CLIMATE-SMART AGRICULTURE ACTION PLAN

JORDAN

Investment opportunities in the agriculture sector's transition to a climate resilient growth path

THE WORLD BANK IBRD • IDA | WORLD BANK GROUP
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Alliance Bioversity International CIAT
ICARDA Science for resilient livelihoods in dry areas
CGIAR
RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security

PRODUCTIVITY RESILIENCE LOWER EMISSIONS

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Second edition: The second edition includes updated data on emission reduction for the vegetable investment package and combined investment packages and water productivity for the transition from open field vegetables to the greenhouse system.

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Cover illustration and design: Fernanda Rubiano and Brad Amburn

Abbreviations

ADOPT	Adoption and Diffusion Outcome Prediction Tool
AEZ	Agroecological Zone
CBA	Cost-benefit analysis
CC	Climate change
CCAFS	CGIAR Research Program on Climate Change, Agriculture, and Food Security
CF	Conventional farming
CGIAR	Consortium of International Agricultural Research Centers
CIAT	International Center for Tropical Agriculture
CMIP	Coupled Model Inter-comparison Project
CO2eq	Carbon dioxide equivalent
CSA	Climate-Smart agriculture
FAO	Food and Agriculture Organization of the United Nations
GCM	General Circulation Model
GDP	Gross domestic product
GEF-6	Global Environment Facility (period June 30, 2014 to July 1, 2018)
GHG	Greenhouse gas
GIDS	Gradient plus Inverse Distance Squared
ICARDA	International Center for Agricultural Research in the Dry Areas
ICT	Information and communications technology
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
IRR	Internal rate of return
M&E	Monitoring and evaluation
MoA	Ministry of Agriculture
MT	Million tonnes (Megatonnes)
NARC	National Agricultural Research Center
NDC	Nationally Determined Contribution
NoCC	No climate change
NPV	Net present value
NRW	Non-revenue water
OECD	Organisation for Economic Co-operation and Development
RCP	Representative Concentration Pathway
RICCAR	Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region
SDG	Sustainable Development Goal
SME	Small and Medium-Sized Enterprises
SSP2	Shared Socioeconomic Pathway 2
UN	United Nations

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ES

Executive Summary

Key messages

1. Climate change will place pressure on Jordan's water resources and adversely affect agricultural production through water scarcity, higher temperatures, and more frequent extreme events.
2. The suitability profile of the key crops currently grown in Jordan will change. Potato suitability will deteriorate, and that of barley and wheat will become more marginal. Olive yields will remain stable, while those of tomatoes and dates are expected to increase.
3. Climate-smart agriculture (CSA) offers opportunities to adapt to and mitigate the impacts of climate change, while promoting continued growth and job creation.
4. This CSA Action Plan used quantitative and participatory tools to prioritize investment packages for each of Jordan's agroecological zones: expansion of date palms and protected vegetables in irrigated parts of the Jordan Valley and highlands, olive production and processing and barley production in rain-fed regions, and small ruminant value chains and Badia restoration in agropastoral areas.
5. At both the farm and aggregated levels, the cost-benefit analysis shows a generally good return on investment for all CSA packages.
6. All the packages also promise to increase water productivity, create jobs in high-value export chains, and benefit farmers and vulnerable populations both directly and indirectly. The aggregated economic profitability of the six packages was estimated based on a combination of the net incremental benefit at the farm level, the annual adoption rate and, the large-scale investment costs beyond the farm level, such as for trainings and equipment for post-harvest storage and processing: and the number of targeted beneficiaries.

The economic profitability and payback period of investment packages at the on-farm and aggregated levels.

CSA package*	Area	Farmers	Investments**			Payback period (years)	
	Ha	#	On-farm (mil JD)	Large scale (mil JD)	Aggregated (mil JD)	On-farm	Aggregated
Date palms	800	500	6.34	1.30	7.64	12	3.1
Vegetables (a)	250	500	106.86	0.37	107.23	9.8	1.6
Vegetables (b)	100	200	39.74	0.19	39.93	8.9	1.7
Vegetables (c)	20	40	8.95	0.09	9.04	10.3	2.6
Olive	1,000	1000	16.82	2.12	18.94	3	2.6
Barley	1,000	1000	0.47	0.60	1.07	4	5.5
Small ruminants	n/a	900	23.26	0.54	23.80	3	1.6
Badia restoration	5000	250	0.1	1.39	1.49	3	6.9

n/a = not applicable Notes: *Vegetables are produced as follows: (a) open field to greenhouse, (b) low tunnel to greenhouse, and (c) open field to hydroponics; **1 JD = US$1.41.

7. All the investment packages proposed by this CSA Action Plan have a negative net carbon balance, with a total reduction of greenhouse gas (GHG) emissions of 823,665 tons of carbon dioxide equivalent combined. The total estimated GHG reduction represents a value of more than US$25 million.
8. Based on results from the Adoption and Diffusion Outcome Prediction Tool, maximum adoption rates for all CSA investments will be high, reaching 93 percent to 98 percent in a 20-year period.

Jordan is facing harsh climatic changes that affect agricultural production, and these challenges are expected to worsen in coming years. Climate change will place significant food security and livelihood stress on Jordan's poor and vulnerable populations. It may also hamper the further development of Jordan's agricultural sector, which increasingly depends on export markets. To address climate change, and in collaboration with the Alliance of Bioversity International and the International Center for Tropical Agriculture, and with the International Center for Agricultural Research in the Dry Areas, the World Bank assisted the government of Jordan in preparing this Climate-Smart Agriculture Action Plan. Climate-smart agriculture (CSA) heightens productivity in an environmentally and socially sustainable way, strengthens farmers' adaptation and resilience to climate change, and supports mitigation efforts.[1] Jordan's Action Plan to identify CSA investments follows the Climate-Smart Agricultural Investment Planning Framework and builds on the initiatives and work of government agencies and local institutions.[2] There is no CSA silver bullet; rather, climate-smart potential is highly contextual, and climate-smart program design requires an understanding of local circumstances and priorities.

Jordan is an extraordinarily dry country, and water resources are the limiting factor that determines its agricultural production systems. Only about 8 percent of Jordanian territory receives more than 200 mm of rainfall annually. Portions of the area receiving more than 200 mm are irrigated and portions are unirrigated, effectively creating two agroecological zones (AEZ). The unirrigated areas constitute the rain-fed AEZ.[3] The remainder constitutes the irrigated AEZ. The irrigated AEZ is the most productive and consists of the Jordan Valley and irrigated areas in the highlands; it extends from south of the Dead Sea to the northern national border and includes small portions of the highlands and agropastoral areas. The agropastoral AEZ comprises about 90 percent of Jordanian territory and primarily supports livestock production.[4] Jordan's extremely scarce water resources mean the country has already achieved exceptional water judiciousness, withdrawing only a fraction of its neighbors' consumption per capita. In contrast, synthetic fertilizers have historically been widely used in Jordan.

Jordan's agriculture is increasingly productive, and as of 2020, the sector contributed about 5.9 percent of the total national gross domestic product.[5] Agriculture accounts for about 15 percent of the total export value of US$1.1 billion and 25 percent of total imports, which are worth US$4.2 billion, making Jordan a net importer.[6] The livestock subsector dominates the vast agropastoral AEZ and was valued at US$1.47 billion in 2019. Jordan is self-sufficient in olives, olive oil, tomatoes, goat meat, fresh milk, and eggs. Additionally, it produces a significant portion of the poultry and some vegetables consumed domestically. In contrast, local diets rely heavily on imported cereal, legumes, fruits, and some vegetables. Jordan produces only about 3 to 4 percent of the wheat and barley it consumes. Nearly all its barley is dedicated to livestock feed.

Jordan's agricultural sector produced about 1.15 million metric tons (MT) of carbon dioxide equivalent in 2017. The primary agricultural greenhouse gas (GHG) emissions sources include enteric fermentation, manure left in pasture, nitrous emissions from agricultural soils, and secondary and tertiary emissions, including from portions of value chains, processing, and the associated electricity production, industry, and transport.[7] The forestry sector reported 0.87 million metric tons of carbon dioxide equivalent emissions in 2014 as a result of soil organic carbon loss in the rangelands.[8] This phenomenon is closely linked with unsustainable livestock practices, including overgrazing and consequent land degradation. It represents an important area of mitigation potential in Jordan's agropastoral systems.

The Ministry of Agriculture is the main actor charged with developing the agricultural sector. Research is provided primarily by the Ministry of Agriculture's National Agricultural Research Center, while extension services are now a department under the Ministry of Agriculture.[9] The National Agricultural Research Center has eight regional centers and 13 research stations that operate across 10 departments.[10] Water management is a major focus. The Jordan Valley Authority and the Water Authority of Jordan represent potentially valuable models for expanding and improving extension services in the country.[11] Private-sector activity in Jordan remains far below potential. Most non-profit initiatives center around the Syrian humanitarian crisis.

Jordan is a party to the Paris Agreement. The country submitted its Nationally Determined Contribution (NDC) in November 2016, detailing its intent to cut GHG emissions by 14 percent, with a 13 percent reduction conditional on international financial support.[12] The updated submission of Jordan's first NDC in 2021 enlarged its GHG emission reduction target to 31 percent. Jordan joined the NDC partnership in 2018, and in 2019 approved its NDC Action Plan, led by the Ministry of Environment and the Secretary General of the Ministry of Planning and International Cooperation. This Action Plan identifies priority areas for mitigation and adaptation. It also sets objectives for transitioning to a low-carbon climate-resilient economy, including bolstering the resilience of water resources and agriculture while mainstreaming climate change into local and regional development planning. The updated NDC presents the following key strategic objectives and approaches to address climate change impacts in the agricultural sector: (1) integrating climate resilience into policy and institutional reforms; (2) improving irrigation system efficiency; (3) supporting hydroponic and other water-tolerant agricultural productivity systems; (4) enhancing the productivity of rangeland management; and (5) boosting the sustainable productivity of food chains. Greater efforts are needed to mobilize opportunities for climate financing from both public and private sources. Jordan has received more than US$100 million since 2015 for climate-change related programming from the World Bank, the Global Environment Facility GEF-6, the Clean Technology Fund, the Green Climate Fund, and the Adaptation Fund.[13]

Jordan's national climate policies demonstrate good alignment with these international commitments. The National Climate Change Policy (2013–2020, slated to extend to 2030) is a key piece of legislation that informs various subsequent strategies and plans for a climate-resilient, low-carbon Jordan; the Third National Communication on Climate Change (2014) builds on the National Climate Change Policy with specific objectives, proposed actions, and projected impacts.[14] The Green Growth National Action Plans support the NDC Action Plan and Sustainable Development Goals.[15] Additionally, in 2016 the Jordan Ministry of Agriculture launched its third National Strategy for Agricultural Development for 2016 to 2025 as part of general national development efforts under Jordan Vision 2025. The strategy was recently updated for 2020–2025. The National Water Strategy 2016–2025 makes lowering the percentage of water that is lost or unaccounted for in the system a high priority. Achievement of this goal would maintain Jordan's continued resiliency in the face of extreme water scarcity.[16] Other relevant policies include the Special Programme for Food Security, the Forest Strategy, the National Strategy and Action Plan to Combat Desertification, Comprehensive Food and Nutrition, Drought Mitigation, Poverty Alleviation, and the National Agenda.[17] Nevertheless, there is currently no comprehensive policy to protect natural resources in Jordan.[18]

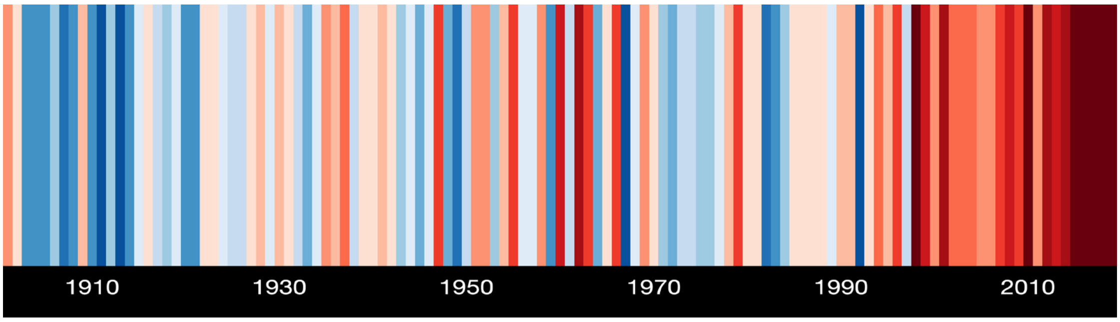
Jordan's agricultural sector is also facing growing challenges as population pressures increase, including production area, food security and trade, natural resources, and the enabling environment.[19] Extreme annual variations in rainfall have made the crop production area extraordinarily volatile over the past 40 years. Jordan depends heavily on imports for its staple foods, and import value exceeds exports threefold.[20] The export of vegetables and animals declined dramatically during the Syrian and Iraqi crises, and later rebounded as Jordan reoriented to fill the market niches left open by these two countries. Nevertheless, various national and regional factors drive continued expansion of the export-to-import gap ratio.[21] Jordan's residents currently have access to a mere 61 liters of water per capita per day on average. In addition to being one of the most water-scarce countries on the globe, Jordan is experiencing accelerating land degradation and desertification because of a loss of vegetative cover. Solutions to these issues are undermined by a dearth of funding and weak institutional coordination among ministries and between the public and private sectors.[22]

