CONSORTIUM FOR
RED PALM WEEVIL
CONTROL

C4RPWC Socioeconomic Impact and Policy Assessments of the Red Palm Weevil in UAE, Egypt, and Morocco

Conceptual Framework

June 2026

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Workstream 5: Translate research to action -pathways to scaling

Work Package 1: Socioeconomics and Policy

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Acronyms

ADAFSA	Abu Dhabi Agriculture and Food Safety Authority
AOAD	Arab Organization for Agricultural Development
BSI	Baseline Survey Instrument
CGE	Computable General Equilibrium (Modelling)
CIHEAM	International Centre for Advanced Mediterranean Agronomic Studies
CS	Consumer Surplus
FAO	Food and Agriculture Organization of the United Nations
FAOStat	Food and Agriculture Organization Statistical Database
FGD(s)	Focus Group Discussion(s)
GAP(s)	Good Agricultural Practice(s)
GCC	Gulf Cooperation Council
ICARDA	International Center for Agricultural Research in the Dry Areas
ICM-FFS	Integrated Crop Management – Farmer Field School
I-O	Input–Output (Analysis)
INRA	National Institute for Agricultural Research
IPM	Integrated Pest Management
ISPM	International Standards on Phytosanitary Measures
KII(s):	Key Informant Interview(s)
LR:	Literature Review
MCA:	Multi-Criteria Analysis
MCDM	Multi-Criteria Decision Making
MEW	Ministry of Environment and Water (UAE)
MOCCAE	Ministry of Climate Change and Environment (UAE)
MoU(s)	Memorandum(s) of Understanding
NENA	Near East and North Africa
NGO(s)	Non-Governmental Organization(s)
NPV	Net Present Value

ONSSA	National Office for Food Safety (Morocco)
PBA	Partial Budgeting Analysis
PEM	Partial Equilibrium Modelling
PRA	Pest Risk Analysis
PS	Producer Surplus
RPW	Red Palm Weevil
SAFA	Sustainability Assessment of Food and Agriculture Systems
SEIA	Socioeconomic Impact Assessment
SEIAD	Socioeconomic Impact Assessment and Diagnostic
UAE	United Arab Emirates
UM6P	Mohammed VI Polytechnic University
USD	United States Dollar

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1. RATIONALE AND IMPORTANCE OF STUDY ON RPW

1.1. Rational and Importance of the Study

1.1.1 Background

The Red Palm Weevil (RPW: *Rhynchophorus ferrugineus*) is a major transboundary pest designated by the Food and Agriculture Organization of the United Nations (FAO 2017) as Category-1 pest of date palms for the Near East and North Africa (NENA) countries. A Category-1 pest is an invasive or transboundary pest that causes severe economic, environmental, and social damage, spreads rapidly across borders, and poses a serious threat to strategic crops or natural resources. Such pests require immediate, coordinated national and regional action, including strict quarantine measures, intensive monitoring, and long-term management programs. Failure to control a Category-1 pest can result in large-scale crop losses, trade restrictions, and irreversible impacts on livelihoods and ecosystems.

The pest attacks around 40 palm species in more than 50 countries and is believed to have significant socioeconomic impacts through losses in production, destruction of productive assets (date palms, coconuts and oil plam), and reduction in income, in addition to the added costs of control measures and possible associated environmental hazards and externalities. Climate change is expected to further exacerbate the problem, as warmer and more humid conditions favor RPW reproduction and survival, while extreme weather events such as storms may facilitate long-distance dispersal (IPPC, 2021).Date palms (*Phoenix dactylifera*), are trees of high importance across the NENA region due to their economic and cultural importance, as well as their role as a renewable natural resource and provider of ecosystem services. Since its arrival in the NENA region, a main date palm production region, RPW has been causing widespread damage to date palms and negatively affecting their production, which has had a significant impact on the livelihoods of farmers as well as the environment.

A review of the literature on the topic reveals the limited research addressing the environmental and socio-economic impact of RPW on date palms worldwide and particularly in the NENA region. This is mostly due to the fact that reliable estimates of environmental impacts and other financial costs of biological invasions are difficult to obtain. However, these estimates remain critical for developing credible management, trade and regulatory policies, as well as for effective decision making regarding potential remediation investments.

Two types of financial losses caused by the RPW can be identified. Firstly, direct costs can be attributed to the value of the destroyed date palms and the progressive production loss. These costs are also associated with the implementation of RPW management programs, including expenses for the elimination and disposal of infested palms. Other direct costs include expenditures on monitoring and surveillance programs, the purchase and maintenance of trapping systems, the costs of quarantine enforcement, and labor associated with pest detection and treatment. Secondly, indirect costs are substantial and are mostly related to import restrictions on trees, especially their offshoots. These restrictions result in substantial reductions in trade both among countries and between regions (i.e., GCC countries), limiting the establishment of new plantations and the exchange of germplasm, particularly due to the high risk of spreading infested planting material. Indirect costs also arise from the adverse environmental and landscape impacts of biological invasions, particularly as a result of chemical treatments as well as human health, potential of pesticide resisnt RPW population. These costs include expenditures on purchasing and applying pesticides, as well as medical care for individuals affected by chemical exposure. Excessive use of chemical pesticides during eradication programs can contaminate soil and water, harm non-target organisms, and threaten human health (Ahmad et al., 2024). Additional indirect costs stem from the removal of infested palms, losses in tourism, and diminished aesthetic value in urban and coastal areas where palms are a key landscape feature. Furthermore, reduced date palm production negatively affects household incomes and employment opportunities in related sectors, such as processing, packaging, and handicrafts.

According to FAO (2017), RPW is the most destructive insect pest affecting date palms in the Middle East.. The estimated annual loss during 2009 in the Gulf region of the Middle East, due to the removal of severely infested palms, ranged from 1.7 to 8.7 million USD, corresponding to a 1–5% infestation, respectively. However, this figure remains significantly underestimated if the full range of environmental costs, including losses in ecosystem services, is considered. Nevertheless, considering such environmental costs remains challenging, especially conceptually. The extent of damage caused by RPW varies depending on environmental conditions, date palm variety, farming systems, socio-economic context, and the effectiveness of applied control technologies.. In addition, not all NENA governments have solid programs to monitor and systematically evaluate losses occurring in date palm farming activities due to RPW. Damage caused by RPW also depends on several factors, including environmental conditions, farming systems, the socio-economic context of farmers, the level of technology employed, and the enforcement of quarantine measures, which are often weak and allow the uncontrolled movement of infested planting material across borders (FAO and CIHEAM, 2017). In Egypt, RPW is now recorded in 25 governorates with infestation ranging from 2% to 35%. The estimated total annual cost of RPW control is about $20 million (Abbas, 2018). The annual loss in the Gulf countries due to eradication of severely infested palms has been estimated to range from US$5.18 to 25.92 million at 1 and 5% infestation levels, respectively (El-Sabea et al., 2009). In Southern Europe, RPW has killed thousands of palms, significantly impacting many tourist resorts. The direct cost of removing and replacing dead palms has been estimated at more than €500 million. Ferry (2010) reported that in Italy, Spain, and France, the combined cost of pest management, eradication, and replacement of infested palms, along with loss of benefits, was projected to increase to €200 million by 2023 if a rigorous containment program is not implemented.

To reduce both direct and indirect losses, sustainable RPW management requires an Integrated Pest Management (IPM) approach that combines biological control, pheromone trapping, and cultural practices in a cost-effective and environmentally sound manner (Kassem et al., 2020).Technological innovations, including remote sensing, fiber optic systems, acoustic detection using high-sensitivity microphones, thermal sensors, drones, sniffer dogs, and artificial intelligence tools such as machine learning, offer promising solutions for early detection and effective management of RPW (Mohammed et al., 2020; Wang et al., 2021). Nevertheless, access to these advanced technologies remains limited among smallholder farmers (MEWA, 2025), highlighting the need for capacity building, technology transfer, and locally adapted solutions to ensure affordability and practicality across diverse farming systems in the NENA region.

Consequently, given the transboundary nature of RPW, effective management requires coordinated action at national, regional, and international levels. Governments, research institutions, international organizations, and the private sector must collaborate to develop integrated, sustainable, and cost-effective control strategies. At the same time, these strategies should prioritize technological innovation, consider local socio-economic contexts, and promote participatory approaches that enhance farmer awareness, education, and engagement in management efforts. As Kassem et al. (2020) noted, farmers with greater knowledge of RPW symptoms show higher adoption levels of IPM practices, which underscores the importance of capacity building and knowledge dissemination in achieving sustainable control. For RPW management strategies to be effective and scalable, they must be guided by robust socio-economic assessments that quantify the full costs and benefits of alternative control interventions.

1.1.2. Rationale

Despite these conceptual challenges, robust economic and policy assessments of RPW impacts are essential to provide decision-makers with credible evidence for prioritizing interventions and justifying the substantial public and private investments required for RPW management.. Although policy decisions are often made in the absence of complete data, it is crucial to explicitly identify and address uncertainty through scenario development and sensitivity analysis to support transparent and defensible decision-making.

This assessment focuses on the socio-economic and environmental impacts of RPW control and eradication interventions across multiple levels of prevention and management. This will be carried out using rigorous assessment methods to estimate the impacts of RPW control or eradication, along with the associated costs and benefits across different farming systems and farm sizes. The assessment will include a farm-to-market situational analysis to generate evidence on the financial, economic, social, and environmental impacts of RPW control interventions implemented by project partners. The assessment will emphasize ex-post analysis at the farm level to evaluate the realized performance of implemented RPW control interventions.. This will include cost–benefit and welfare analyses of implemented RPW control methods and alternative approaches across different farming systems and farm sizes in Egypt and UAE. The ex-post assessment results will inform key stakeholders—including palm growers, local communities, development agencies, and decision-makers—about the efficiency, effectiveness, and feasibility of implemented control methods, as well as the comparative performance of alternative options. The analysis will focus primarily on the impacts on date palm production, yield, date quality, growers' income, the national date supply of dates, and impact on trade.

