artificial intelligence (AI) and machine learning: AI and machine learning can be used to analyse large amounts of data and to identify patterns and trends in the VC. This can be used to support better decision-making, to optimize production processes, and to improve the efficiency of the value chain. v) Geographic Information Systems can be used to map the locations of olive production and to track the flow of products from the field to the consumer. This information can be used to support better decision-making and to improve the transparency and efficiency of the VC.

[97] Rather than developing from scratch, the suggestion here is to build on platforms that already provide many base functions. These platforms are formally referred to as Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). The initial development costs of IaaS and PaaS are lower; they scale well and are more agile. The operational costs of PaaS and IaaS are however a factor to be considered carefully.

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Annex 14

[122] Based on the expert comments from KIIs. In this simple model, other external benefits or costs are excluded to identify a simple profit and loss from a private export company.

[123] Based on the expert comments from key informant interviews.

[124] Small and medium enterprises in date palm value chains in Egypt are roughly defined by the expert as firms selling up to 150 tonnes of dates.

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