Jordan's national policy does not generally favor agricultural-sector growth. Agricultural investment in the country overall is about half the regional average.[23] Irrigation water and pumping are incentivized, and the import tariff scheme encourages domestic production of crops that require significant water resources.[24] For example, barley imports have been subsidized for decades, discouraging domestic production and inflating the livestock sector beyond the sustainable carrying capacity of rangelands.[25] Most land is public, and legislation has led to significant fragmentation of privately owned land.[26] The Jordanian regulatory environment is particularly distortionary in terms of the ease of doing business. The Syrian refugee crises and the COVID-19 pandemic have exacerbated this situation.[27]

Historical data and future model projections indicate clear climate change impacts in Jordan. Historical climate trends since the 1960s show that annual maximum temperatures have climbed between 0.3 °C and 1.8 °C and minimum temperatures have risen in the range of 0.4 °C to 2.8 °C across the country (Figure ES.1). Annual precipitation has also declined by about 5–20 percent at a rate of 6–27 mm per decade.[28] Future climate modelling indicates the following additional developments:

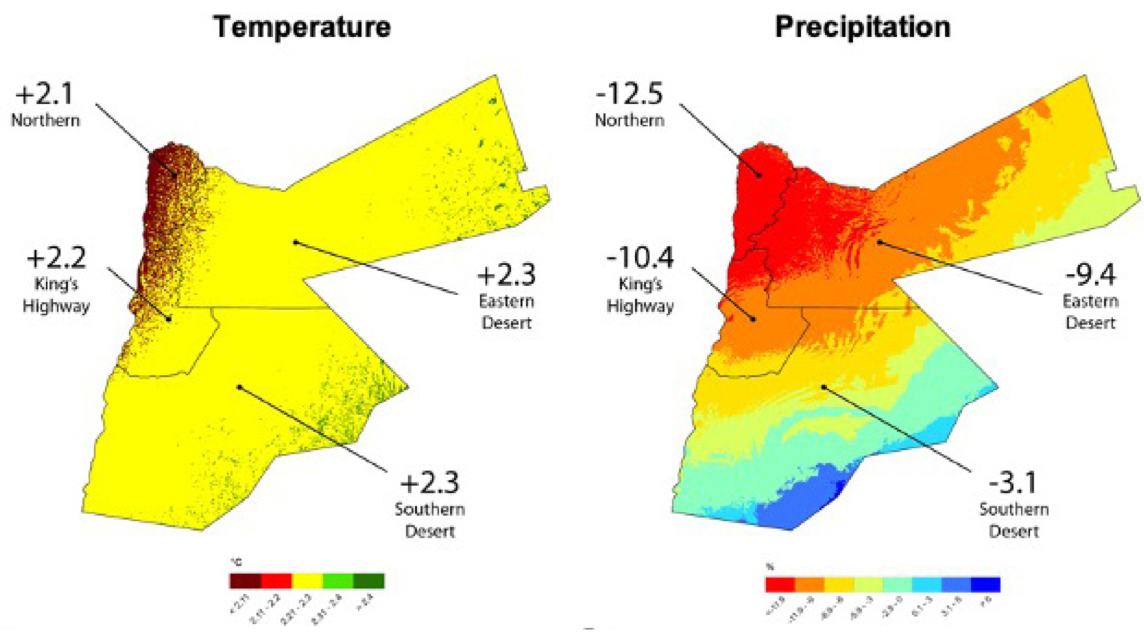
(1) further decreases in total precipitation by 6 percent, 12 percent, and 19 percent by 2030, 2050, and 2070, respectively under Representative Concentration Pathway (RCP) 8.5 (Figure ES.2); (2) increasingly unpredictable and heterogeneous precipitation across the landscape; (3) an increase in average temperatures of up to 4 °C; (4) heightened rates of drought occurrence, length, and severity; and (5) more frequent extreme events, such as cyclones.[29] The combination of diminishing average seasonal rainfall with greater rainstorm intensity implies fewer and heavier rainstorms. Less precipitation, higher temperatures, and more extreme drought conditions in tandem will markedly augment evapotranspiration and, consequently, plant water demands.

Figure ES.1 Annual mean temperature in Jordan[30]



Note: Dark blue represents the coolest relative temperatures, and dark red indicates the highest relative temperatures.

Figure ES.2 Projected changes in annual mean temperature and total annual precipitation in Jordan



Note: These changes by 2030 are projected under the high-emission Representative Concentration Pathway 8.5.

An evaluation of the occurrence and severity of physical climate hazards for the three AEZs of Jordan indicate that soil moisture stress, long dry spells, and the frequency and duration of heat stress are the most pressing agricultural issues. The irrigated AEZ will experience more hot days and heat waves. Moisture and heat stress will increase in the rain-fed AEZ, and the extent and intensity of water stress will remain severe throughout the entire agropastoral AEZ.

Such generalized warming and drought stress can severely hinder agricultural production. Temperatures, especially during spring, are already supra-optimal for wheat and potato growth on many days. Changes in the physical climate imply likely yield reductions, which are particularly worrisome for staple crops such as wheat and barley in rain-fed areas. Notably, future climate projections indicate that potatoes, a staple crop in Jordan, will be acutely affected by the rising number of hot days in the growing season as well as by the increasing hot spells. Date palm cultivation is not expected to experience negative impacts from elevated temperatures.

Given these threats, the authors modeled the change in suitability of important crops in Jordan over the next 10 years. The analysis indicates that rain-fed agriculture and rangeland production will experience the greatest losses under climate change. For the irrigated AEZ tomatoes, potatoes, and date palms were analyzed; for the rain-fed AEZ, potatoes, wheat, barley, and olives; and for the agropastoral AEZ, barley was examined as a primary indicator of the availability of animal feed. Results suggest that by the 2030s, the irrigated AEZ will become less suitable for potatoes and more so for tomatoes. In the rain-fed AEZ, wheat will remain marginal, and potatoes will experience even greater reductions in suitability than in the irrigated AEZ. The agropastoral AEZ will continue to be either marginally or moderately suitable for barley. Notably, this modeling assumes steady groundwater and irrigation water supplies. In reality, however, water resources for agriculture are expected to decrease 25–20 percent in the coming years; this decline will particularly threaten the irrigated AEZ, where the bulk of Jordan's agricultural gross domestic product is generated.[31]

Climate change impacts will continue worsening beyond 2030. For example, the barley yield is expected to decrease 50–25 percent by 2050 due to higher temperatures and less rainfall, which would significantly shrink the availability of livestock feed. Declining rainfall and rising temperatures will also continue to diminish water and pastureland for livestock.[32] Losses may be further exacerbated by water resource reductions not captured in this model. Such marked reductions in crop and livestock productivity could further heighten Jordan's reliance on imports and weaken food security. A more comprehensive assessment of crop productivity using process-based models would support a more complete understanding of potential future scenarios.

Except for potatoes, all the selected Jordanian crops experience a relative increase in yields under climate change according to International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) projections (Table ES.1). That is, yields improve relative to other local crops and to the same crop on the global marketplace. The area under cultivation for these key crops is projected to remain relatively stable. Production is expected to grow for barley, fruits, vegetables, and wheat. Negligible increases are likely for dairy and poultry, and potatoes and lamb will see relative decreases in production. Livestock numbers will also be minimally affected.

Table ES.1 The impact on yields of two climate change scenarios in 2050 based on the IMPACT model

Commodity	NoCC (%)	CC RCP 4.5 2020-2050 (%)	RCP4.5 impact (percentage points)	CC RCP 8.5 2020-2050 (%)	RCP8.5 impact (percentage points)
Barley	62.1	78.6	16.5	78.8	16.7
Potato	25.8	19.7	-6.1	13.7	-12.1
Tropical fruit	50.3	63.8	13.5	63.0	12.7
Vegetables	49.5	62.1	12.7	61.4	11.9
Wheat	77.2	96.4	19.2	97.1	19.9

Note: NoCC = no climate change; CC = climate change; the impacts of RCP 4.5 and RCP 8.5 are presented relative to the NoCC scenario.

Expected food availability will experience a small negative impact from climate change of less than 1 percentage point for most crop and livestock commodities. Climate change will also result in slight declines in the total demand for the selected crops and livestock, except for that of barley and wheat. Potatoes show a larger decrease of 6 to 8 percentage points. In a middle-income country such as Jordan, such a slight shrinkage in the food supply will not adversely affect the overall access to food given existing surpluses and the capacity for importation. However, it will cause an increase in food prices for all crops except barley. Prices increases will be most pronounced for potatoes, vegetables, and wheat, consistent with corresponding reductions in the projected food availability of each crop.

From 2020 to 2050, a subset of the priority commodities shows heightened differentiation in trade under climate change. IMPACT projects the increasing export of vegetables, consistent with recent trade studies reflecting an average of 11 percent growth per year and over 80 percent growth of the total exported commodities in some years.[34] There is also a tendency toward increased importation of both barley and wheat, illustrating that demand will outstrip domestic supply even though both crops fare well under climate change. Exports of vegetables are projected to expand, and the trends for poultry are unclear.

Expert consultations supported the research findings. Experts indicated that changes in temperature, rainfall, and moisture have been observed in Jordanian agriculture. Water availability and quality were also general concerns. Price fluctuations and labor availability challenges were identified in the irrigated and rain-fed AEZs. Conflict in other countries is a primary risk in the irrigated AEZ, while resource scarcity conflicts and refugee migration hold higher importance in the rain-fed and agropastoral AEZ. Animal-related issues were also noted in the agropastoral AEZ. In terms of policy considerations, experts generally prioritized food security, price volatility, value chain development, and youth employment. Water allocation and trade were important topics in the irrigated AEZ, and poverty alleviation is critical in the rain-fed and agropastoral AEZ. Opportunities for women were mentioned infrequently by experts, least of all for the irrigated AEZ.

This extensive process of research, analysis, and expert consultations resulted in six CSA investment packages designed to address adaptation, mitigation, and productivity across the three Jordanian AEZs (Table ES.2). This Action Plan assesses and prioritizes these investment packages based on their potential contribution to CSA, taking a broad perspective across AEZs and commodities. In addition to their climate-smart potential, the proposed packages promise to add important economic value and strong contributions to ecosystem services, food and feed security, and livelihood development. Importantly, they offer gains in water productivity far greater than the anticipated 25–20 percent reduction in water resource availability. Each of the investment packages also creates and amplifies employment opportunities throughout the relevant value chain. Selected packages must be further developed with potential partners and funding organizations as a follow-up to the groundwork in this report. The packages are as follows:

- High-value date palm development, processing, and marketing using modern irrigation and improved cultural practices in irrigated areas.
- Expansion and upgrades of protected vegetable production with advanced technology, processing, and marketing options in irrigated areas.
- Upgrades of olive production and processing through low-cost modern technologies for collection, cold pressing and pickling, and alternative waste use in rain-fed areas.
- Enhanced barley production through rainwater harvesting and improved management in rain-fed areas and the Badia.

- Elevated small ruminant production through intensive farming systems and dairy chain development in agropastoral areas.
- Badia restoration with micro-catchment water harvesting and improved grazing management in agropastoral areas.