The overall objective of the socio-economic impact assessment (SEIA) is to inform the design of socially equitable and economically sustainable RPW management strategies that enhance the resilience of date palm production systems in rural areas and reduce the risk of pest spread into urban landscapes.**Specific objectives:**

- Assess the socio-economic impacts of RPW in the two target countries, including associated social and environmental effects.Identify the economic efficiency and effectiveness of the applied control methods and their suitability across different farming systems and farm sizes.
- Assess the economic impacts of RPW control methods on farm-level production.

Approach:

By integrating quantitative and qualitative approaches, the SEIA seeks to provide a holistic understanding of social, economic, and environmental consequences of RPW infestations. The findings will help identify priority challenges and opportunities in RPW management and provide evidence-based guidance for policy formulation and sustainable intervention planning.

This contribution is conceptualized through:

1. Characterizing and analyzing the current status of Red Palm Weevil (RPW) spread and control measures in Egypt, the UAE, and Morocco.

2. Diagnosing and quantifying the varied socio-economic impacts of RPW spread and the main intervention measures currently used to combat it in both rural and urban areas of the three target countries.Elucidating the perceptions of key stakeholders in date production and RPW management regarding the pest's spread and the effectiveness of containment efforts.

1.2. Date Palm and Red Palm Weevil

1.2.1. Importance of date palms in the Arab and NENA Region

Dates are economically, socially, culturally and ecologically important fruit crop in the Arab and NENA Region[1] and continue to play an important role in the history, heritage and socioeconomic life of their population. They are one of the basic sources of income and employment and are among the main stable foods for local inhabitants, especially in the oases. Date palms give multiple benefits and services including high energy food, medicine to some diseases, shelter, microclimate, protecting plants growing under their shade from wind and high temperature, secure inputs to food industries and handicrafts, and by-products useful for various purposes.

The Arab Region dominates in date production and trade. About 87.5% of the global area of 1.29 million ha (FAO 2023) under date palm is in the Arab Region, producing more than 89.75% of the world production of about 9.6 million metric tons of dates in 2023. Both the cultivated area and total production have continued to grow over time, as shown in Figures 1 and 2.

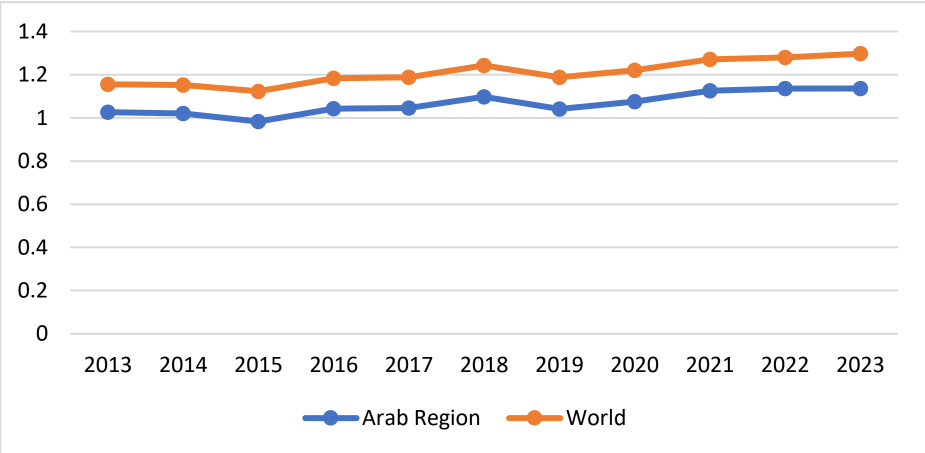

Figure 1. Area under Date palms (million ha)

Source: FAO Stat 2023.

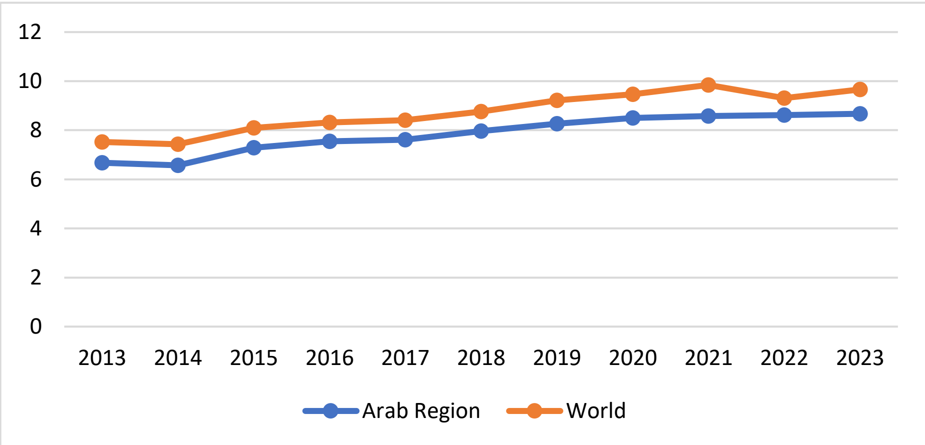

Figure 2. Production of Dates (million metric ton)

Source: FAO Stat 2023.

[1] The strategic framework for the sustainable development of the date palm value chain developed by AOAD/FAO in 2016 provides a concise account of the importance of date palms in NENA Region.

The five top leading countries in date production worldwide are Egypt, Saudi Arabia, Algeria Iran and Iraq contributing about 68% of the global dates production in 2023, as shown in Table 1 Egypt and Saudi Arabia alone produced slightly more than one third of world production; 19.3% for Egypt (1.86 million metric ton) and 17% (1.64 million metric ton) for Saudi Arabia, and their production continued to grow over time as reflected in Figure 3.

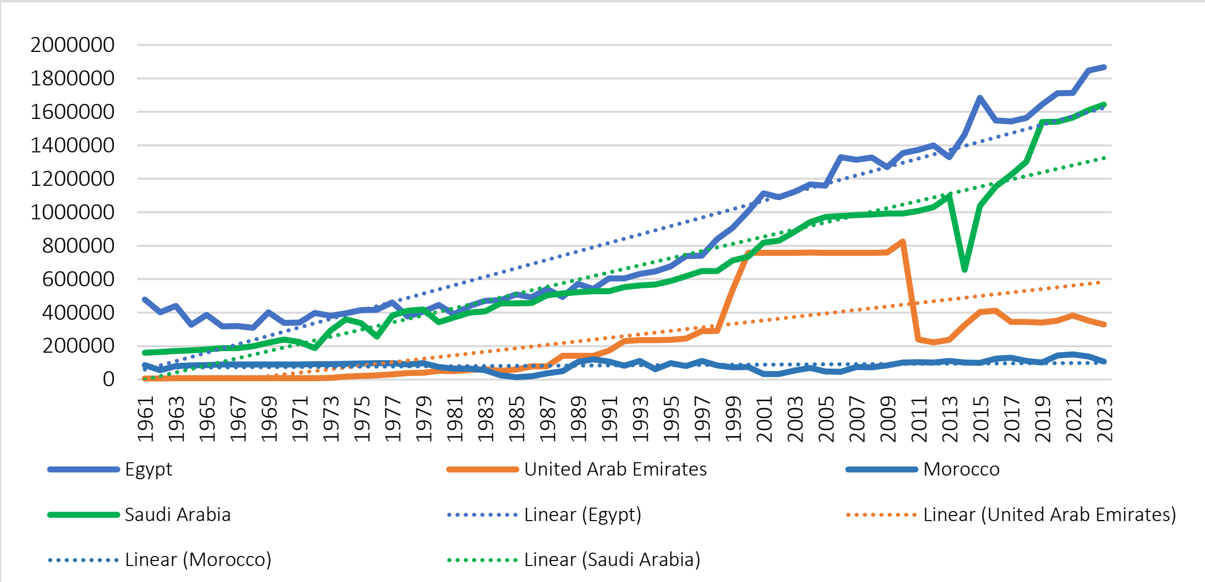

Figure 3 . Dates production in Egypt, Saudi Arabia, UAE and Morocco (Tons)

Source: FAO Stat 2023.

Table 1. Top Five Countries in Global Dates Production 2023

Country	Production (Million MT)	% Share of Global Production
Egypt	1.867	19.3
Saudi Arabia	1.643	17.0
Algeria	1.325	13.7
Iran	1.024	10.6
Iraq	0.636	6.6
Total of top 5 countries	6.495	67.22
Other countries	3.166	32.77
Total World Production	9.6	100.0

Source: Calculated from FAO data

With respect to trade, the Arab Region contributes to more than 75% of the global exports of dates. A summary of exports and imports of dates is portrayed in Table 2.

Table 2. Imports and Exports of Dates in 2023

	Import		Exports	
	Quantity (Tons)	Share %	Quantity (Tons)	Share %
World	1655,132	100.0	1587,506	100
Arab Countries	415,098	25.1	1268,603	79.9
Asia	1081,930	65.4	1119,254	70.5
Europe	216,538	13.1	50,976	3.2

Source: FAO Stat 2023.