Table ES.2 Investment rationale for climate-smart agriculture implementation

CSA investment	On-farm value	Jordanian importance[38]	Projected CC-response	Scenario without investment	Main investment objectiveW
Date palm	Economic promise and nutrition	Export and local consumption. An estimated 25,000 metric tons produced annually on approximately 4,000 hectares.	Increased suitability. Date palms thrive in higher temperatures and tolerate water stress.	Stable production.	Growth
Vegetables	Economic promise, nutrition, and food security	Export and local consumption. An estimated 1.7 million metric tons produced annually on more than 37,000 hectares. Tomatoes alone contribute 280,000 metric tons to export markets valued at US$223 million.	Increased suitability for tomatoes, decreased suitability for potatoes. The growing season of fruiting vegetables extends with greater numbers of warm days, although high temperatures stress plants. Hot spells dramatically reduce tuber formation, weight, and yields.	Decreased open-field production, increased post-harvest losses.	Adaptation and growth
Olives	Economic promise and nutrition	A major production system in rain-fed areas with potential to increase processed quality for export. An estimated 145,000 metric tons produced on over 56,000 hectares, of which more than 1,000 metric tons are exported.	Moderate suitability in the rain-fed zone. Olives tolerate heat and water stress.	Increased post-harvest losses, exacerbated environmental degradation.	Adaptation and growth
Barley	Economic promise and food and feed security	Essential livestock feed during periods of fodder shortage. Domestic production contributes nearly 50,000 metric tons, while 960,000 metric tons are imported annually.	Poor response to climate change. Lengthier and commoner heat-stress days concentrated towards spring reduce grain filling and maturity. Warming and drought stress cause 25–50 percent yield reductions by 2050.	Decreased yield by 25–50 percent by 2050, increased imports.	Adaptation and growth
Small ruminants	Economic promise and food security	Reliably high demand; a key sector for women. Annual exports of nearly 500,000 sheep and goats with a value of nearly US$170 million.	Good adaptation to climate change. Higher summer temperatures may nevertheless hinder livestock productivity and affect human labor. Increased heat and moisture stress reduce grazing and fodder sources, detracting from livestock health.	Increased land degradation, decreased feed security.	Adaptation and growth

Badia restoration	Ecosystem services, including feed security for livestock	Mitigation and prevention of desertification. Badia restoration supports barley and small ruminant investments along with several national policies.	Diminished livestock and crop production. Hotter summers and drier winters reduce the soil's ability to support vegetative growth.	Continuing loss of arable land, decreased productivity.	Adaptation and mitigation

A cost-benefit analysis shows a positive net present value for all the CSA packages at both the farm and aggregate scales, indicating a generally good return on investment. The Adoption and Diffusion Outcome Prediction Tool (ADOPT) forecasts high maximum adoption rates for all CSA investments—between 93 percent and 98 percent—within a -20year period. Diffusion rates differ, presumably due to the diverse characteristics of the target beneficiaries of each package. The CSA investment packages have various levels of sensitivity to discount rates, climate change, and output price variability. The sensitivity varies along with the scale of the analysis particularly for climate change and output price variability (Table ES.3). Overall, taking a value chain approach substantially reduces the payback period for most CSA investments while also increasing financing opportunities through private-sector involvement.

Table ES.3 **The economic profitability and payback period of investment packages at the on-farm and aggregated levels based on ADOPT**

CSA package*	Area	Farmers	Investments**			Payback period (years)	
	Ha	#	On-farm (mil JD)	Large scale (mil JD)	Aggregated (mil JD)	On-farm	Aggregated
Date palms	800	500	6.34	1.30	7.64	12	3.1
Vegetables (a)	250	500	106.86	0.37	107.23	9.8	1.6
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Olive	1,000	1000	16.82	2.12	18.94	3	2.6
Barley	1,000	1000	0.47	0.60	1.07	4	5.5
Small ruminants	n/a	900	23.26	0.54	23.80	3	1.6
Badia restoration	5000	250	0.1	1.39	1.49	3	6.9

Notes: *Vegetables are produced as follows: (a) open field to greenhouse, (b) low tunnel to greenhouse, and (c) open field to hydroponics; **1 JD = US$1.41. n/a = not applicable

All the CSA investment packages proposed by this Action Plan have a negative net carbon balance, with a total GHG emission reduction potential of 823,665 tons of carbon dioxide equivalent. Badia restoration contributes the most to GHG emission reduction at 64 percent, followed by the small ruminant and date palm value chains at 13–12 percent each, and then the vegetable value chain at 4.6 percent; olives and barley contribute the least at 3.4 percent each. The total estimated GHG reduction potential represents a value of more than US25$ million and must be evaluated when considering investment in the CSA packages.

Overarching barriers to investment in Jordan include political and security issues, resource scarcity and conflicts, climate risks, financial constraints, and market failures. Most of these challenges or constraints are embedded in the policy environment, and as a result can be addressed or controlled as part of CSA program design and implementation. For example, there is a substantial opportunity to further align national policies with the country's NDC Action Plan. This CSA Action Plan constitutes an excellent opportunity to begin such policy alignment while supporting the Sustainable Development

Goals. Boosting water productivity through these CSA investments along with appropriate policies to restrict the rebound effect would relieve agricultural pressure on groundwater. Improved information flow, capacity building, financial services, value chain integration, and strong local community engagement will enable the success of all CSA programming in Jordan. Blended finance may be an important option for mobilizing public and private finance to scale up effective, high-potential CSA investments.[36]

A vital aspect of this CSA Action Plan is monitoring and evaluation (M&E). M&E establishes assumptions about how change will occur, provides evidence and information to implement results-based management, and allows managers to obtain up-to-date information about whether projects are on track in terms of their work plans, budgets, and objectives.[37] The overall M&E structure consists of the theory of change, impact pathways, a results framework, and relevant indicators. The theory of change serves to simplify and visualize the main objectives of a project and indicates how these changes will occur. Building on the theory of change, the impact pathways describe the different ways such improvements can be realized. This Action Plan aims to address several key climate-related issues ranging from food security to livelihood improvements in the agricultural sector. The theory of change and impact pathways designed for this Action Plan revolve around a stronger, more climate-resilient and sustainable agricultural sector across the various commodities and regions of Jordan.

To achieve productive, sustainable, and climate-resilient farming systems and value chains, four pathways have been identified: higher production and incomes, increased adaptive capacity, reduced climate exposure and sensitivity, and improved marketability of commodities. The success of the investments will be measured through the various activities that must be implemented to establish the necessary outputs as shown in the theory of change. Portfolio-level investment results can be monitored against a limited set of primary indicators, including the number of beneficiaries and changes in productivity, adaptive capacity, resilience, and GHG emissions. Likewise, at the project level, primary indicators can be selected for each individual investment during the development phase. The results framework, with indicators at the program level and for each investment component, can be used to evaluate project performance.

Several additional steps are still needed to build an M&E system and ensure the sustainability of current and future projects that may be undertaken beyond the scope of the CSA Action Plan itself. The CGIAR research program on Climate Change, Agriculture, and Food Security has outlined 11 steps, categorized under indicators, M&E system, capacity development, and finance, that must be in place.[38] These M&E activities must be formalized and institutionalized in a programmatic M&E plan that describes the specific actions and responsibilities required to conduct a comprehensive M&E assessment. An M&E plan is hallmarked by its cross-cutting nature, bringing together multiple institutions, government agencies, implementing partners, and stakeholders to attain broad-reaching benefits for the agricultural sector and the environment and to reach national development targets. Moreover, when aligned with the Jordanian government's goals and ministry objectives, investments in M&E will result in institutional capacity building and generate comprehensive data sets that can be used for policy- and decision-making. Projects with a strong M&E program can reveal essential information for future interventions.

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الملخص التنفيذي

الرسائل الرئيسية

1. يواجه الأردن تغيرات مناخية قاسية تؤثر سلباً على الإنتاج الزراعي، وستضع الموارد المائية للبلاد تحت مزيد من الضغط.
2. بفعل التغير المناخي، ستشهد ملائمة العديد من المحاصيل تدهوراً (البطاطا) أو ستصبح هامشيةً (الشعير والقمح)؛ وستبقى ملائمة الزيتون مستقرةً وستزداد بالنسبة للبندوره وأشجار النخيل. رغم ذلك، وعلى افتراض حدوث تطور تكنولوجي وتوفر المياه لأغراض الري، قد تشهد محاصيل الفواكه الاستوائية والخضراوات والشعير والقمح تحسناً طفيفاً في المستقبل القريب بالرغم من التغير المناخي.
3. تساهم الزراعة الذكية مناخياً في التكيف مع التغير المناخي والتخفيف من آثاره، وعلى تشجيع الإنتاج والنمو. وقد تم التركيز على التوسع في زراعة أشجار النخيل والخضروات المحمية كونها تمثّل فرصةً للزراعة الذكية مناخياً في المناطق المروية؛ وإنتاج ومعالجة الزيتون وإنتاج الشعير في المناطق البعلية؛ وسلاسل القيمة للحيوانات المجترة الصغيرة وإعادة تأهيل البادية في المناطق الزراعية الرعوية.
4. تُظهر الحزم الاستثمارية ذات الأولوية في خطة عمل الزراعة الذكية مناخياً إمكانات كبيرة لزيادة إنتاجية المياه. كما أنها تعد هامةً لاستحداث الوظائف عبر سلاسل القيمة المرتفعة (الصادرات)، بينما توفر، بشكل مباشر وغير مباشر، الدعم للسكان الاكثر فقراً.
5. تُظهر تحليلات التكلفة والمنفعة صافي قيمة حالية ومعدل عائد داخلي إيجابي لكافة حزم الزراعة الذكية مناخياً سواء على مستوى المَزارع (المدخلات والإنتاج) او على المستوى التجميعي (بما في ذلك التخزين والمعالجة والتسويق)، مما يشير إلى عائد جيد بشكل عام على الاستثمار.
6. ستحقق كافة الحزم الاستثمارية للزراعة الذكية مناخياً المقترحة بموجب خطة عمل الزراعة الذكية مناخياً رصيدا كربونياً سلبياً، مع خفض إجمالي لانبعاثات الغازات الدفيئة بمقدار 823,665 طن لمكافئ ثاني أكسيد الكربون. وتتجاوز القيمة الإجمالية التقديرية لخفض الغازات الدفيئة 25 مليون دولار أمريكي.
7. تعتبر معالجة التحديات الرئيسية المتعلقة بالتمويل، والضغوطات المالية، وقلة الاستثمارات، والافتقار إلى نهج منسَّق لرصد الاتجاهات الرئيسية في النظام الغذائي ككل أمراً بالغ الأهمية للتحول للزراعة الذكية مناخياً؛ حيث يتضمن ذلك الابتكارات الذكية مناخياً (على سبيل المثال، الزراعة المائية)، والحوافز الذكية، وتعديل السياسات التي تعاني من القصور.

يواجه الأردن تغيرات مناخية قاسية تؤثر سلباً على الإنتاج الزراعي، ومن المتوقع أن تشتد وطأة هذه التحديات في السنوات القادمة. وسيشكل التغير المناخي ضغطاً كبيراً على الأمن الغذائي وسبل كسب الرزق بالنسبة للفقراء وغير المحصنين في الأردن. كما قد يثير مشكلات أمام إحداث المزيد من التطور في القطاع الزراعي الأردني، والذي أصبح يعتمد بشكل متزايد على التصدير. وبغرض المساعدة في التصدي لظاهرة التغير المناخي، وبالتعاون مع التحالف الدولي للتنوع البيولوجي والمركز الدولي للزراعة الاستوائية، والمركز الدولي للبحوث الزراعية في المناطق الجافة، قدّم البنك الدولي المساعدة إلى الحكومة الأردنية لأعداد خطة العمل هذه للزراعة الذكية مناخياً. تعمل الزراعة الذكية مناخياً على زيادة الإنتاجية بطريقة مستدامة بيئياً واجتماعياً، وتعزيز تكيّف وصمود المزارعين أمام التغير المناخي، ودعم الجهود التخفيفية[1]. وتتبع خطة العمل الأردنية لتحديد استثمارات الزراعة الذكية مناخياً الإطار التخطيطي للاستثمارات الزراعية الذكية مناخياً، وتبنى على مبادرات وعمل الجهات الحكومية والمؤسسات المحلية[2]. ولا يوجد حل سحري يتعلق بالزراعة الذكية مناخياً؛ حيث ترتبط إمكانات الذكاء المناخي كثيراً بالسياق، ويتطلب تصميم برنامج ذكي مناخياً وجود فهم للظروف والأولويات المحلية.

يعتبر الأردن من الدول الجافة بشكل استثنائي، وتعد الموارد المائية العامل الذي يحدد نظم الإنتاج الزراعي فيها. وتعد المنطقة الزراعية البيئية المروية في الأردن الأكثر إنتاجيةً وتتواجد بشكل رئيسي على غور الأردن، والممتد من جنوب البحر الميت وصولاً إلى الحدود الشمالية لكنها تضم أيضاً أجزاءً صغيرةً من المرتفعات والمناطق الزراعية الرعوية. ولا تحصل سوى نحو 8% من الأراضي في الأردن على معدل تساقط مطري يزيد عن 200 ملم سنوياً. ومن بين هذه النسبة، تشكل المناطق غير المروية المنطقة الزراعية البيئية البعلية[3]. وتشكل المنطقة الزراعية البيئية الزراعية الرعوية نحو 90% من الأراضي الأردنية وتدعم بشكل رئيسي الإنتاج الحيواني[4]. ويشير الشح الشديد في الموارد المائية في الأردن إلى أن البلاد قامت باستخدام المياه بحكمه، حيث قامت باستهلاك جزء يسيرللفرد مقارنه بدول الجوار. وعلى النقيض من ذلك فان استخدام الأسمدة الاصطناعية غير مقنن منذ القدم في الأردن.

أضحت الزراعة في الأردن منتجةً بشكل متزايد. واعتباراً من العام 2020، بلغت مساهمة الزراعة في الناتج المحلي الإجمالي الوطني ما يقرب من 5.9%[5]. . كما تمثل الزراعة نحو 15.1% من إجمالي الصادرات (1.1 مليار دولار أمريكي) و19% من مجموع الواردات (4.2 مليار دولار أمريكي)، مما يجعل الأردن مستورداً خالصاً[6]. ويسيطرقطاع الثروة الحيوانية على المنطقة الزراعية-الرعوية الشاسعة، وتبلغ قيمته 1.47 مليار دولار أمريكي. ويتمتع الأردن بالاكتفاء الذاتي من الزيتون، وزيت الزيتون، والبندوره، ولحم الضأن، والحليب الطازج، والبيض. فضلاً عن ذلك، يقوم الأردن بإنتاج حصة كبيرة من الدواجن وبعض الخضروات المستهلكة محلياً. وعلى النقيض من ذلك، تعتمد الوجبات المحلية بشكل كبير على المستوردات من الحبوب والبقوليات والفواكه وبعض الخضراوات. ويقوم الأردن بإنتاج 3-4% فقط من القمح والشعير الذي يستهلكه. ويتم تخصيص جميع كميات الشعير تقريباً لإطعام الحيوانات. وقام القطاع الزراعي في الأردن بإنتاج نحو 1.15 مليون طن من مكافئ ثاني أكسيد الكربون في العام 2017. وتتضمن المصادر الرئيسية لانبعاثات الغازات الدفيئة الزراعية التخمر المعوي، والسماد الطبيعي المتبقي في المراعي، وانبعاثات أكسيد النيتروز من التربة الزراعية، والانبعاثات الثانوية والثالثة، بما في ذلك من أجزاء سلاسل القيمة، والمعالجة، وإنتاج الطاقة الكهربائية، والصناعة، والنقل[7]. ونتج عن قطاع الحراج 0.87 مليون طن من مكافئ ثاني أكسيد الكربون كنتيجة لفقدان الكربون العضوي من التربة في المراعي[8]. وترتبط هذه الظاهرة بصورة وثيقة بممارسات الثروة الحيوانية غير المستدامة، بما في ذلك الرعي الجائر وما يعقب ذلك من تدهور في نوعية التربة. ويمثل ذلك مجالاً هاماً لإمكانية التخفيف منه في النظم الزراعية الرعوية في الأردن.

تعتبر وزارة الزراعة الجهة الرئيسية المسؤولة عن تطوير القطاع الزراعي. ويتم إجراء البحوث بشكل رئيسي من قبل المركز الوطني للبحوث الزراعية التابع للوزارة، بينما أصبحت خدمات الإرشاد الزراعي حالياً تقدم من خلال دائرة تابعة للوزارة[9]. وتعمل المراكز الإقليمية بالإضافة إلى 13 محطة بحثية تابعة للمركز عبر 10 دوائر[10]. وتعد إدارة المياه من المجالات الرئيسية التي يتم التركيز عليها في بحوث المركز الوطني للبحوث الزراعية. وتمثل سلطة وادي الأردن وسلطة المياه نماذج قيمة حول كيفية التوسع في خدمات الإرشاد وتحسينها في الأردن[11]. يضم القطاع الخاص في الأردن المصدّرين وتجار المدخلات، ومجموعات المزارعين المنضوين تحت جمعيات متطورة[12]. وعلى الرغم من هذه الدرجة من التنظيم، لا يزال نشاط القطاع الخاص في الأردن أقل بكثير من طاقاته الكامنة. وتتمحور معظم الأنشطة غير الربحية في الأردن حاليا حول الأزمة الإنسانية السورية.

قامت خطة تحفيز النمو الاقتصادي الأردني بوضع العديد من الأهداف بما يتوافق مع أهداف التنمية المستدامة والتي تملك آثار محتملة كبيرة على السبل الزراعية لكسب الرزق في الريف. تتضمن هذه الأهداف إيجاد التوازن بين الإنتاج والاستهلاك (هدف التنمية المستدامة 12)، ومضاعفة النمو الاقتصادي وفرص العمل (هدف التنمية المستدامة 8)، وتشجيع الصناعة والابتكار (هدف التنمية المستدامة 9)، وتحسين أمن وتوفر الطاقة (هدف التنمية المستدامة 7)، والقضاء على الجوع (هدف التنمية المستدامة 2) والفقر (هدف التنمية المستدامة 1). ومن المتوقع أن يحقق الأردن هدف التنمية المستدامة 2 بحلول العام 2030. ويعتبر الأردن طرفاً في العديد من الاستراتيجيات الإقليمية التي تتوافق مع تلك الأهداف، بما في ذلك البرنامج العربي للأمن الغذائي، والتنمية الزراعية المستدامة في المنطقة العربية، واستراتيجية الأمن الغذائي للدول العربية والإفريقية[13].

كما يعتبر الأردن أحد الدول الأطراف في اتفاق باريس. حيث قام الأردن بتقديم تقريره حول الالتزامات المحددة وطنياً في تشرين الثاني 2016، مقدماً تفصيلات حول عزمه خفض انبعاثات الغازات الدفيئة بمقدار 14%، مع اشتراط الخفض بنسبة 12.5% بالحصول على دعم مالي دولي[14]. وقد انضم الأردن إلى شراكة الالتزامات المحددة وطنياً في العام 2018، وقام باعتماد خطة العمل الوطنية في العام 2019، بقيادة وزارة البيئة والأمانة العامة لوزارة التخطيط والتعاون الدولي. تحدد خطة العمل المجالات الهامة للتخفيف والتكيّف. كما أنها تضع أهدافاً للتحول إلى اقتصاد مرن مناخياً وقليل الكربون، بما في ذلك تعزيز صمود الموارد المائية والزراعة في وجه التغير المناخي وتعميم التغير المناخي في الخطط التنموية المحلية والإقليمية. وينبغي بذل جهود كبيرة لحشد الفرص لأغراض التمويل المناخي من القطاعين العام والخاص. ومع ذلك، حصل الأردن على أكثر من 100 مليون دولار أمريكي منذ العام 2015 بموجب البرامج المتعلقة بالتغير المناخي من قبل البنك الدولي، ومرفق البيئة العالمية، وصندوق التكنولوجيا النظيفة، وصندوق المناخ الأخضر، وصندوق التكيّف[15].

تُظهر السياسات الوطنية للمناخ في الأردن بشكل عام توافقاً جيداً مع هذه الالتزامات الدولية. حيث تشكل السياسة الوطنية لتغير المناخ (2013-2020، والتي من المتوقع تمديدها لغاية العام 2030)، تشريعاً رئيسياً يعمل على توفير المعلومات للعديد من الاستراتيجيات والسياسات اللاحقة وصولاً إلى أردن مرن مناخياً وقليل الكربون؛ ويرتكز تقرير البلاغات الوطنية الثالث حول التغير المناخي في الأردن (2014) على السياسة الوطنية لتغير المناخ مع أهداف محددة، وإجراءات مقترحة، وآثار متوقعة[16]. وتدعم خطط العمل الوطنية للنمو الأخضر خطة عمل الالتزامات المحددة وطنياً وأهداف التنمية المستدامة[17]. إضافةً لذلك، وفي العام 2016، قامت وزارة الزراعة بإطلاق الاستراتيجية الوطنية الثالثة للتنمية الزراعية للأعوام 2016-2025 كجزء من الجهود التنموية الوطنية بموجب رؤية 2025. وقد تم مؤخراً تحديث الاستراتيجية للأعوام 2020-2025. وتضع الاستراتيجية الوطنية للمياه للأعوام 2016-2025 من خفض نسبة المياه المهدورة أو غير المحتسبة في النظام أولويةً كبرى. وسيعمل تحقيق هذا الهدف بشكل قوي على مواصلة الأردن الصمود في وجه الشح الشديد في المياه[18]. وتتضمن السياسات الأخرى ذات الصلة البرنامج الخاص للأمن الغذائي، والاستراتيجية الحرجية، والاستراتيجية الوطنية وخطة العمل لمكافحة التصحر، والاستراتيجية الشاملة للغذاء والتغذية، والإجراءات التخفيفية للجفاف، والحد من الفقر، والأجندة الوطنية[19]. رغم ذلك، لا توجد في الوقت الحالي سياسة شاملة لحماية المصادر الطبيعية في الأردن[20].

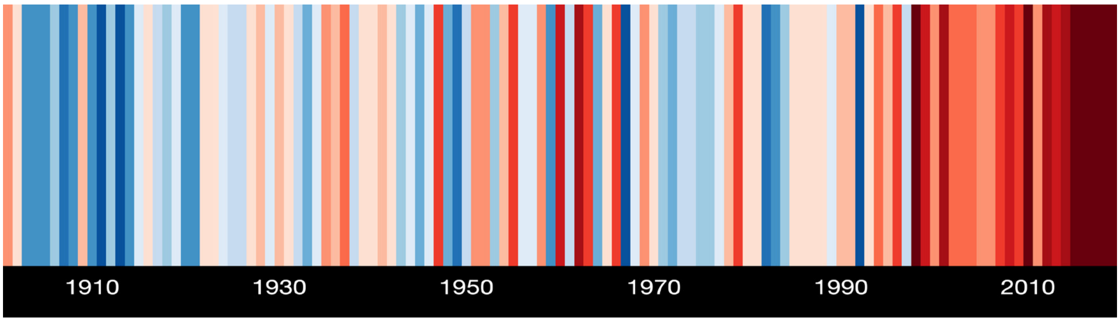
كما يواجه القطاع الزراعي في الأردن تحديات متنامية مع ازدياد الضغوطات السكانية، بما في ذلك (1) في مجال الإنتاج، (2) الاكتفاء الذاتي والتجارة، (3) المصادر الطبيعية، (4) البيئة التمكينية[21]. فقد جعلت التباينات السنوية الحادة في تساقط الأمطار منطقة إنتاج المحاصيل في الأردن متقلبةً بشكل كبير خلال الأعوام الأربعين الماضية. ويعتمد الأردن بصورة كبيرة على الواردات فيما يتعلق بالمواد الغذائية الأساسية، كما تتجاوز قيمة الواردات قيمة الصادرات بثلاثة أضعاف[22]. وعلى الرغم من الجهود الحكومية الهادفة إلى بناء وإدامة مخزون استراتيجي ومرافق تخزين عامة، من المتوقع أن يواصل الأردن إلى حد كبير الاعتماد على الواردات من القمح والشعير، وهما محصولي الحبوب الرئيسيين في البلاد. وقد انخفضت الصادرات من الخضراوات والحيوانات بشكل ملحوظ مع استمرار الأزمة في سوريا والعراق، ثم عاودت تلك الصادرات الارتفاع مع قيام الأردن بإعادة توجيه صادراته لسد الفجوات السوقية المتاحة في الدولتين. رغم ذلك، تقود العديد من العوامل الوطنية والإقليمية الاتساع المتواصل في الفجوة في نسبة الصادرات إلى الواردات[23]. ويستطيع القاطنون في الأردن حالياً الحصول على 61 لتر/للفرد/ من المياه يومياً كمتوسط فقط. وبالإضافة إلى كونه أحد أفقر دول العالم مائياً، يواجه الأردن تسارعاً في تدهور نوعية التربة والتصحر بسبب قلة الغطاء النباتي وعوامل اخرى. وتواجه الحلول لهذه المشكلات تحديات تتمثل في شح التمويل وضعف التنسيق المؤسسي بين الوزارات وبين القطاعين العام والخاص[24].

لا تعتبر السياسة الوطنية في الأردن بشكل عام داعمةً لنمو القطاع الزراعي. حيث تشكل الاستثمارات الزراعية في البلاد نحو نصف المتوسط الإقليمي[25]. حيث يتم تقديم حوافز لمياه الري والمضخات، بينما يشجع نظام تعرفة الواردات الإنتاج المحلي للمحاصيل التي تتطلب قدراً كبيراً من الموارد المائية[26]. فعلى سبيل المثال، تم دعم الواردات من الشعير لعقود، مما أدى إلى عدم تشجيع الإنتاج المحلي وتضخم القطاع الحيواني بما يتجاوز القدرة المستدامة للمراعي[27]. وتعد معظم الأراضي حكوميةً، وأدى التشريع الخاص بتقسيم الأراضي إلى تشتت ملحوظ في الأراضي المملوكة من قبل أفراد وشركات[28]. وبالرغم من انخفاض الأموال الأميرية وبالتالي تنامي الأثر المقبول لاستثمارات القطاع الخاص، يتم بشكل منهجي التقليل من الدور المحتمل للقطاع الخاص والمجتمعات في التنمية الريفية وإدارة الموارد، ولا يوجد تعاون يذكر بين مؤسسات القطاعين العام والخاص. وتعاني البيئة التنظيمية في الأردن على وجه التحديد من القصور من حيث سهولة ممارسة أنشطة الأعمال. وقد فاقمت أزمة اللجوء السوري وجائحة كوفيد19- من هذا الوضع[29].