1.2.2. A general overview of the Red Palm Weevil (RPW)

The Red Palm Weevil is a major destructive pest for many palm species, including date palms. Originating in southeast Asia, the RPW has spread mainly through infested planting material and reached almost every corner of the globe. Ever since it was reported from Rass-El-Khaima in the UAE in 1985, it spread rapidly to all countries of the Gulf region in the Middle East. In 1987 it was reported in Al Qatif area in the Eastern Region of Saudi Arabia and in November 1992 crossed to Africa and reached Salehia locality between Ismailia and Ash Sharqia Governorates of Egypt. The increased and rapid movement of date palm seedlings coupled with inappropriate management practices have contributed to the escalation and rapid spread of RPW within countries. The infestation spreads almost all over the two countries, except Paries and East Owenite oases in the Western Desert in Egypt and Jizan and the Northern Borders regions in Saudi Arabia. The last discovery in Egypt was in 2017 in Dakala Oases.

The adult weevil is a strong flyer, covering up to 7 km in less than five days and flying up to 900 meters at a time. The insect goes through the ordinary life cycle which extends 3-6 months and is affected by season, place of infestation and age of date palm tree (prefers young trees 6-7 years of age) and most infestations occur between land surface and 2 meters high . The larvae excavate holes in the trunk of palm tree and devour the tree from within, interfering with the flow of nutrients through the trunk, thereby weakening and eventually killing the host plant. In most cases, the infestation goes unnoticed until the tree exhibits certain symptoms depending on the stage of attack like oozing of brownish fluid together with frass excreted by feeding grubs which has a typical fermented odour, drying of infested offshoots and outer leaves and fruit bunches. Usually palms in the early stage of attack respond to treatment with insecticide (fumigation and stem injection) and can be saved, while palms in the advanced stage of infestation harbour overlapping stages of the pest with extensive tissue damage and may fell in.

1.2.2.1. Overview of the Red Palm Weevil in Egypt

The Red Palm Weevil (RPW) is one of the most destructive pests of date palms (*Phoenix dactylifera* L.) in Egypt. It was first detected in November 1992 in El-Hussinia, Sharkia Governorate, following the importation of infested offshoots from the United Arab Emirates (Habood et al., 2022). Although initially limited to northeastern provinces, RPW spread rapidly to other regions, primarily due to the uncontrolled movement of infested offshoots and adult palms (Ferry and Gómez, 2002). As a result, infestation levels increased from 5% during 1996–2000 to 76% between 2011 and 2020 (Eissa et al., 2023). A survey conducted by AOAD, involving 360 respondents from Ash Sharqia, Al Wahat Al Bahariya, and Aswan, examined RPW prevalence in relation to farming systems, farmer demographics, and awareness of pest management (Dhehibi and Frija, 2022). Farming systems were classified into three categories: traditional scattered, with irregular spacing and flood irrigation; traditional organized, with even spacing and flood irrigation; and modernized, with localized irrigation methods such as drip or bubbler. The survey revealed that RPW was detected on 94% of farms, affecting approximately 20 million palms, with the highest infestation recorded in Al Wahat Al Bahariya at 96.6% (AOAD and FAO, 2016). RPW primarily attacks young palms of mixed varieties, accounting for 81% of infestations, whereas dry date varieties are less affected at 8%. The lower trunk, from 0 to 2 meters, is the most frequently attacked site at 46%, followed by the middle trunk at 30% and the crown at 23%, mainly because of abundant tender tissues. Consequently, flood-irrigated systems exhibit higher infestation levels at 21.1% compared to 6.11% in drip-irrigated systems (El-Lakwah et al., 2011). Head infestations are often fatal, with a mortality rate of 76%, whereas bottom and middle-trunk infestations are less severe. Approximately 68% of new infestations originate from neighboring farms, with neglected or abandoned plots acting as reservoirs. This pattern is particularly pronounced in Aswan, where 95% of farmers reported nearby farms as the main source of infestation (Eissa et al., 2023). Socioeconomic factors also influence RPW spread. For instance, most farmers, 86%, manage their own farms, with 76% having at least intermediate education and 70% possessing more than ten years of experience. Although awareness of management practices is high, with 93% disinfecting offshoot wounds and 87% understanding proper irrigation and spacing, financial constraints often lead to improper pruning. This increases infestation risk by nearly 90% due to wounds suitable for egg-laying (Eissa et al., 2023). Regarding larvae, which live entirely inside the trunk, they cause the greatest damage. However, 75% of farmers lack adequate training, and 96% rely solely on visual inspection, often detecting infestations only after severe internal damage. Preventive measures include restricting movement of offshoots and infested palms, proper waste management, and reporting infestations. Nevertheless, 61% of farmers remain unaware. Trunk infestations are generally managed through manual clearance, covering pits with mud or cement, and chemical injections, which are used by 67% of farmers, while lower and head infestations are treated with pesticide dipping. Fumigation is applied on a limited scale. Common pesticides include Methomyl, chromophore group chemicals, and Fripnel group chemicals. Moreover, agricultural extension officers support these management efforts. In Aswan and New Valley, advisory performance scored 68.2% to 72.0%, primarily through field visits, seminars, and printed materials (Hemari and Gadalla, 2018). Despite these interventions, long-term control rarely exceeds 75% efficiency because of difficulty reaching all developmental stages, low farmer participation, insufficient funding, irregular planting, limited detection and injection equipment, poor palm hygiene, lack of certified nurseries, scarce biocontrol resources, high treatment costs, and challenges enforcing quarantine, including mountain routes allowing movement of palms from infected zones (Ferry and Gómez, 2002; Hemari and Gadalla, 2018). The economic impact is substantial. National treatment costs, largely borne by farmers, are estimated at USD 5.7 million annually. In addition, each fallen palm results in an average revenue loss of USD 549 from lost fruit, offshoots, and byproducts. Approximately 390,000 palms, 27.7% of infested trees, are lost annually, totaling around USD 213 million. Furthermore, Upper Egypt, particularly Aswan, receives only 21% of national control resources while suffering the highest infestation at 34% and the lowest treatment success, with one in three infested palms collapsing each year (Eissa et al., 2023). Therefore, effective management requires reforming pest governance, enforcing quarantine regulations, establishing a comprehensive date palm database, and integrating modern technologies such as remote sensing, pheromone traps, and detection dogs. Additionally, farmers should be supported with training, knowledge, and financial assistance to adopt Good Agricultural Practices and Integrated Pest Management, which includes early monitoring, proper pruning, moderate irrigation avoiding trunk contact, adequate spacing, offshoot disinfection, and timely removal of infested palms. Moreover, community sanitation, waste management, and awareness campaigns further reduce reinfestation, while documenting outbreaks supports data-driven decision-making. In line with this, the FAO and Egypt's Ministry of Agriculture have launched integrated strategies to strengthen these practices (FAO, 2025).

1.2.2.2. Overview of the Red Palm Weevil in UAE

Date palm cultivation represents a fundamental pillar of the agricultural sector in the United Arab Emirates (UAE), both economically and culturally. Nationally, there are about 32,588 date palm farms comprising approximately 9,401,771 trees, with Abu Dhabi holding the largest share of 22,980 farms and around 6,849,814 palms, representing nearly 73% of the total. The cultivation structure is dominated by medium-sized farms, which make up 74% of all farms, each averaging 330 palms over roughly three hectares, followed by small farms, which account for 25% with about 90 palms each, and a minor proportion of large farms at 1%. The Red Palm Weevil, RPW,, was first detected in Ras Al Khaimah in 1985 (Al Asfour et al., 2016) and has since become the most destructive pest of date palms in the Gulf region. It later spread to the Arabian Peninsula, the Mediterranean Basin, the Caribbean, and the United States. The weevil now occurs in nearly all oases across the UAE, where extensive palm planting over the last three decades, combined with abundant offshoots and large mature trunks, has created highly favorable conditions for infestation. Pest management is primarily overseen by governmental authorities and specialized companies, in cooperation with institutions responsible for date palm protection. In response to the growing threat, the UAE launched the Nakheelna Initiative in 2012 as an Integrated Pest Management (IPM) strategy led by the Ministry of Climate Change and Environment (MOCCAE) and supported by local authorities such as the Abu Dhabi Agriculture and Food Safety Authority (ADAFSA). The initiative aims to enhance date palm productivity, improve fruit quality, support related industries, and contribute to food security and the national economy, while maintaining the UAE's global leadership in date palm cultivation. The national target is to keep Red Palm Weevil infestation rates below 1.5%. The IPM approach combines agricultural, mechanical, and biological control methods while limiting pesticide use to emergency situations. Furthermore, it promotes the concept of economic thresholds, encourages farmer education and awareness, and supports the use of environmentally safe biological control agents such as entomopathogenic fungi, bacteria, viruses, and nematodes (Kaakeh & Zayed, 2019). Monitoring activities are conducted quarterly through field surveys and the installation of traps across both productive and non-productive palms. Consequently, the Ministry has implemented advanced technologies to enhance efficiency, including electronic systems for farmer service requests, GPS-based monitoring, and a national pest database that links infestation data with climatic conditions to strengthen surveillance and decision-making. In addition, the program standardized pheromone and light trapping systems, assigning one pheromone trap for every 100 date palms and one light trap for every 500 palms, with regular maintenance and monthly pheromone replacement. Specialized teams are responsible for detecting and treating infested trees while systematically recording data at both regional and national levels. Agricultural extension services were also expanded to include awareness programs, training workshops, and field visits offering multilingual guidance to farmers and technicians (MEW, 2015). As a result of continuous surveillance and targeted interventions, significant progress has been achieved. Infestation rates declined from 3.15% in 2016 to 0.68% in 2023, which is well below the national target, and steady improvement was recorded throughout the years, with rates of 1.72% in 2017, 1.42% in 2018, and 1.35% in 2019. Recent studies in the Ras Al Khaimah and Abu Dhabi regions indicate that Red Palm Weevils (RPWs) are most active between 3:00 and 6:00 a.m., during which 85.72% of adults were captured, and that adding pheromones to food bait increased capture rates by 6.95 times compared with using pheromones alone (NA et al., 2024).

1.2.2.3. Overview of the Red Palm Weevil in Morocco

The RPW was first detected in Morocco in December 2008, in the northern regions of Tangier and Nador, primarily infesting Canary Island date palm (*Phoenix canariensis)* of the Arecaceae family. Since its introduction, the pest has caused the destruction of approximately 1,600 palm trees between 2008 and 2020. Infestation levels have gradually declined over time, from about 250 infested palms in 2008 to 190 palms in 2020. To mitigate these impacts, the National Office for Food Safety (ONSSA) launched in 2016 a National Integrated Strategy for RPW Management, structured around six key components: (1) defining intervention zones, (2) conducting regular field surveillance and early detection, (3) installing and maintaining pheromone traps, (4) applying mechanical and chemical treatments, (5) removing and destroying heavily infested palms, and (6) carrying out awareness and education campaigns for stakeholders and palm owners. Firstly, three intervention zones were established to organize and prioritize control operations. The Infested Zone covers more than 12,000 palms, both infested and healthy, mainly Canary Island palm. The Buffer Zone (Protection Area) extends roughly 19 km around Tangier, containing about 950 palms that are treated regularly to prevent the pest's spread. The Intermediate Zone, located between the two, includes scattered palm trees treated every three to four weeks. This zoning system allows for targeted interventions and efficient allocation of resources, reducing the risk of further spread beyond affected areas. Secondly, systematic field surveillance and early detection are implemented through daily survey rounds. These rely on visual inspection to detect abnormal symptoms, particularly on Canary Island palm. Trees showing suspicious signs are carefully examined by trained specialists who open the crown by removing fronds to inspect internal tissues. A weekly inspection schedule prioritizes the infested areas and is adjusted based on pheromone trap monitoring data. All findings are digitally recorded in a dedicated RPW management system to ensure effective tracking and analysis. Thirdly, a dense network of pheromone traps (white traps, 24 cm high and 13 cm wide, with eight openings and a 6 cm water level) has been deployed across the affected regions. These traps serve dual purposes: reducing adult weevil populations, particularly females to limit egg-laying, and monitoring pest activity across different times and locations. The data collected is used to guide the scheduling of surveillance and treatment operations. Trap installation and maintenance are carried out by four specialized teams, each consisting of qualified workers. The infested area is divided into four monitoring sectors, and all trap data are stored in a centralized digital system for real-time analysis and informed decision-making. Fourthly, two main treatment approaches are applied: mechanical and chemical. The mechanical treatment targets fruit-bearing date palms where offshoots (suckers) are removed to prevent weevil entry into the trunk. The chemical treatment involves alternating Imidacloprid and Bifenthrin applications on a monthly basis for all palms within the three zones, with both curative and preventive treatments continuing until trees are confirmed pest-free. In curative treatments, pesticides are sprayed every three weeks on the upper parts of palms, using 10 to 20 liters of solution until the crown is completely wetted. The infested area is further divided into 27 treatment sectors, serviced by trained operators using portable sprayers equipped with 100-liter tanks to facilitate mobility. Treatment operations cover approximately 12,000 palm trees per month in the Infested Zone and around 1,000 palm trees in the Intermediate and Buffer Zones. All treatment data are digitally recorded to ensure compliance with treatment intervals and full coverage of all trees.

Fifthly, severely infested palms undergo a sanitation and eradication protocol that includes complete defoliation, wrapping the crown in plastic to prevent weevil escape, cutting the trunk into small pieces, and burning or shredding all residues. The treated site is then chemically disinfected. To contain the pest geographically, the Tangier–Asilah region has been declared a quarantine zone, prohibiting any movement of palms or offshoots into or out of the area. Confiscated palms are immediately destroyed, with enforcement ensured by local authorities and the Royal Gendarmerie. Sixthly, awareness and training programs have been implemented to educate palm owners, municipal services, hotel managers, and landscapers about the dangers of RPW and the importance of early reporting. Several workshops and outreach campaigns have provided detailed information on pest identification, infestation symptoms, and best management practices. These awareness initiatives are vital for public engagement and the long-term success of control operations. Moreover, a set of national phytosanitary and agricultural regulations reinforces these measures. These include the prohibition of palm pruning between March 1 and November 30, the mandatory sealing of pruning wounds, and the burning of pruning residues to prevent reinfestation. In addition, the movement of palm trees and offshoots from infested to pest-free regions is strictly forbidden, and all activities are subject to official inspection and enforcement. Furthermore, to enhance early detection capabilities, ONSSA has signed a contract with a private company for the installation of electronic detection devices on numerous palm trees in Tangier. Installation is ongoing, and the system will be tested over two consecutive years to evaluate its performance and reliability under field conditions. Despite significant progress, the national program continues to face several operational challenges, including adverse weather conditions (rain and strong winds) that delay treatments, difficulty accessing tall palms exceeding 6–8 meters, maintenance issues related to detection devices, and restricted access to private or abandoned properties for inspection. Finally, to strengthen the program's sustainability and effectiveness, Morocco emphasizes the need for greater financial investment, stronger research collaboration, the adoption of advanced technologies, and improved regional cooperation across North Africa and the Near East. Continuous scientific evaluation of the national strategy remains essential to identify weaknesses, propose practical solutions, and ensure the long-term success of Morocco's Red Palm Weevil management efforts (Bouabid, 2021).

2. METHODOLOGICAL FRAMEWORK AND DATA SOURCES

2.1. Methodological Framework

2.1.1. Scoping the Socioeconomic Impact, Policy, and Diagnostic of RPW Spread

The main purpose of the scoping activity is to span the nature and boundaries of the socioeconomic impact assessment, and diagnostic (SEIAD) of RPW and henceforth craft a relevant and cost-effective pest management. The achievement of this purpose is nonetheless frustrated by the general deficiency of the literature on the SEIA for invasive plant pest and diseases, and more so for the RPW. On the other hand, the conduct of SEIAD for Egypt and UAE in the rural date palm tree farming systems, and in Morocco for the ornamental palm trees in the urban areas is also thwarted by the striking paucity of information required to characterize and diagnose the current health situation of date palm plantations and ornamental palm tress in the three target countries and to provide empirical evidence as to the impact of RPW spread on date production, farmers' income, livelihoods, other socioeconomic attributes, and widespread risk from the urban areas, mamong others. It is therefore seen essential to undertake socio economic and policy studies in the three countries to provide guidance on:

- Crafting the method of SEIAD that could best profile the current impact and establish a benchmark scenario (i.e., the current situation) for both ex-ante and ex-post monitoring and evaluation of the measures that would be proposed to contain and to control spread of this pernicious menace.
- Interveiwing the key potential experts and decision makers in the three countries towards developing procedures and guidelines, for implementing RPW quarantine measures, and assessing current policies and programs addressing RPW management.
- Marking out the sources of the required socioeconomic and policy information and the methods to use for obtaining such information in a more representative and cost-effective manner (i.e., information required and sources of information; types of groups impacted and their selection for information and data collection; and resources required for information and data collection).

2.1.2. Process and methods used for the SEIA of RPW

The assessment of the economic and social impacts of the RPW spread and its control regimes, and the evaluation of the existing procedures and guidelines, for implementing RPW quarantine measures, and the current policies and programs addressing RPW management shall focus on both quantitative and qualitative techniques that would assess the pecuniary impacts as well as the perceptions of the impacted groups (stakeholders) to RPW spread and its control measures. Such methods, and sources of required information are discussed in the next section.

2.1.3. Analytical methods used for the SEIA of RPW

2.1.3.1. Qualitative Analysis Techniques: Indices to Risk and Governance

2.1.3.1.1. Introduction

This methodological framework aims to identify a group of indicators, in the frame of assessment of the socioeconomic impacts, useful to evaluate the perception risk of the RPW establishment and spread, and the effectiveness governance of the pest management system (ex-ante interventions) for RPW, inside the supply chain.

The conceptual framework is based on FAO Sustainability Assessment of Food and Agriculture Systems (SAFA) tool, particularly the dimension of sustainability "Good governance" at the farm level. The concept proposed here is a structured system of indices that ranks and score the concerned countries and their selected governorates according to their likelihood and suitability for RPW establishment and spread. As such, we divide the assessment of the concerned farms into two macro areas: (i) Perception risk (P) and (ii) Governance effectiveness (G) towards RPW invasion. Each area involves a set of indices (indicators) as follows:

- **Perception risk (overall index P): Indices and justification**

Based on the data to be obtained from the baseline study, the vulnerability of each target country (and its selected governorates) to the overall perception risk[2] index of the RPW establishment and spread were assessed through five partial indices that are described and justified as follows:

- **Socio-economic index (partial index P1)** of the respondents. For this purpose, this index will be derived by using data generated from the baseline survey that generates 5 sub-indices (Data to be used from the survey):
    - Education Level by Governorate and the Whole Sample
    - Farmers' Experience in Date Palm Cultivation by Governorate
    - Main Sources of Sampled Farmers Income by Governorate
    - Date Palm Farm Size, Mode of Cultivation, Fruitful and Unfruitful and Variety Produced by Governorate.
    - Types of Date Palm Cropping System by Governorate

- **Information & Communication index (partial index P2)** about the Date Palm Infestation by RPW. Such index aims to assess the level of information and

[2] Note: As such, we highlight that higher is the perception risk, lower is the damage that can be induced by RPW.

communication of the disease in terms of source of information, importance of public awareness, importance of exchange and sharing information, collaboration with local authorities. As such, this assessment index identifies the main sources of information about the disease and how reliable they are (according to the respondent's appreciation); evaluates the knowledge/consciousness of the different levels of responsibility (and corresponding authorities) in disease management. Here, this index was assessed using data presented in the following Tables that generate 6 sub-indices:

- Farmers' Perception on Date Palm Infestation by RPW by Governorate
- Description of Infestation by Governorate
- Farmers Perception of the Impact of RPW infestation on Tree Productivity
- Methods Used by Farmer to Detect RPW infestation

- Inspection perception index (partial index P3). In the frame of the technical support about inspection in Date Palm pest management, such index aims to provide insights on what respondents know about the problem, how they feel about it, what perception they have about the severity and causes of the problem, and what actions they are currently taking (i.e. RPW preferences, infested and treated trees, frequency of inspection, importance of inspection, early detection, uses of digital apps, knwolge/technology sharining from commercial farmers technical assistance, training participation). Here, this index will be defined using data presented in the following and that generates 1 sub-index:

    - Farmers' Perception of Inspection of RPW and other date palm pests

- Training index (partial index P4): In the frame of the level of the training perception on early detection of RPW, such index expresses the perception of importance and satisfaction of training, here, this index will be elaborated using data that generates 1 sub-index:

    - Farmers' Perception on Inspection Training for Early Detection of RPW
    - Technical management index (partial index P5): Such index expresses the strategies and the containment measures deemed most effective in each target country. Further, this area assesses the type and evaluation of methods control used, preventive measures, IPM, legislative measures and cultural practices. Here, this index will be elaborated using data that generates 7sub-indices:
        - Adoption of the Recommended Preventive Measures Against RPW by Governorate.
        - Sample Farmers Knowledge of Legislation by Governorate.
        - Sample Farmers' Adherence to IPM by Governorate.
        - Farmers Commitment to GAPs as a Measure to Protect Date Palm from RPW.
        - knowledge of Components of Mechanical Control by Governorate.
        - Knowledge of Component of Chemical Control by Governorate.

- Knowledge of Component of biological Control by Governorate.

- **Governance effectiveness (overall index G): Indices and justification**

Based on the data to be generated from the baseline survey, the vulnerability of each target country (and its selected governorates) to the governance effectiveness of the RPW establishment and spread will be assessed through one index that is described and justified as follows:

- **Public support index (partial index G6)**. Regarding the stakeholders in the governance of the pest management system for RPW disease, such index assesses the capability of the target countries and their governorates in facing the occurrence of an RPW outbreak. The government support, the performance of inspection and control team. This index will be elaborated using data that generate 2 sub-indices:
  - Farmers' Perception of Government Support
  - Performance of Inspection and Control Team

2.1.3.1.2. Assessment model

Each area stage will be assessed separately as follows. At "perception risk" level, the target countries and their selected governorates will be scored and ranked for each index (indicator), according to obtained survey data, assembled into five relative score/rank categories, and then arranged so that each country and governorate is positioned between the following evenly-spaced percentiles: *Least risk (value 1)* is below the 20th percentile; *Lower risk (value 2)* is between the 20th and 40th percentiles; *Medium risk (value 3)* is between the 40th and 60th percentiles; *High risk (value 4)* is between the 60th and 80th percentiles, and *Highest risk (value 5)* is above the 80th percentile. The percentile compares the category risk of one governorate to the others. In other words, it is the percentage of data (*i.e.* indices) for which the assessed governorate falls at, below or above a certain observation. Therefore, it shows where a governorate's score falls in comparison to other governorates. For example, if a governorate (A) is in the over 80th percentile, it is ranked as having a higher level of perception risk for RPW invasion than 80% of the other assessed governorates, therefore governorate (A) carries out value 5 *(see Excel file "Country Matrix" and Excel sheet "Risk Score & Legend")*.

Except for the Pi1.1 and Pi1.2 indices, we will adopt a qualitative approach to assess their correspondent Perception risk.

A similar process or scheme will be applied to the assessment of the overall governance effectiveness index from the least effectiveness to the highest effectiveness.

2.1.3.1.3. Variables weighting schemes and aggregation

In order to give a predictive power to each index used in the assessment model, their weights are generally determined by statistical tools (chi-square analysis, logistic regression) or by expert judgement. In this assessment, coefficients weights will be straightforwardly assigned to perception and governance indicators, based on a focus RPW experts' approach. In other words, starting from overall perception risk index (P), the first step is to calculate the sub-index from each table, in the frame of each partial index from 1 to 5, considering the five relative score/rank categories (value from 1 to 5). In case there are more sub-indices correlate to each index, we, then, calculate their total rank for the assessment macro area per governorate and country (hereafter $R_{PERC/governorate/country}$), corrected by their coefficient weights, and then combined additively as follows:

P (PERC/governorate/country) for each partial index = [P (PERC 1) x CW (PERC 1)] + [P (PERC 2) x CW (PERC 2)] + [P (PERC i) x CW (PERC i)] + [P (PERC n) .x CW (PERC n)] **(1)**

P (PERC/governorate/country) for each partial index = value from 1 to 5 of each partial perception risk index in each governorate and country.

$P_{(perc\ n)}$ = value from 1 to 5 according to the risk spectrum mentioned above (from least to highest risk) for each table.

$CW_{(PERC\ n)}$ = weight %.

Subsequently, the second step is to calculate the overall index (A), using the similar above process and formula where to the correlated partial indices from 1 to 5, considering the weights %.

P (PERC/governorate/country) for overall perception risk index = [P (PERC 1) x CW (PERC 1)] + [P (PERC 2) x CW (PERC 2)] + [P (PERC i) x CW (PERC i)] + [P (PERC n) .x CW (PERC n)] **(2)**

P (PERC/governorate/country) for overall index = value from 1 to 5 of each overall perception risk index in each governorate and country.

P(perc n) = value from 1 to 5 according to the risk spectrum mentioned above (from least to highest risk) for each partial index.

$CW_{(PERC\ n)}$ = weight %.

A similar process will be applied at the "governance effectiveness" level in order to obtain the total ranking/scoring assessment for this macro area per target governorate and country (hereafter $G_{EFFE/governorate/country}$), using the partial indices from 7. to 8. index (see above), as follows in the first step:

G (GOV/governorate/country) for each partial index = [G (GOV 1) x CW (GOV 1)] + [G (GOV 2) x CW (GOV 2)] + [G (GOV i) x CW (GOV i)] + [G (GOV n) .x CW (GOV n)] **(3)**

G (GOV/governorate/country) for each partial index = value from 1 to 5 of each partial governance risk index in each governorate and country.

$G_{(GOV\ n)}$ = value from 1 to 5 according to the risk spectrum mentioned above (from least to highest effectiveness) for each table.

$CW_{(GOV\ n)}$ = weight %.

Subsequently, the second step as follows:

G (GOV/governorate/country) for overall governance effectiveness index = [G (GOV 1) x CW (GOV 1)] + [G (GOV 2) x CW (GOV 2)] + [G (GOV i) x CW (PERC i)] + [G (GOV n) x CW (GOV n)] **(4)**

G (GOV/governorate/country) for overall governance effectiveness index = value from 1 to 5 of each overall governance risk index in each governorate and country.

$G_{(GOV\ n)}$ = value from 1 to 5 according to the risk spectrum mentioned above (from least to highest effectiveness) for each partial index.

$CW_{(GOV\ n)}$ = weight %.

Regarding the overall assessment risk ranking, we combined the two macro areas levels (Equations 2 and 4) using the matrix shown in Figure 4, where both levels have five possible ranks/scores, and the overall assessment of vulnerability to invasion ranges from the least, lower, medium, or high to the highest level. This matrix tool is more informative and transparent, so that one individual (i.e. governorate) can easily be compared to another, and that it is more consistent for decision-making and risk management.

overnance effectiveness – G (Results of equuantiions 4)						
	Highest					Highest (5)
	Higher				**High (4-5)**	
	Medium			**Medium (3-4)**		
	Lower		**Lower (2-3)**			
	Least	**Least (1)**				
		Least	Lower	Medium	Higher	Highest

Perception risk – P (Results of equation 2)

Figure 4. Method for combining the levels of perception and governance effectiveness risk indices to form an overall assessment of vulnerability to RPW invasion. The diagram assembles five relative rank categories at each macro area considered in our assessment model.

Source: Own elaboration (2025).

2.1.3.2. Quantitative Analysis

2.1.3.2.1. Introduction

In the literature, several conceptual modelling frameworks have been proposed, and the choice of an approach depends largely on the objective of the model and the availability of data. In this proposal, the applied methodological framework will be based on the following process:

In the literature, three techniques for quantitative economic assessment: partial budgeting, partial equilibrium analysis and computable general equilibrium analysis. Partial budgeting is a method that addresses the additional costs and lost revenues that are incurred at the producer level when a pest invades. This method takes into account the area attacked by the pest, the loss per unit area, and the price of the product, but it does not include relationships between production volume and prices, or interlinkages between markets. Partial equilibrium modelling does take into account the price effects of changes in production volume in addition to those factors already taken into account by partial budgeting. Partial equilibrium modelling techniques also address linkages to other agricultural markets, e.g., due to substitution of one product by another. Computable general equilibrium modelling techniques are the most comprehensive and complex tools to look at effects of pest invasion on the whole economy. The techniques thus differ markedly in scope, i.e., the extent to which the impacts for the economy at wide are addressed. As a result, they differ in data requirements, the level of expertise needed to conduct the analysis, and the time investment required to complete an analysis. Partial budgeting is the easiest and fastest to conduct, and computable general equilibrium modelling the most difficult and time consuming. No guidance is given in International Standards on Phytosanitary Measures (ISPM) No.11 as to the pros and cons of different techniques for conducting economic impact assessment.