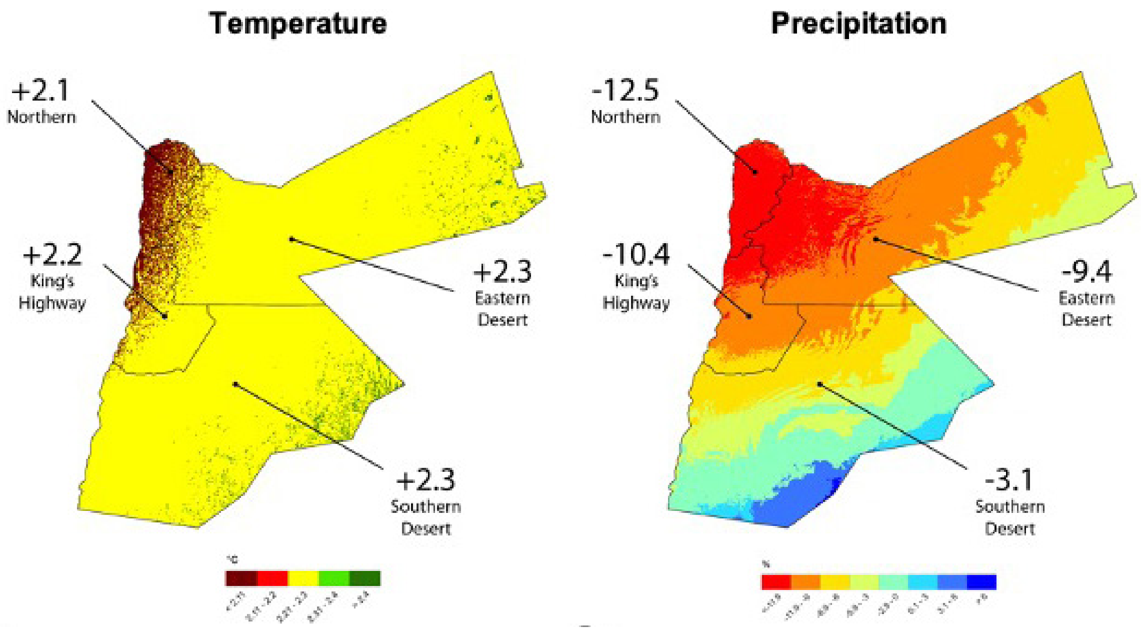
تشير البيانات التاريخية وتوقعات النماذج المستقبلية إلى أنه سيكون للتغير المناخي آثار واضحة في الأردن. حيث تشير الاتجاهات المناخية التاريخية منذ الستينيات إلى أن درجات الحرارة القصوى السنوية قد ازدادت بمقدار 0.3-1.8 درجة مئوية، كما ارتفعت درجات الحرارة الدنيا في نطاق 0.3-1.8 درجة مئوية عبر البلاد (الشكل ES.1). كما حدث انخفاض في المعدل السنوي لتساقط الأمطار بنحو 5-20% عبر الأردن (27-6 ملم لكل عقد من الزمن)[30]. وتشير النماذج المناخية المستقبلية إلى (1) المزيد من الانخفاضات في إجمالي التساقط المطري بمقدار 6%، 11.5%، 19% بحلول الأعوام 2030، 2050، 2070، على التوالي (مسار

التركز التمثيلي 8.5، الشكل ES.2)؛ تساقط مطري غير قابل للتوقع وغير متجانس بشكل متزايد عبر التضاريس؛ (3) زيادة في متوسط درجات الحرارة لغاية 4 درجات مئوية؛ (4) ازدياد معدلات وقوع وطول مدة وشدة الجفاف؛ (5) المزيد من الأحداث الشديدة المتكررة، مثل الأعاصير[31]. ويشير المزيج من انخفاض متوسط تساقط الأمطار الموسمي مع ازدياد شدة العواصف المطرية إلى حدوث عدد أقل من العواصف المطرية لكنها ستكون أكثر شدةً. وسيعمل انخفاض التساقط المطري، وارتفاع درجات الحرارة، والمزيد من ظروف الجفاف القاسية جنباً إلى جنب على زيادة التبخر والنتح بصورة ملحوظة، وبالتالي، زيادة الطلب على المياه لأغراض الزراعة.

الشكل ES.1: الوسط الحسابي السنوي لدرجة الحرارة في الأردن[32]
يمثل اللون الأزرق الداكن درجات الحرارة الأدنى نسبياً، بينما يمثل اللون الأحمر الداكن درجات الحرارة الأعلى نسبياً.



الشكل ES.2: التغيرات المتوقعة في الوسط الحسابي لدرجات الحرارة السنوية وإجمالي التساقط المطري السنوي في الأردن
التغيرات المتوقعة بحلول العام 2030 لمسار التركز التمثيلي 8.5 (انبعاثات عالية)



يوضح تقييم لحدوث وشدة المخاطر المناخية المادية للمناطق الزراعية البيئية الثلاث في الأردن أن الإجهاد الناشئ عن انخفاض رطوبة التربة، وفترات الجفاف الطويلة، وتكرارية ومدة الإجهاد الحراري تعد الأكثر تأثيراً على صعيد الزراعة. وستواجه المنطقة الزراعية البيئية المروية عدداً متزايداً من الأيام الحارة والموجات الساخنة. وسيزداد الضغط الناتج عن الرطوبة والحرارة في المنطقة الزراعية البيئية البعلية، وسيبقى مدى وشدة الضغط الناتج عن المياه كبيراً في كافة أنحاء المنطقة البيئية الزراعية- الرعوية.

يمكن أن يؤثر هذا الارتفاع في درجات الحرارة والجفاف بشدة على الإنتاج الزراعي. وتعتبر درجات الحرارة، وخصوصاً في فصل الربيع، مثاليةً للغاية لنمو القمح والبطاطا في العديد من الأيام. ومن المرجح أن تشير التغيرات في المناخ إلى انخفاضات في المحاصيل،

وهو ما يعد مقلقاً على وجه التحديد بالنسبة للمحاصيل الأساسية، مثل القمح والشعير في المناطق البعلية. وبشكل مثير للاهتمام، تشير التوقعات المناخية المستقبلية إلى أن البطاطا، والتي تعد من المحاصيل الأساسية في الأردن، ستتأثر بشكل حاد بفعل ارتفاع عدد الأيام الحارة في موسم النمو بالإضافة إلى تزايد فترات الحر. وبحسب تحليلنا، لن تتأثر زراعة أشجار النخيل بفعل ارتفاع درجات الحرارة.

بالنظر إلى تلك التهديدات، فقد قمنا بإعداد نموذج للتغير في ملائمة المحاصيل الهامة في الأردن خلال السنوات العشر القادمة. حيث يشير تحليلنا إلى وجود "مستفيدين" و"خاسرين"، مع توقع تلقي الزراعة البعلية وإنتاج المراعي لأقصى الضربات. فبالنسبة للمنطقة الزراعية البيئية المروية، قمنا بإعداد نماذج للبندوره والبطاطا وأشجار النخيل؛ أما بالنسبة للمنطقة الزراعية البيئية البعلية، فقد قمنا بتحليل البطاطا والقمح والشعير والزيتون؛ وبالنسبة للمنطقة البيئية الزراعية الرعوية، قمنا بتحليل الشعير، والذي يعد مؤشراً رئيسياً لتوفر العلف للحيوانات. تشير النتائج إلى أنه وبحلول العام 2030، ستصبح المنطقة الزراعية البيئية المروية أقل ملاءمةً للبطاطا وأكثر ملائمةً للبندوره. وفي المنطقة الزراعية البيئية البعلية، سيبقى القمح هامشياً، وستواجه البطاطا المزيد من الانخفاضات من حيث الملاءمة مقارنةً مع المنطقة الزراعية البيئية المروية. وستبقى المنطقة الزراعية البيئية الزراعية الرعوية هامشيةً أو ملائمةً بشكل متواضع للشعير. وتفترض هذه النماذج توفر ثابت للمياه الجوفية وإمدادات المياه للري؛ وفي الواقع، من المتوقع انخفاض الموارد المائية للزراعة بمقدار 20-25% في السنوات القادمة؛ وسيهدد ذلك بشكل خاص المنطقة الزراعية البيئية المروية، والتي يتحقق فيها معظم الناتج المحلي الإجمالي الزراعي في الأردن[33].

ستزداد آثار التغير المناخي سوءاً ما بعد العام 2030. فعلى سبيل المثال، من المتوقع أن ينخفض محصول الشعير بمقدار 25-50% بحلول العام 2050 بسبب ارتفاع درجات الحرارة وتناقص التساقط المطري، مما سيكون له أثر بالغ على توفر العلف للحيوانات. كما سيواصل انخفاض التساقط المطري وارتفاع درجات الحرارة من تقليص المتاح من المياه والمراعي لأغراض الثروة الحيوانية34. كما يمكن أن تؤدي هذه الانخفاضات الواضحة في إنتاجية المحاصيل والثروة الحيوانية في زيادة اعتماد الأردن على الواردات وإضعاف الأمن الغذائي. وسيكون من الهام للغاية إجراء تقييم أكثر شموليةً لإنتاجية المحاصيل باستخدام نماذج مرتكزة على العمليات من أجل الوصول إلى فهم كامل للسيناريوهات المستقبلية[35].

بشكل متزامن، يقوم النموذج الدولي لتحليل السياسات المتعلقة بالسلع الزراعية والتجارة بدراسة السيناريوهات المتعلقة بالمناخ، والنواحي الاقتصادية والاجتماعية، والمحاصيل من أجل تشخيص استجابة كل محصول للتغير المناخي من حيث أداءه في الأسواق المحلية والدولية[36]. تدرس توقعات النموذج الأثر المحلي للتغير المناخي على عوائد المحاصيل وكيفية استجابة المحصول ذاته حول العالم. ولأغراض هذه الدراسة، قمنا بتحديد المحاصيل الهامة إقليمياً ونظم الإنتاج ذات الصلة على أساس معايير مثل القيمة الغذائيه للسلعة، وقيمتها الاقتصادية، والمنطقة قيد الإنتاج. وتم إعداد نماذج لبعض هذه المحاصيل كجزء من منهجية النموذج وتم تمثيل محاصيل أخرى بشكل أكثر عموميةً بموجب فئات واسعة للمحاصيل غير المحددة (باستثناء الزيتون، والذي لم يتم شموله). ومرةً أخرى، تفترض هذه النتائج توفر إمدادات لمياه الري بشكل مستمر، بينما، وفي الواقع، من المتوقع أن تنخفض إمدادات مياه الري بمقدار 20-25% خلال السنوات القادمة.

باستثناء البطاطا، ستشهد كافة المحاصيل الأردنية المختارة زيادةً نسبيةً في العائد في ظل التغير المناخي بموجب توقعات النموذج الدولي لتحليل السياسات المتعلقة بالسلع الزراعية والتجارة (الجدول ES.1). بعبارة أخرى، ستتحسن العوائد بالمقارنة مع محاصيل محلية أخرى ومقارنةً مع نفس المحصول في السوق العالمي. ومن المتوقع أن تبقى المنطقة قيد الزراعة للمحاصيل الرئيسية مستقرةً نسبياً. ومن المتوقع أن يرتفع الإنتاج بالنسبة للشعير والفاكهة والخضروات والقمح. ومن المتوقع حدوث زيادات لا تُذكر بالنسبة لمنتجات الألبان والدواجن، كما يتوقع حدوث انخفاضات نسبية في الإنتاج بالنسبة للبطاطا والأغنام. وتشير نتائج النموذج أيضاً إلى أنه سيكون للتغير المناخي أثر صغير على العدد النسبي للثروة الحيوانية.