The limited use of quantitative economic techniques, and advanced economic techniques in particular, may be due to limited familiarity with these techniques in the professional field of regulatory plant protection. More generally, it is not clear whether the greater scope of more advanced techniques justifies the extra effort required in terms of data collection and human resources (Vose, 2001; Sansford, 2002). Also, it is felt that advanced techniques may require data that are impossible to obtain or characterize with sufficient certainty. It is felt that the more comprehensive techniques may introduce more uncertainty in the results than is justified by the extra insights they may provide (Vose, 2001; Sansford, 2002). The key question is: what added value does an advanced quantitative method for assessing economic impacts bring to the pest risk analysis (PRA), and does this extra value justify the costs in terms of data and resources? In this section we review the main quantitative methods that may be used for estimating the economic impact of pest invasions. We evaluate characteristics of these methods in terms of goals, founding principles, scope, and data requirements, and provide criteria that may be used in selecting the most appropriate technique for conducting a pest risk analysis.

2.1.3.2.2. Partial Budgeting Analysis

Partial Budgeting Analysis (PBA) is a basic method designed to evaluate the economic consequences of minor adjustments in a farming business. The method is based on the principle that a small change in the organization of a farm business will reduce some costs and revenues, but at the same time add others. The net economic effect of a change will be the sum of the positive economic effects minus the sum of the negative effects (Table 3). Due to the marginal approach, PBA is not designed to show the profit or the loss of a farm as a whole, but the net increase or decrease in farm income.

Partial Budget Analysis Comparison current plan (no RPW) versus alternative plan (RPW invasion)	
A) Additional costs incurred: **Costs under the RPW Spread and treatment that are not required under the Control situation**	*E) Costs foregone:* Costs under the Control situation that will be avoided under the RPW Spread and treatment
B) Revenue foregone: **Returns under the Control situation that will not be received under the RPW Spread and treatment**	*D) Additional Revenue generated:* Returns under the RPW Spread and treatment that are not received under the Control situation
Total Costs: C =A+B	Total Benefits: B =E+D
Net Change: (B – C)	

Table 3. Partial budgeting Analysis

With respect to plant production, various PBA applications are known, primarily assessing the profitability of management options such as irrigation, pesticide use and fertilizer use (e.g., Arpaia et al., 1996; Donovan et al., 1999; Pemsl et al., 2004). Partial budgeting is also a suitable tool for assessing the economic impact of pests (Macleod et al., 2003; FAO, 2004). The strength of PBA in conducting a pest risk assessment is its simplicity and transparency. PBA has a low complexity level with respect to resource needs as it requires a limited amount of data, skills, and time investment (Holland, 2007). Although the method is designed to evaluate the direct impact at the producer level, PBA can also be used at the national or continental level by scaling up the budgetary impacts of the individual farms (Rich et al., 2005). Macleod et al. (2003) and Breukers et al. (2008) used PBA to assess economic consequences of invasion of a quarantine pest or disease at the national level. However, PBA is not suited to measure long-term effects or impacts in other sectors of the economy due to its reliance on fixed budgets with predetermined coefficients (i.e., price) to describe an isolated activity. Any change in production caused by a pest invasion could have a long-term effect on total market supply and prices, thereby affecting other producers and other sectors of the economy such as transport and the processing industry (Macleod et al., 2003). Aggregation of PBA results from a representative farm to reflect costs at a higher scale will therefore only be representative if price effects and interlinkages with other sectors are weak. These shortcomings of PB can be counterbalanced by a complementary use of techniques that are described below.

In our case, the benefit/cost comparison is based on the with and without situations, which compare cost and revenue parameters under the control or no (*without*) RPW infestation versus the *with* RPW infestation situation. The need for the use of analytical techniques other than PBA is precluded since the RPW infestation in the targeted countries (i.e, Egypt and UAE), as generally believed by key informants and by small- and large-scale producers to be interviewed during the baseline study implementation and during scoping missions, does not affect quality of dates nor cause reduction in production to the extent that significantly influence market forces and prices, and henceforth warrants the use of other analytical techniques that could capture these market changes[3].

The economic consequences with regard to RPW infestation shall also pay due consideration to the dynamics of both investment/cost and revenue streams, as these consequences normally extend beyond the period of one year encountered in the case of treated trees to include an indeterminate period of several years (nearly between 5 and 6 years) until the new replacement offshoots reach full and stable production in the case of felling down trees. The total economic consequences over more than one year shall be expressed as net present value (NPV) of annual economic consequences, discounted at an appropriate discount rate[4] to calculate NPV for the whole 10- year period.

PBA evaluates the direct impact of change per a single tree (both felling and treated tree) which would then be scaled up by the potential pest spread (infestation level)[5] to estimate results at the producer/farm level. These results can again be scaled up to the regional and national levels by the relevant regional and national incidence of RPW infestation.

2.1.3.2.3. Partial Equilibrium Modelling

Partial Equilibrium Modelling (PEM) is a powerful tool to evaluate the welfare effects on participants in a market which is affected by a shock like a policy intervention or an introduction of a pest. The approach is based on defining functional relationships for supply and demand for the commodity of interest to determine the market equilibrium or, in other words, the combination of prices and quantities that maximizes social welfare (Mas-Colell, 1995). Maximum social welfare is realized when consumers and producers - in aggregated terms - maximize their utilities and profits as illustrated in Figure 5.

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[3] FAO IPPC 2017 ISPM 5; *Glossary of phytosanitary terms.* Supplement No. 2: Guidelines on the understanding of potential economic importance and related terms including reference to environmental considerations.
[4] The discount rate applied for investment feasibility studies or opportunity cost (saving rate) of the Central Bank shall be used.
[5] The potential spread (incidence of infestation) is defined as the proportion (percentage) of date palms infested with RPW. For direct impact assessment the incidence of both felling down and treated trees are required.

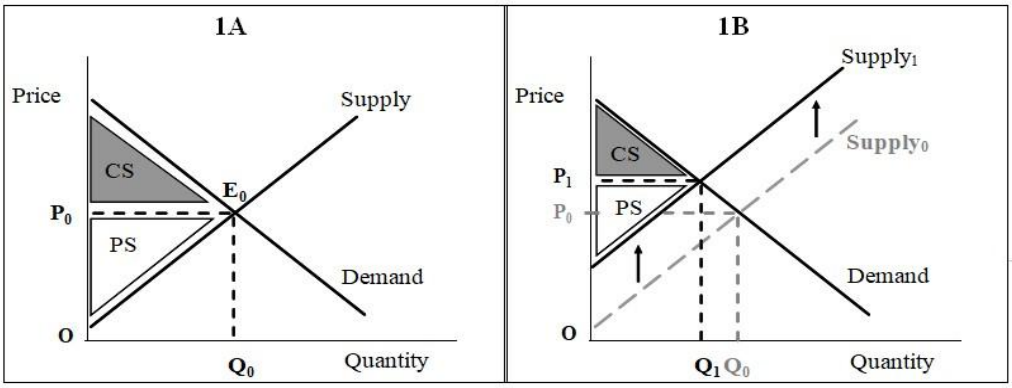

Figure 5. Impact of shock on market equilibrium.

This figure shows a downward-sloping demand curve, reflecting diminishing marginal utility as consumption increases, and an upward-sloping supply curve, reflecting increasing marginal costs of production. The market equilibrium (E0), where quantity supplied equals quantity demanded, occurs at an equilibrium price of P0 and quantity Q0. The difference between P0 and the demand curve represents how much consumers benefit by being able to purchase the product for a price that is less (P0) than they would be willing to pay. This total benefit derived by the consumers, or consumer surplus, is represented by the triangle labeled CS. Since the supply curve represents the marginal variable cost of production, the area below the curve equals the total variable costs. The revenues from sales are equal to price (P0) times quantity (Q0), which is the area enclosed between the dashed lines. Hence the producer surplus, defined as the difference between total revenue and total variable costs is reflected by the triangle PS. Social welfare is defined as the sum of consumer surplus and producer surplus.

By PE analysis, the aggregated impact of a shock is determined by measuring the differences in equilibrium price and quantity, and change in welfare before and after the shock. A shock, like a pest invasion, may lead to a loss in yield and an increase in production costs, resulting in an upward shift in the supply curve (Figure 5). This shift in the supply curve alters the equilibrium point (Figure 5.1A), implying a decrease in quantity supplied (from Q0 to Q1) and an increase in market price (from P0 to P1). Producer losses, or the reduction in producer welfare, that result from the new equilibrium point can be calculated by comparing PS before and after invasion. In the same way, changes in consumer welfare can be calculated. The change in social welfare is determined by the aggregated impact of the changes in producer welfare and consumer welfare (Just et al., 1982). For the purpose of illustration, the demand curve in Figure 5.1B is assumed to be unaffected by the shock. In reality, demand can also be affected; for instance, the presence of a pest might affect consumer preferences, thereby shifting the demand curve down, resulting a lower price and quantity at equilibrium.

Partial equilibrium modelling has been widely applied to the analysis of agricultural policy, international trade, and environmental issues (e.g., Qaim and Traxler, 2005; Elobeld and Beghin, 2006; Cook, 2008; Kaye-Blake et al., 2008; Schmitz et al., 2008). Examples of recent applications on pest risk assessment are the analyses performed by Arthur (2006), Breukers et al (2008) and Surkov et al (2009). Arthur (2006) used PE to evaluate the impact on net social welfare of liberalizing the Australian apple market for imports from New Zealand, accounting for the risk of entry of fire blight disease in Australia. The benefits were presented in terms of consumer welfare gain, resulting from lower apple prices due to an increased supply from abroad, while the costs were derived from the reduction in producer welfare as a consequence of losses in production and expenditures to control the pest. Measuring the change in net social welfare, Arthur concluded that Australia would be better off by $90 million even if fire blight became established across all areas. Breukers et al. (2008) modelled the impacts of repeated brown rot outbreaks on supply and (national and export) demand of seed potatoes. They found that the indirect effects as a consequence of reduced export demand are far bigger than the direct effects (yield losses). Surkov et al. (2009) determined the optimal phytosanitary inspection policy in the Netherlands given the estimated costs of introduction of pests through trade pathways. In this study the PE approach was used to account for the potential price effects due to a pest introduction.