الجدول ES.1: الأثر على العائد لسيناريوهين للتغير المناخي، مسار التركز التمثيلي 4.5 ومسار التركز التمثيلي 8.5، بالمقارنة مع سيناريو عدم حدوث تغير مناخي بحلول العام 2050

السلعة	عدم حدوث تغير مناخي (%)	تغير مناخي مسار التركز التمثيلي 4.5 (%) 2020-2050	أثر مسار التركز التمثيلي 4.5 (نقطة مئوية)	تغير مناخي مسار التركز التمثيلي 8.5 (%) 2020-2050	أثر مسار التركز التمثيلي 8.5 (نقطة مئوية)
الشعير	62.1	78.6	16.5	78.8	16.7
البطاطا	25.8	19.7	-6.1	13.7	-12.1

الفاكهة الاستوائية	50.3	63.8	13.5	63.0	12.7
الخضراوات	49.5	62.1	12.7	61.4	11.9
القمح	77.2	96.4	19.2	97.1	19.9

من المتوقع أن يشهد توفر الغذاء بالنسبة لكافة المحاصيل والثروة الحيوانية أثراً سلبياً صغيراً بفعل التغير المناخي بأقل من 1 نقطة مئوية بالنسبة لمعظم السلع. كما سيؤدي التغير المناخي إلى حدوث انخفاضات طفيفة في الطلب الإجمالي على المحاصيل والثروة الحيوانية المختارة، بعيداً عن الشعير والقمح. وستكون الآثار السلبية محدودةً باستثناء البطاطا، والتي تُظهر مجدداً انخفاضاً أكبر ما بين 6-8 نقطة مئوية. وفي دولة متوسطة الدخل مثل الأردن، لا تؤثر هذه الانخفاضات الطفيفة في إمدادات الغذاء بشكل ضار إجمالاً على الوصول إلى الغذاء بالنظر إلى الفوائض الحالية والقدرة على الاستيراد. وبينما قد لا يكون للانخفاضات في إمدادات الغذاء أثر ضار على الوصول إلى الغذاء، فإنها ستؤثر على أسعار الغذاء. حيث سترتفع اسعارالمنتجات بشكل عام في ظل التغير المناخي باستثناء الشعير. وستكون هذه الزيادات في الأسعار أكثر وضوحاً بالنسبة للبطاطا والخضراوات والقمح، وبشكل يتسق مع الانخفاضات في التوفر المتوقع في الغذاء لكل محصول.

خلال الفترة ما بين 2020-2050، تُظهر مجموعة فرعية من السلع الهامة اختلافاً متزايداً في التجارة في ظل التغير المناخي. إذ يتوقع النموذج زيادةً في صادرات الخضراوات، وبما يتفق مع الدراسات التجارية الحديثة والتي تعكس نمواً سنوياً يبلغ في متوسطه 11% ونمواً بأكثر من 80% في إجمالي السلع المصدَّرة في بعض السنوات37. كما توجد نزعة نحو زيادة الواردات من الشعير والقمح، مما يوضح أن الطلب سيفوق الإمدادات المحلية بالرغم من أن كلا المحصولين سيبقيان بحالة جيدة في ظل التغير المناخي. كما أن من المتوقع حدوث زيادة في صادرات الخضراوات، بينما لا تعد الاتجاهات بالنسبة للدواجن واضحةً.

تدعم مشاورات الخبراء الاستنتاجات التي توصل بحثنا إليها. إذ أشار الخبراء الذين تمت مشاورتهم إلى أن التغيرات في درجة الحرارة، والتساقط المطري، والرطوبة قد لوحظت على صعيد الزراعة في الأردن. كما يشكل توفر ونوعية المياه أموراً مثيرةً للقلق. وتم تحديد التقلبات السعرية والمخاطر المتعلقة بتوفر العمال بالنسبة للمناطق الزراعية البيئية المروية والبعلية. كما يشكل النزاع في الدول الأخرى بصورة رئيسية خطراً على المناطق المروية، بينما تحمل النزاعات المتعلقة بشح الموارد واللاجئين أهميةً أكبر في المناطق البعلية والزراعية الرعوية. وتمت الإشارة أيضاً إلى المسائل المتعلقة بالحيوانات في المناطق الزراعية الرعوية. وفيما يتعلق باعتبارات السياسات، اعتبر الخبراء بشكل عام الأمن الغذائي، والتقلبات السعرية، وتطوير سلاسل القيمة، وتشغيل الشباب مجالات ذات أولوية. كما تمت إثارة قضايا تخصيص المياه والتجارة بشكل متكرر بالنسبة للمناطق المروية، وكان الحد من الفقر أكثر أهميةً في المناطق البعلية والرعوية. وتم احياناً التطرق إلى الفرص المتاحة للنساء وبصورة أقل في المناطق المروية.

أدت هذه العملية المكثفة من البحوث والتحليل ومشاورات الخبراء إلى إعداد ستة حزم استثمارية للزراعة الذكية مناخياً والتي جرى اختيارها للتطرق لمسائل التكيف والتخفيف والإنتاجية عبر المناطق الزراعية البيئية الثلاث في الأردن (الجدول ES.2). وتعمل خطة العمل هذه على تقييم وتحديد الأولوية للحزم الاستثمارية على أساس مساهمتها المحتملة في الزراعة الذكية مناخياً، بالاعتماد على تصور واسع عبر المناطق الزراعية البيئية والسلع. كما يجب إجراء المزيد من التطوير على الحزم المختارة مع الشركاء المحتملين والمؤسسات التمويلية أثناء مرحلة المتابعة بحسب العمل الميداني الذي يوفره هذا التقرير. رغم ذلك، وبالإضافة إلى إمكانات التحلي بالذكاء المناخي، تعتبر الحزم المقترحة واعدةً من حيث إضافة قيمة اقتصادية هامة ومساهمات قوية لخدمات النظام البيئي، والغذاء والأمن الغذائي، وتطوير سبل كسب الرزق. وبشكل مهم، توفر الحزم الاستثمارية مكاسب على صعيد إنتاجية المياه تتجاوز بكثير نسبة الخفض المتوقعة والبالغة 20-25% في توفر الموارد المائية. كما تعمل كل حزمة استثمارية على إيجاد وزيادة فرص العمل طوال سلسلة القيمة المعنية. وهذه الحزمة الاستثمارية هي كما يلي:

- تطوير ومعالجة وتسويق **أشجار النخيل** ذات القيمة العالية باستخدام ممارسات ري حديثة والممارسات الزراعيه المحسّنة (المناطق المروية).
- التوسع والتطوير في إنتاج **الخضراوات** المحمية باستخدام التقنيات وخيارات المعالجة والتسويق المتطورة (المناطق المروية)
- تطوير إنتاج ومعالجة **الزيتون** من خلال إدخال تقنيات حديثة منخفضة التكلفة فيما يتعلق بالجمع، والعصر البارد والتخليل، والاستخدامات البديلة للنفايات (المناطق البعلية)
- تعزيز إنتاج الشعير من خلال حصاد مياه الأمطار وتحسين الإدارة (المناطق البعلية والبادية)
- تعزيز إنتاج **الحيوانات المجترة الصغيرة** من خلال النظم الزراعية المكثفة وتطوير سلسلة منتجات الألبان (المناطق الزراعية الرعوية)
- **اعاده تاهيل** البادية من خلال المستجمعات المائية الصغرى للحصاد المائي وتحسين إدارة الرعي (المناطق الزراعية الرعوية).

الجدول ES.2: المكاسب من تنفيذ الزراعة الذكية مناخياً: مسوغات الاستثمار

استثمار الزراعة الذكية مناخياً	القيمة في المَزارع	الأهمية بالنسبة للأردن[38]	الاستجابة المتوقعة للتغير المناخي	السيناريو بدون استثمار	الهدف الرئيسي للاستثمار
أشجار النخيل	اقتصادية وتغذوية	التصدير والاستهلاك المحلي. يقدَّر الإنتاج السنوي بنحو 25,000 طن متري على مساحة تتجاوز 4,000 هكتار.	زيادة في الملاءمة. تزدهر في درجات الحرارة المرتفعة، وقادرة على التعامل مع الإجهاد المائي.	إنتاج مستقر.	النمو
الخضراوات	اقتصادية وتغذوية والأمن الغذائي	التصدير والاستهلاك المحلي. يقدَّر الإنتاج السنوي بنحو 1.7 طن متري على مساحة تتجاوز 37,000 هكتار. تساهم البندوره لوحدها بمقدار 280,000 طن متري لأسواق التصدير بقيمة 223 مليون دولار أمريكي.	زيادة في الملاءمة للبندوره، انخفاض في الملاءة للبطاطا. اتساع موسم النمو للخضراوات الثمرية مع تزايد عدد الأيام الدافئة، بالرغم من أن درجات الحرارة المرتفعة تجهد النباتات. تؤدي فترات الحر بشكل كبير إلى تقليل تكون الدرنات، والوزن، والمحاصيل.	انخفاض إنتاج الحقول المفتوحة؛ زيادة خسائر ما بعد الحصاد.	التكيّف والنمو
الزيتون	اقتصادية وتغذوية	نظام إنتاج رئيسي في المناطق البعلية؛ إمكانية زيادة نوعية المعالجة للصادرات. أكثر من 56,000 هكتار تنتج أكثر من 145,000 طن متري، من بينها أكثر من 1,000 طن متري يتم تصديرها.	ملاءمة بشكل متوسط في المنطقة البعلية؛ قادرة على التعامل مع الحر والإجهاد المائي.	زيادة خسائر ما بعد الحصاد؛ تفاقم التدهور البيئي.	التكيّف والنمو
الشعير	اقتصادية وغذائية وأمن الأعلاف	علف أساسي للثروة الحيوانية خلال فترات نقص الأعلاف. يساهم الإنتاج المحلي بنحو 50,000 طن متري، بينما يتم سنوياً استيراد 960,000 طن متري.	استجابة ضعيفة للتغير المناخي. تؤدي أيام الإجهاد الحراري الطويلة والأكثر عموميةً والمتركزة في فصل الربيع إلى تقليل امتلاء ونضج الحبوب. سيؤدي ارتفاع درجات الحرارة والإجهاد الناتج عن الجفاف إلى تقليل المحصول ما بين 20-50% بحلول العام 2050.	تقليل المحصول ما بين 20-50% بحلول العام 2050؛ ازدياد المستوردات.	التكيّف والنمو
الحيوانات المجترة الصغيرة	اقتصادية والأمن الغذائي	طلب مرتفع موثوق، قطاع رئيسي للنساء. تبلغ الصادرات السنوية نحو 500,000 من الأغنام والماعز بقيمة تبلغ تقريباً 170 مليون دولار أمريكي.	تتكيف الحيوانات المجترة الصغيرة بشكل جيد مع التغير المناخي، بالرغم من أن درجات الحرارة المرتفعة في فصل الصيف قد تعيق إنتاجية الثروة الحيوانية وتؤثر على العمالة البشرية. يقلل ارتفاع درجة الحرارة والإجهاد الناتج عن الرطوبة من مصادر الرعي والعلف، مما يقلل من صحة الثروة الحيوانية.	زيادة تدهور الأراضي؛ انخفاض أمن الأعلاف.	التكيّف والنمو

إعاده تأهيل البادية	خدمات النظام البيئي، بما في ذلك أمن الأعلاف للثروة الحيوانية	تخفيف ومنع التصحر. دعم الاستثمارات في الشعير والحيوانات المجترة الصغيرة بالإضافة إلى العديد من السياسات الوطنية.	تقلل فصول الصيف الأكثر حرارةً وفصول الشتاء الأكثر جفافاً من قدرة التربة على دعم النمو النباتي، مما يعيق الفرص أمام الثروة الحيوانية أو إنتاج المحاصيل.	تواصل خسارة الأراضي القابلة للزراعة؛ انخفاض الإنتاجية.	التكيّف والتخفيف

يُظهر تحليلنا حول التكلفة والمنفعة صافي قيمة حالية إيجابية لكافة حزم الزراعة الذكية مناخياً على مستوى المَزارع والمستوى التجميعي، مما يشير إلى عائد جيد بشكل عام على الاستثمار. وباستخدام أداة توقع نتيجة الاعتماد والنشر، فإننا نتوقع أقصى معدلات اعتماد لكافة استثمارات الزراعة الذكية مناخياً- ما بين 93%-98%-- في غضون فترة 20 عاماً. لكن تختلف معدلات النشر، حيث يُفترض أن يكون ذلك بسبب الخصائص المتنوعة وقابلية التعلم لدى المستفيدين المستهدفين لكل حزمة. ويوجد للحزم الاستثمارية للزراعة الذكية مناخياً مستويات مرتفعة من الحساسية تجاه معدلات الخصم، والتغير المناخي، وتنوع أسعار المخرجات، وخصوصاً فيما يتعلق بالتغير المناخي وتنوع أسعار المخرجات، وتتنوع حساسيتها تجاه هذه المخاطر مع مقياس التحليل. يقارن الجدول (ES.3) بين الاستثمار على مستوى المَزارع والمستوى التجميعي. وبشكل إجمالي، يؤدي اتباع نهج سلسلة القيمة إلى تقليل فترة السداد لمعظم استثمارات الزراعة الذكية مناخياً بصورة كبيرة، مع زيادة فرص التمويل من خلال إشراك القطاع الخاص.

الجدول ES.3: الربحية الاقتصادية وفترة السداد للحزم الاستثمارية على مستوى المَزارع والمستوى التجميعي.

حزمة الزراعة الذكية مناخياً*	المساحة	المزارعون	الاستثمارات**			فترة السداد (سنوات)	
	هكتار	العدد	في المزرعة (مليون دينار)	نطاق واسع (مليون دينار)	تجميعي (مليون دينار)	في المَزارع	تجميعي
أشجار النخيل	800	500	6.34	1.30	**7.64**	**12**	3.1
الخضراوات (أ)	250	500	106.86	0.37	**107.23**	**9.8**	1.6
الخضراوات (ب)	100	200	39.74	0.19	**39.93**	**8.9**	1.7
الخضراوات (ج)	20	40	8.95	0.09	9.04	10.3	2.6
الزيتون	1,000	1000	16.82	2.12	18.94	3	2.6
الشعير	1,000	1000	0.47	0.60	1.07	4	5.5
الحيوانات المجترة الصغيرة	n/a	900	23.26	0.54	23.80	3	1.6
إحياء البادية	5000	250	0.1	1.39	1.49	3	6.9

* الخضراوات: (أ) زراعه مكشوفه إلى بيت زجاجي؛ (ب) نفق صغير إلى بيت زجاجي؛ (ج) حقل صغير إلى الزراعة المائية، **1 دينار أردني=1.41 دولار أمريكي

ستحقق كافة الحزم الاستثمارية للزراعة الذكية مناخياً المقترحة بموجب خطة عمل الزراعة الذكية مناخياً رصيداً كربونياً سلبياً، مع خفض إجمالي لانبعاثات الغازات الدفيئة بمقدار823,665 طن لمكافئ ثاني أكسيد الكربون. ويساهم إحياء البادية في معظم الخفض لانبعاثات الغازات الدفيئة (64%)، تتبعه الحيوانات المجترة الصغيرة وسلاسل القيمة لأشجار النخيل (12-13% لكل منها)، ثم سلسلة القيمة للخضراوات (4.6%)؛ ويساهم الزيتون والشعير بالنسبة الأقل (3.4% لكل منها). وتبلغ القيمة الإجمالية التقديرية للخفض المحتمل لانبعاثات الغازات الدفيئة أكثر من 25 مليون دولار أمريكي ويجب أخذها بعين الاعتبار عند دراسة الاستثمار في حزم الزراعة الذكية مناخياً.

توجد عوائق رئيسية أمام الاستثمار في الأردن، بما في ذلك المسائل السياسية والأمنية، وشح الموارد والنزاعات، والمخاطر المناخية، والقيود المالية، والإخفاقات السوقية. وتترسخ معظم هذه التحديات أو العوائق في بيئة السياسات، وبالتالي يمكن معالجتها أو السيطرة عليها كجزء من تصميم وتنفيذ برنامج الزراعة الذكية مناخياً. فعلى سبيل المثال، توجد فرصة كبيرة لإحداث المزيد من التوافق بين السياسات الوطنية وخطة عمل الأردن للالتزامات المحددة وطنياً. وتشكل خطط عمل الزراعة الذكية مناخياً المستعرضة في هذا التقرير فرصةً ممتازةً للبدء في إحداث هذا التوافق على مستوى السياسات، بالإضافة إلى دعم تحقيق أهداف التنمية المستدامة. وستعمل زيادة إنتاجية المياه من خلال هذه الاستثمارات للزراعة الذكية مناخياً وبشكل مشترك مع السياسات المائية المناسبة للحد من

الأثر الارتدادي على تخفيف الضغوط الزراعية على المياه الجوفية. كما يعتبر تحسين تدفق المعلومات، وبناء القدرات، والخدمات المالية، وتكامل سلاسل القيمة، والإشراك القوي للمجتمعات المحلية أمراً أساسياً لضمان نجاح كافة برامج الزراعة الذكية مناخياً في الأردن. وقد يشكل التمويل المختلط خياراً هاماً لحشد التمويل من القطاعين العام والخاص للتوسع في استثمارات الزراعة الذكية المناخية الناجحة وذات الإمكانات المرتفعة[39].

تشكل المتابعة والتقييم جانباً بالغ الأهمية في خطة عمل الزراعة الذكية مناخياً. حيث أنها تساعد في تحديد الافتراضات المتعلقة بكيفية حدوث التغيير، وتوفر البراهين والمعلومات لتنفيذ الإدارة الموجهة بالنتائج، وتسمح لمدراء المشاريع بالحصول على معلومات محدَّثة حول ما إذا كانت المشاريع تسير بحسب ما هو مقرر من حيث خطط عملها وميزانياتها وأهدافها40. يتألف الإطار العام للمتابعة والتقييم من نظرية التغيير، ومسارات الأثر، وإطار النتائج، والمؤشرات ذات الصلة. حيث تساعد نظرية التغيير في تبسيط وتخيل الأهداف الرئيسية للمشروع وكيفية حدوث هذه التغييرات؛ وبالاعتماد على نظرية التغيير، تصف مسارات الأثر الطرق المختلفة لتحقيق هذه التغييرات والتحسينات. تهدف خطة العمل هذه إلى التطرق إلى العديد من المسائل المناخية، والتي تتراوح ما بين الأمن الغذائي وصولاً إلى التحسينات في سبل كسب الرزق في القطاع الزراعي. وتتمحور نظرية التغيير ومسارات الأثر المصممة لخطة عمل الزراعة الذكية مناخياً في الأردن حول قطاع زراعي أقوى وأكثر صموداً مناخياً واستدامةً عبر مختلف السلع والمناطق في الأردن.

وبغرض الوصول إلى نظم زراعية وسلاسل قيمة منتجة ومستدامة وصامدة مناخياً، فقد تم تحديد أربعة مسارات: زيادة الإنتاج والدخل؛ وزيادة القدرة التكيّفية؛ وتقليل التعرّض والحساسية للمناخ؛ وتحسين قابلية تسويق السلع. وسيتم قياس نجاح الاستثمارات من خلال العديد من الأنشطة التي يجب تنفيذها للوصول إلى المخرجات الضرورية كما هو مبيّن في نظرية التغيير. ويمكن رصد نتائج الاستثمارات على مستوى المحفظة قياساً بعدد محدود من المؤشرات الأساسية، بما في ذلك عدد المستفيدين والتغيرات في الإنتاجية، والقدرة التكيّفية، والصمود، وانبعاثات الغازات الدفيئة. على نحو مماثل، وعلى مستوى المشاريع، يمكن اختيار مؤشرات أساسية لكل استثمار فردي خلال مرحلة التطوير. ويمكن استخدام إطار النتائج، مع المؤشرات على مستوى البرامج ولكل مكون استثماري، لقياس أداء المشاريع.

لا تزال هنالك العديد من الخطوات الإضافية المطلوبة لإعداد نظام للمتابعة والتقييم وضمان استدامة المشاريع الحالية والمستقبلية والتي يمكن تنفيذها ما بعد نطاق خطة عمل الزراعة الذكية مناخياً. حيث قام البرنامج البحثي للمجموعة الاستشارية للبحوث الزراعية الدولية حول التغير المناخي، والزراعة، والأمن الغذائي بتحديد 11 خطوة، والمصنفة بموجب مؤشرات، ونظام للمتابعة والتقييم، وتطوير القدرات، والتمويل، والتي يجب أن تتوفر من أجل إيجاد نظام شامل ومترابط للمتابعة والتقييم41. وينبغي إضفاء الطابع النظامي والمؤسسي على أنشطة المتابعة والتقييم في خطة برامجية للمتابعة والتقييم والتي تصف الإجراءات والمسؤوليات والخطوات المحددة الواجب اتخاذها لإجراء تقييم شامل للمتابعة والتقييم. وتتسم خطة المتابعة والتقييم بطبيعتها المتشابكة، حيث تعمل على الجمع بين عدة مؤسسات، وجهات حكومية، وشركاء تنفيذيين، وأصحاب الشأن من أجل الحصول على منافع واسعة النطاق للقطاع الزراعي والبيئة وللوصول إلى المستهدفات التنموية الوطنية. فضلاً عن ذلك، وعند التوافق مع أهداف الحكومة الأردنية والأهداف الوزارية، سيؤدي الاستثمار في المتابعة والتقييم إلى بناء القدرات المؤسسية وإيجاد مجموعات بيانات شاملة يمكن استخدامها لأغراض رسم السياسات وصنع القرار. ويمكن أن تكشف المشاريع ذات البرامج القوية للمتابعة والتقييم عن معلومات أساسية للتدخلات في المستقبل.

Chapter 1

Introduction and approach

Highlights

- Climate change, including diminishing rainfall and rising temperatures, poses challenges to Jordan's agricultural sector and especially to poor and vulnerable populations.
- Climate-smart agriculture (CSA) addresses these problems by increasing productivity while also fostering sustainability, resilience, and mitigation.
- Jordan's CSA Action Plan aims to enhance CSA across Jordan's agroecological zones (AEZs) and major value chains in alignment with national climate priorities and international commitments, including their Nationally Determined Contributions to the Paris Agreement.

1.1 Why Climate-Smart Agriculture (CSA)?

Jordan is facing harsh climatic conditions that are affecting agricultural production and which are expected to become even more challenging in the future. In recent decades, there has been a steady decline in average annual rainfall across West Asia. Changes in precipitation amounts and patterns and increased temperatures are straining crop and livestock production in Jordan. Climate change will place significant stress on Jordan's poor and vulnerable population. In addition to causing setbacks in terms of food security, climate change may also pose problems for the further development of Jordan's agricultural sector, which is increasingly dependent on value chains and export markets. A robust and broad-scale package of development initiatives can help Jordan's agricultural sector address current and future climate change impacts, meet food demand, and advance the growth of agribusiness under climate change. This document outlines a portfolio of potential investments to support Jordan's agricultural sector in addressing climate change through CSA.

CSA increases productivity in an environmentally and socially sustainable way, strengthens farmers' adaptation and resilience to climate change, and supports mitigation efforts from its negative impacts (Figure 1.1)[39]. Economic investments that account for climate change can increase agricultural productivity while providing climate-related benefits, supporting adaptation, building resilience, and reducing emissions. CSA focuses on agriculture sector, but it is multi-sectoral and also includes commitments to enhancing livelihoods while ensuring food security. Although CSA aims to create wins across its three pillars: productivity, adaptation, and mitigation, it recognizes trade-offs based on the biophysical, agricultural, and socioeconomic context of a given place at a given time.

Figure 1.1 Climate-smart agriculture: the triple win of sustainability, resilience, and lower emissions[43]

This CSA Action Plan builds on the experience of the World Bank and its partners in assessing the impact of climate change on food systems. Since 2014, the World Bank and partners have released 30 CSA Profiles, helping countries across Asia, Africa, and Latin America understand the climate challenges their food systems face, assess how climate-smart their agriculture sectors already are, and explore possible solutions to mitigate climate risks.[44] The World Bank is now building on these CSA profiles and moving toward the next phase, namely, bringing CSA to life at the country level with CSA Investment or Action Plans.[45] The approach and methodology used in these CSA Investment Plans were developed in cooperation with a wide range of partners, including the Alliance of Bioversity International and CIAT, and have already been applied in several countries around the world.

1.2 The Climate-Smart Agricultural Investment Planning Framework

Jordan's Action Plan to identify CSA investments follows the Climate-Smart Agricultural Investment Planning Framework. The framework is based on the four components of CSA planning and implementation: (i) situation analysis, (ii) prioritizing interventions, (iii) program design, and (iv) M&E.[46] All four components depend on strong engagement with the key decision-makers, experts, and institutions involved. Each step serves as input to the others, moving from a careful analysis of the agricultural context, climate change projections and risks, and economic impacts, to the prioritization of CSA investments and program design with climate-smart analysis – all embedded in a comprehensive Theory of Change and Results Framework. This Investment Planning Framework (Figure 1.2) guided the development of Jordan's CSA Action Plan and the organization of this report.

The World Bank, in collaboration with the Alliance of Bioversity International and CIAT and with ICARDA, assisted the government of Jordan in the preparation of this CSA Action Plan. This Action Plan will, firstly, address vulnerabilities and risks in the agricultural sector due to climate change and unsustainable land and water management and use. Secondly, it will also assess GHG emissions from the agri-food sector, mitigation potentials, and policy options for scaling CSA and solutions along key value chains. The objective of the plan is to identify actions that boost CSA across AEZs and major agricultural commodities' value chains, in the form of both investments and policies. The result is a series of recommended investment packages based on an encompassing analysis spanning all Jordan's AEZs and a variety of agricultural commodities. Additional, focused analysis of specific value chains and markets will be necessary to elaborate detailed investment plans for the diverse programs and projects submitted for consideration herein. This Action Plan will contribute to the implementation of Jordan's NDCs, the Green Growth National Action Plan, and national targets of the agricultural sector.