The use of PE within a pest risk assessment is appropriate when the pest impacts are expected to change prices or social welfare significantly. PE analyses can be conducted with respect to one sector (single-sector model) or multiple sectors (multi-market model). Multimarket models link related markets and are, therefore, able to capture spillover effects between main markets as, for example, the impact of a pest affecting wheat supply on supply and demand of potential substitute crops like corn. The calculation of producer and consumer surplus in multiple markets involves sequentially computing the effects in each of the affected markets. Within each PE model main assumptions needs to be made to define the structure of the affected market(s) (e.g., perfect competition), the level of homogeneity for products from exogenous markets and the influence of domestic producers on the world market. Data requirements can be substantial (Mas-Colell, 1995; Rich et al., 2005; Backer et al., 2009) as data are needed to reflect the affected markets, including data on prices, quantities, and price elasticities of both supply and demand. Despite its suitability for the evaluation of effects on markets of agricultural commodities, PE is limited in its ability to account for economy-wide effects. PRA by PE is, therefore, only appropriate when the indirect impact of the pest is not expected to significantly affect other non-agricultural markets or to generate measurable macroeconomic changes (e.g., changes in income and employment). For applications that require an economy-wide scope Input-Output analyses or Computable General Equilibrium modelling approaches may be needed.

2.1.3.2.4. Input – Output Analysis (I-O)

The technique of I-O analysis focuses on the interdependencies of sectors in an economy (regional or national), making it suitable to predict an economy-wide impact of changes within a particular sector (Leontief, 1986). Central to an I-O analysis is the specification of an I-O table to describe the monetary flows of inputs and outputs among the productive sectors of an economy (Miller and Blair, 1985). In an I-O table, economic sectors are aggregated into representative groups. Each sector-group is represented by a row and a column. The rows of the table specify the distribution of total output of a specific sector sold to other sectors (i.e., to intermediate demand) or to final demand (e.g. to final consumption, investments and exports). The columns refer to the production side of a given sector, by denoting the value of inputs of each sector required to produce output.

Any change in final demand for the products of a sector generates direct as well as indirect effects on the economy as a whole. Changes create large primary “ripples” by causing a direct change in the purchasing patterns of the affected sector. The suppliers of the affected sector must alter their purchasing patterns to meet the demands placed upon them by the sector originally affected by the change in final demand, thereby creating a smaller secondary “ripple”. In turn, those who meet the needs of the suppliers must change their purchasing patterns to meet the demands placed upon them by the suppliers of the original sector, and so on. The relationship between the initial change and the total effects generated by the change is known as the multiplier effect of the sector, or the impact of the sector on the economy. To compute this multiplier effect, I-O tables are mathematically converted into matrices of multipliers that reflect the amount by which production, employment and income would alter as a result of one-unit change in final demand (Miller and Blair, 1985).

Based on I-O analysis, the impact of a pest invasion on an economy can be evaluated by adjusting the final demand in the affected agricultural sector according to the expected shock to demand (e.g., reduction in exports), multiplied by the multiplier matrix. Examples of recent applications to pest risk assessment are the analyses performed by Elliston et al. (2005) and Julia et al. (2007). Elliston et al. (2005) used I-O analysis to investigate the regional economic impact of a potential incursion of Karnal bunt in wheat in Queensland. As Karnal bunt is considered a quarantine disease in Australia's most important wheat export markets, an incursion in Australia would lead to a significant loss of export markets. In the scenario of a widespread incursion the direct effect in the wheat and other grains industries was estimated as an $89 million decline in output over a fifteen-year planning horizon and a loss of 400 full time jobs. The indirect effects of the incursion in all other industries were estimated as a decline of $38 million in output and a decline in employment of 200 full time jobs. Another example of I-O analysis is the analysis of the total costs of the invasive weed Yellow starthistle in the rangelands of Idaho (Julia el al., 2007). In this analysis, direct and indirect economic effects of the weed were determined in relation to its interference with agricultural and non-agricultural benefits (e.g., wildlife recreation expenditure and water winning). Agricultural related economic impacts accounted for 79% of the total impact on the rangeland-economy, and non-agricultural impacts for the remaining 21%. The strength of the I-O approach is its ability to capture spillover effects between economic sectors. The accuracy of this 'capture' depends on the level of sector aggregation in the I-O tables. If the level of aggregation is too high, indirect impacts of a shock will be overestimated. Lower levels of aggregation are, however, associated with substantial increases in data requirements. In addition to its high data requirement, the potential use of I-O analysis is restricted by two fundamental assumptions. First, I-O models only account for changes in the economy due to shifts in demand; supply is assumed to be perfectly elastic. Since supply constraints are often present in agriculture, I-O models may miss important effects of a pest introduction. Second, due to the use of fixed coefficients, I-O models cannot account for changes in prices or for changes in the structure of a sector over time. This means that I-O models assume fixed prices, no substitution between inputs, and constant returns to scale. However, this static assumption can be justified if the I-O technique is used to analyze only short-term impacts. To conclude, the I-O approach provides the opportunity to measure short-term, spillover impacts across broad sectors of the economy given plant health incidents that affect the demand side only. For applications that require the economy-wide scope of I-O models as well as the economic realism of PE models, a Computable General Equilibrium Modelling approach would be more appropriate.

2.1.3.2.5. Computable General Equilibrium Modelling (CGE)

The CGE approach combines the strengths of I-O analyses and PE models to answer a wide range of questions. It uses I-O tables to represent the entire economy with the inclusion of functional relationships between actors in this economy as in a PE model. The basic structure of a CGE model can be described in terms of "blocks" of equations that specify demand relationships, production technologies, relationships between domestic and imported goods, prices, household income and numerous equilibrium conditions. Such a framework enables CGE models to address questions concerning impacts across sectors and employment groups as well as price changes and longer-run impacts. This capacity, however, makes CGE models highly complex, imposing high costs in the development of such a model as well as in the interpretation of its results (Sadoulet and de Janvry, 1995; Dixon and Parmenter, 1996).

By nature, CGE models are highly aggregated, making it difficult to analyze a change in a sub sector of the economy. Many CGE models are disaggregated into only two agricultural sub-sectors, such as tradable and non-tradable crops, or food crops and cash crops (Bourguignon and Pereira da Silva, 2003). Applications of CGE models are, therefore, only appropriate to address large-scale problems which are most likely to generate measurable macroeconomic impacts. Pest invasion problems rarely generate such major effects as changes in aggregate employment, income or inflation rate. As a consequence, there are few applications of CGE applications in pest risk assessments. Recent applications are those of Wittwer et al. (2005, 2006). In Wittwer et al. (2005) a CGE model was used in order to quantify the impact of a hypothetical outbreak of the Tilletia indica fungus (the causal agent of Karnal bunt) on the wheat crop in west Australia. In their analysis, the effects on output, income, employment, wages, capital stocks and exports were estimated. In a second paper, Wittwer et al. (2006) investigated by the use of CGE the economic consequences of introducing Pierce's disease of grapevine in South Australia. Special attention was given to the adjustment in the labour market as a result of the disease outbreak.

2.1.3.2.6. Decomposition model

Numerous models can be used to analyze the economic performance of Integrated Crop Management Farmer Field School Program (ICM-FFS) including the decomposition model. This model is a mathematical technique to break down something that is aggregated into its components, so it is possible to allocate the difference in the dependent variable to each independent variable (Catelo, 1984). This model had been used to analyze the contribution of each independent variable on income differences, production, and productivity in several studies. Catelo, (1984), for example, used this to analyze the impact of the communal irrigation system on rice production. Kiresur et al. (1995) conducted a study of technological change in the production of sorghum to decompose productivity differences between new and traditional varieties into labor, seeds, fertilizer, and capital. Narayanan et al. (2002) analyzed the impact of shelterbelts on the decomposition of peanut production in the rilands, South India. On the other hand, Simatupang et al. (2004) applied this technique to examine the sources of growth in upland rice production in Indonesia. Feder et al. (2004) used decomposition analysis to assess the impact of the implementation of the Integrated Pest Management Farmer Field School (IPM-FFS) on rice productivity and pesticide use. Thank and Singh (2004) also decomposed changes in crop acreage into production and productivity, as well as the interaction between the two components. Meanwhile, Mehta (2009) examined the contribution of each component to the growth of crops in various regions in India.

2.1.3.2.7. Multi criteria decision making techniques

Decision making in controlling harmful plant diseases is a complex process involving a large range of stakeholders with different and often conflicting interests. Their views may represent the interests of the farming community, other sectors of the economy, the consumer or the environment. This may create a situation of conflicting interests, as economic motives may prevail in the views of some, while landscape, environmental or human-welfare motives may be prominent in the view of others. MultiCriteria Decision Making (MCDM) could support policy makers in choosing the control strategy that best meets all of these conflicting interests. MCDM techniques deal with complex problems that are characterized by any mixture of quantitative and qualitative objectives. It establishes preferences between alternatives to an explicit set of objectives and measurable criteria (Mourits and Oude Lansink, 2006).

Multi-Criteria Decision Making is by now a well-established paradigm in decision sciences. The key characteristic of this paradigm is that a decision maker does not optimize a single defined objective but aims for the achievement of satisfying levels in the goals or seeks an optimal compromise between several, often conflicting objectives (Romero and Rehman 2003). The general purpose of MCDM is to serve as an aid to thinking and decision making, but not to take the decision. MCDM techniques are capable of dealing with complex problems that are characterized by any mixture of quantitative and qualitative objectives. This is done by breaking the problems into more manageable pieces to allow data and judgments to be brought on the pieces. Next, the techniques reassemble the pieces to present a coherent overall picture to decision makers (Voogd 1982).

The applied Multi-Criteria Analysis (MCA) involves eight steps: (1) Establish the decision context, (2) Identify the alternatives to be appraised, (3) Identify objectives and criteria, (4) Scoring, (5) Weighting, (6) Calculate overall value, (7) Examine the results and (8) Sensitivity analysis.

Decision making in quarantine plant diseases is also complex and conflicting, due to the involvement of various epidemiological, economic and social-ethical value judgments. Control measures as the use of a particular pesticide may limit the spread of the infectious disease (= epidemiological value), but could also affect the subsistence of harmless organisms (= social-ethical value), result in residues in potential food products (= economic and social-ethical value) or even influence the existence of a whole ecosystem (= social-ethical value). Controlling the disease by a measure as complete destruction of plants and plant products may be very efficient from an epidemiological point of view but could have serious economic consequences for the affected producers and – depending on the magnitude of the outbreak – even affect the world food supply, resulting in a global social-ethical distress (Mourits and Oude Lansink, 2006).

2.2. Information requiered and Sources of Information

The process of gathering the required secondary and primary information and data for assessing the socioeconomic impact of the RPW encompasses literature review (technical reports, grey literature, governmental reports, etc.), scientific papers and reports, baseline study, key informants' inclusive consultations, focused group discussion and stakeholders' perceptions surveys.

2.2.1. Literature Review (LR)

Involves extensive readings and computer search, and collection of secondary data and information on the required parameters of dates palm production and their spatial distribution and on the RPW spread and control regimes from (a) designated official sources in the three countries, (b) regional and international organizations, notably AOAD, FAO, ICARDA, CIHEAM, World Bank, etc., and (c) studies and reports produced by academia, consultancy firms and other learned entities.

2.2.2. Baseline Survey Instrument (BSI)

Conducting a baseline study on the red palm weevil is essential for understanding its impact, distribution, and management strategies. This instrument is a sample questionnaire that can be used to gather information from farmers, agricultural workers, and stakeholders involved in palm cultivation. The questionnaire will be adapted based on specific research objectives and local contexts. The collected information is used to conduct a descriptive analysis of the current situation at the start of the RPW project to establish a benchmark for measuring future progress and impact. It involves collecting and analyzing data on specific variables to understand the "before" conditions, which can then be used to assess the effectiveness of an intervention, program, or treatment later on.The baseline study will carried out only in Egypt and UAE targeting the date palm trees farming systems.

The purpose of these BSI surveys is to gather qualitative data through a sequence of questions that capture personal views and responses of those to be impacted by the envisaged RPW control and eradication programs (notably date producers) which could contribute to maximization of the program positive impacts. A questionnaire shall be designed for each group to be filled through direct individual interviews managed by enumerators from the mandated national institutions in each country. Adequate arrangements shall be made to test the questionnaires and to train enumerators in the conduct of these interviews and filling-in the structured format. Producers shall be selected at random from the respective farming systems in each selected region or Governorate in the two indicated countries (Table 4).

2.2.3. Key Informants Interview's (KII's)

The key informants include concerned top government officials, researchers, policymakers and national agricultural and phytosanitary officials, and experts at both head quarter and regional level in the three countries to solicit their experience and knowledge, gather factual information and discuss with them the challenges posed by the RPW in the targeted countries and mechanisms to control its spread (Table 4). As in Morocco, the focus will be in urban areas, the edited KII's instrument will be used to assess the status, programmes, and strategies for RPW management in urban areas and the strategic action to overcome this threat before getting it expanded to date palm production areas. With respect to Egypt and UAE, where the target are the date palm production areas, the KII's instrument will allow to document, assess, and evaluate the existing programmes, strategies, and measure to limit the RPW impact is such areas and inhibe its wispread to the new productions areas.

2.2.4. Focused Group Discussion (FGD's)

The focus groups (6-10 persons in each group) will purposefully be selected from each sampled Governorate only in UAE and Egypt with the aim to ensure inclusion of diverse groups of date producers representing all existing farming systems (i.e., traditional, modernized, small and large farms, etc.), exporters, date based agro-processors, farmers' organizations and associations including cooperatives, NGOs and Women associations (Table 4). The discussions will be managed using structured questionnaires to collect the required quantitative data on farm investment, costs and revenue, etc.

Table 4. Field Surveys Planned to Collect Required Information by Country

Country	Instrument	Target	Geographic Focus	#	Purpose	Comment
Morocco	KII's	Experts Matter Specialist	National Level	National Level	Assess the status, programmes, and strategies for RPW management in urban areas	Develop checklist to consult informant groups including policymakers and national agricultural and phytosanitary officials in Morocco
Egypt	KII's	Experts matter specialist	National Level	National Level	Assess the status, programmes, and strategies for RPW management in rural areas	Develop checklist to consult informant groups including policymakers and national agricultural and phytosanitary officials in Egypt
	FGD's	Farmers groups in the 4 target locations	The 4 target locations	Aswan New Valley Matrouh (Siwa) Giza (Bahariya oases)"	Quantitative data on farm investment, cost and revenue	Structured questionnaire to be managed by the Study Team through direct group interviews

	Baseline survey	Farmers	60 farmers in the target locations (15 per location)	Aswan New Valley Matrouh (Siwa) Giza (Bahariya oases)"	Baseline survey: Mainly quantitative and qualitative data dealing with personal judgment, views, experiences, awareness about RPW spread and control measures and on related policies, etc.	Structured questionnaire to be filled through direct individual interviews managed by trained enumerators (for producers)
UAE	KII's	Experts matter specialist	National Level	1 (National level)	Assess the status, programmes, and strategies for RPW management in rural areas	Develop checklist to consult informant groups including policymakers and national agricultural and phytosanitary officials in UAE
	FGD's	Farmers groups in the 13 target locations	The 13 target locations	See note below	Quantitative data on farm investment, cost and revenue	Structured questionnaire to be managed by the Study Team through direct group interviews
	Baseline survey	Farmers	402 farmers	See note below	Baseline survey: Mainly qualitative data dealing with personal judgment, views, experiences, awareness about RPW spread and control measures and on related policies, etc.	Structured questionnaire to be filled through direct individual interviews managed by trained enumerators (for producers)

Main Category	People Involved	Information Sought	Method for Collection of Data and Information
Baseline Surveys			
Key Informants **(Group and individual surveys)**			
Focus Group **(Group surveys)**			
Perceptions **(Individual surveys)**			

2.2.5. Types of Groups Impacted and their Selection for Information and Data Collection

The sampling frame for the selection of respondents for collection of primary data and for soliciting perceptions as to the spread and control regimes of RPW infestation is based on (a) the territorial distribution of date palms within each country, (b) incidence of RPW infestation, and (c) variations in farming systems. More details on the site selection criteria is givn in Table 5.

Table 5. Site selection criteria in the three target countries UAE, Egypt and Morocco

	Criterion	Description	Country
1	Farm Typology	Type of farm (e.g., oasis-based, modern, cooperative) reflects farming systems.	UAE, Egypt
2	Cultivar Type / Agro-Ecological Zone	Date palms grown (e.g., soft, semi-dry, dry); important for matching workstream goals.	UAE, Egypt
3	Farm Size	Preferably 2–3 ha or 150–300 palms; ensures consistency across sites.	UAE, Egypt
4	RPW Infestation Status	If applicable, assess presence of Red Palm Weevil for pest-related research.	UAE, Egypt and Morocco
5	Farm ownership (Govt./Private)	The legal and operational control of the farm and its associated assets.	UAE, Egypt and Morocco
6	Palm Age Categories	Include a mix of palm ages to support diverse research needs.	UAE, Egypt and Morocco
7	Proximity to Research Center	Near research centers facilitate technical support and oversight.	-
8	Farmer Willingness	Farmer's openness to participate in trials, share data, and collaborate with researchers. (Yes/No)	-
9	Lead Institution	UM6P or INRA; responsible for site coordination.	-
10	Workstream Relevance	Site's relevance to specific project workstreams.	-
11	Existing Collaborations	Existing MoUs or joint projects with national partners.	-
12	Technical Staff Availability	Availability of trained staff for fieldwork and data collection.	-
13	Strategic Alignment	Fit with country's agricultural research and development goals.	-
14	Remarks	Additional site-specific notes.	-

2.2.6. Geographical Location

Two-stage selection process is used for selecting sampled localities, namely Region and Governorate selection in each of the two countries:

2.2.6.1. Region Selection in Egypt and UAE

2.2.6.1.1 Egypt

Five governorates will be selected to represent the the country topographical areas and climatic zones. Specific farms with each governorate with be selected for the studies (Matrouh, Aswan, New Valley, Giza and Ismalia). About 60 farms will be selecteded from these sites.

2.2.6.1.2 UAE

Three sites will be selected in the UAE to represent the different typologies of the coatal, central, and high land and the 7 emirates (Abu Dhabi, Dubai, Sharja, Ajman, Um Alquain, Ras Al Khaima, and Fujaira). About 400 farms will be selected from these sites.

2.2.6.2. Region Selection in Morocco

2.2.6.2.1 Morocco

The sites for the study will be selected from Tangier and Nadoor where the weevil is restricted to the Canary Islands date palm in the north.

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