Figure 1.2 Components of the CSA planning framework for Jordan[47]

Chapter 2

The agricultural context

Highlights

- As an emerging urban economy in the Middle East, Jordan faces high rates of poverty, especially in rural areas.
- Jordan is extremely arid, and the country's water resources are under increasing pressure.
- Major commodities in irrigated and rainfed areas include vegetables such as tomatoes and potatoes; fruit trees including olives, almonds, citrus, and dates; field crops such as wheat and barley; and legumes such as lentils and chickpeas. Livestock is a highly valuable subsector dominating the enormous agropastoral AEZ.
- Agricultural value chains contribute significantly to livelihoods, but there are notable disparities in gender and nationality among employees of the agricultural sector.
- Jordan's GHG emissions have been decreasing in recent years, but there remains mitigation potential.
- Key institutional players for the agricultural sector include Jordan's Ministry of Agriculture (MoA) and National Agricultural Research Center (NARC).
- National policies are generally aligned with international climate goals, and could further bolster growth in the agricultural sector.
- Agricultural-sector challenges include production area, self-sufficiency and trade, natural resources, and the enabling environment, all of which have been partially affected by the Syrian, Iraqi, and COVID-19 crises.
- Key issues related to the enabling environment include access to finance, fiscal pressures, a lack of investment in innovation, and a lack of coordinated approaches to monitor key trends in the overall food system.

2.1 Jordan and its people

Jordan is an urbanized Middle Eastern emerging economy. The total Jordanian population has grown from 590,000 in 1950 to 10.6 million in 2020. As of 2018, only about 9% of the population resided in rural areas, and urbanization rates hover around 2.4% annually as of 2020.[48] The capital city, Amman, is the economic center of the country, and at 4.3 million inhabitants, is also the nation's largest city.[49] Other prominent cities include Zarqa, Irbid, and Aqaba. Recent regional conflict has brought about an economic slowdown and a massive influx of refugees, causing Jordan to be reclassified as a low-middle income country in 2018.[50]

Jordan is characterized by a rural-urban divide. The portion of the population in poverty steadily declined to 15.7% in 2002, but has since increased to nearly 18% in 2020, and is expected to continue rising. The rural population represents an outsized percentage of impoverished individuals. The rate of unemployment before the COVID-19 pandemic was 19%, including around 17% of men and 24% of women. At 36%, young women, most of whom hold university degrees, represent a large proportion of the unemployed, versus just 19% of young men.[51] Jordan's unemployment rate is forecasted to increase as a result of COVID-19 and the effects of a national lockdown that greatly impedes the tourism, informal labor, and small and medium-sized enterprise (SME) sectors, the latter comprising approximately 95% of Jordan's private businesses.[52] Jordan's Human Development Index rating increased from 0.62 (medium development) in 1990 to 0.74 (high development) in 2015; the rating has since declined slightly to 0.72 as of 2019 without changing category.[53] Average household income in urban areas is 20% higher than average rural household incomes.[54] International remittances constitute an unusually high portion of income, particularly in rural areas.[55]

Around 97% of the population, including 92% of the rural population, has access to improved drinking water, and nearly 99% of individuals across both urban and rural areas have sanitation services.[56] As of 2012, 99.5% of all households had electricity access.[57] 5.7% of households are estimated to be vulnerable to food insecurity, and an additional 0.5% are categorized as food insecure.[58] Jordan's Global Hunger Index rating is 11.7, where below 9.9 indicates low hunger and above 50 indicates extremely high rates of hunger.[59] About 8% of children under 5 years old suffer from stunting, with a relatively minor rural-urban nutrition gap of 1.5%.[60] Obesity affects around 35% of the adult population.[61]

2.2 Climate, geography, and agroecological zones (AEZs)

The arid Arabian desert and the humid eastern Mediterranean both influence the climate in Jordan, with the precipitation gradient running roughly from the east-northeast to the west-southwest (Figure 2.1). Daily temperatures can exceed 40°C. Crops are generally grown during the winter, when soil and surface water availability is greater. About 70% of annual rainfall occurs between November and March, with the remaining 30% typically falling in April-May and September-October. June through August generally see no rainfall. Precipitation is quite variable across years, seasons, and days, and often concentrated in violent downpours that instigate local flooding and erosion. Water availability for irrigation is mainly dependent on rainfall, and surface water in the Jordan River and its tributaries, Yarmouk and Zarga. Aridity and water scarcity make Jordan highly sensitive to climate hazards. Altitude varies from -400 to 1854 m. The country consists mainly of a plateau between 700 and 1,200 m above sea level, with mountains, valleys, and gorges. To the west of the plateau, land descends from the East Bank of the Jordan Rift Valley, which is part of the Great Rift Valley.

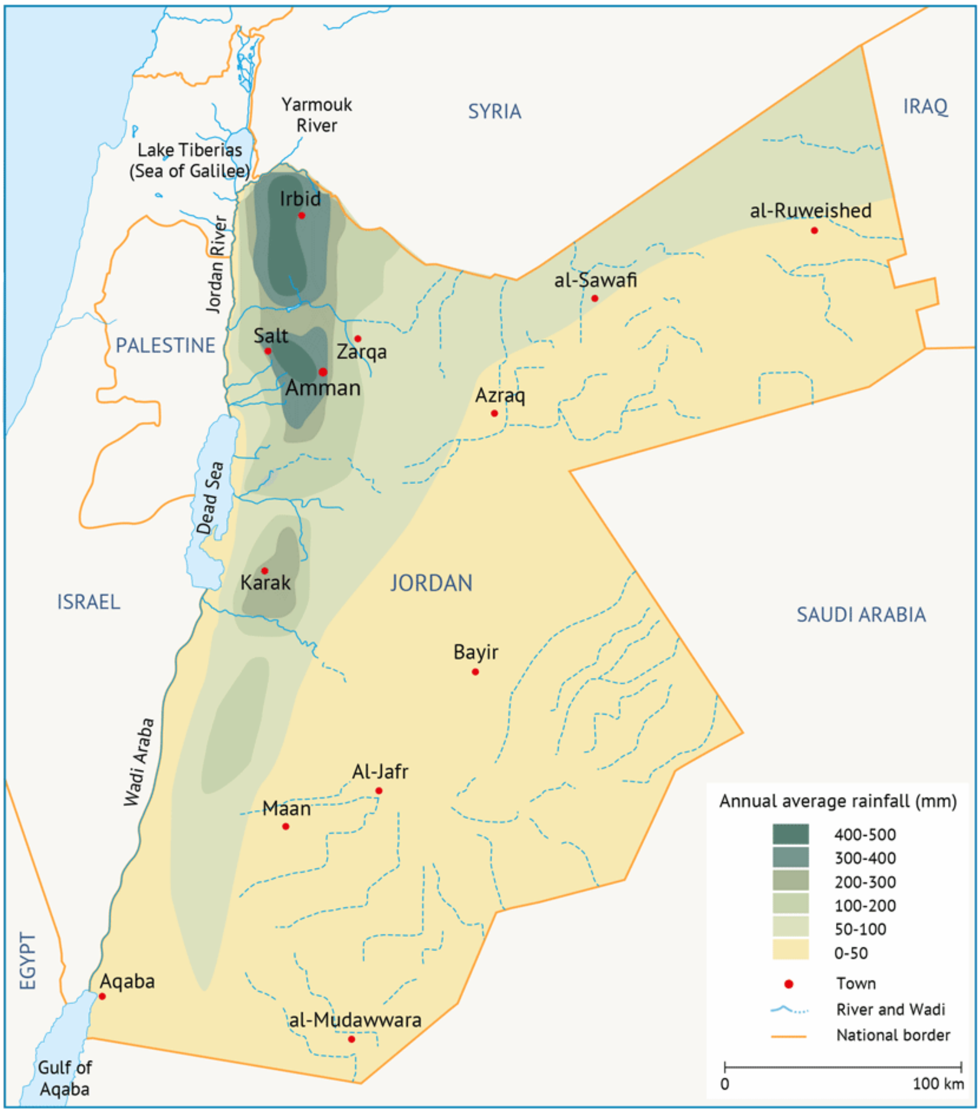
Jordan is a country suffering from severe drought and water resources are the limiting factor of its agricultural production systems. The country recognizes three AEZs. The first two are natural zones, namely the rainfed AEZ that includes all areas that average at least 200 mm of rainfall annually, and the agropastoral AEZ that is comprised of areas receiving less than 200 mm of rainfall annually. The third one, the irrigated AEZ, has been "created" and includes all irrigated areas regardless of the amount of rainfall they receive. In contrast to the national ecological system, Jordan's agroecological system does not recognize any desert zones, since all areas receive a relatively sufficient rainfall to develop rangeland.

Jordan's *irrigated AEZ* is the most productive one and mainly confined to the Jordan Valley, which extends from the Dead Sea to the northern national border and includes portions of the highlands and agropastoral areas. Elevation in this AEZ varies from 400 m below sea level to 700m above sea level. The irrigated AEZ encompasses just 19% of the country's total cultivated area, with the vast remaining majority occurring in the rainfed AEZ. However, the irrigated AEZ consists primarily of high-value crops, and is consequently by far the most important in terms of export and economic value. The irrigated AEZ accounts for 32% of total national fruit production, specializing in lemons, oranges, dates, and bananas; 60% of vegetable production, particularly tomatoes, squash, and eggplants; and 26% of field crop production, including wheat, maize, and clover.

Only about 8% of Jordanian territory receives more than 200 mm of rainfall annually. Of this, the areas that are unirrigated constitute the *rainfed AEZ*.[62] This AEZ is located primarily in the highlands. Most rainfall occurs in winter, and while 200 mm is the lower boundary for this AEZ, large portions of Jordan's rainfed area receive in excess of 350 mm annually. The rainfed AEZ area is four times larger than the irrigated AEZ. Common agricultural systems include tree crops, particularly olives and stone fruits; field crops, particularly barely, wheat, and clover; and vegetable crops, particularly tomatoes, potatoes, and watermelons. Olive production is of particular importance in the rainfed AEZ; two-thirds of the national olive harvest comes from rainfed areas. The rugged terrain and erratic precipitation patterns in the rainfed AEZ make it prone to considerable soil erosion during the rainy season. Most farms, and particularly olive orchards, use terracing to minimize land degradation.

The *agropastoral AEZ* comprises about 90% of Jordanian territory and primarily supports livestock production.[63] This arid AEZ stretches from central Jordan to the east and south and includes the *Badia*. Vegetative cover and, concomitantly, pastoral community density, increases with latitude; about 70% of the nation's pastoral tribes live in the northern rangelands, and the remaining 30% are spread across the central and southern regions of the AEZ.[64] Historically, Bedouin pastoralists were fully nomadic in communal grazing regions called *al dirah*.[65] Today, over 59% of pastoralists are transhumant (semi-mobile), and more than 30% are sedentary agro-pastoralists.[66] Although the agropastoral AEZ is not considered suitable for agricultural activity, tree and field crops, particularly barley, are grown as part of agropastoral systems in which flood irrigation is often used where local water harvesting or groundwater pumping is feasible.[67]

Figure 2.1 Average rainfall distribution in Jordan[68]



2.3 The importance of agriculture

Jordan's economy is one of the smallest in the Middle East, and is driven by services and industry.[69] The national GDP is over US$ 42,9 billion as of 2018, or approximately US$ 4,240 per capita; this classifies Jordan as a lower-middle income country.[70] Its GDP grew by an average of 6.5% from 2000 to 2009 before slowing to an average of 2.5% annual growth from 2010 to the present.[71] Agriculture's contribution to the GDP trended downward from around 13% in the 1970s to an all-time low of 2.7% in 2001. Since then, it has been steadily rising, and as of 2018 constituted about 5.6% of the total national GDP.[72]

Jordan's agricultural system generally classifies agricultural products as livestock, field crops, vegetables, and fruits. The livestock subsector dominates the vast agropastoral AEZ and is valued at US$ 1.38 billion. Small ruminants, including about 3.4 million head sheep and 0.8 million head goats, account for about 35% of this total; broilers and cattle milk are also highly valuable. In terms of crops, olives and barley occupy by far the greatest area, followed by wheat and tomatoes (Table 2.1). Tomatoes are the largest crop by production volume, followed by cucumbers, potatoes, olives, and citrus fruit. All these crops have shown decreasing production since 2016 except olives. Jordan harvests around 150,000 MT to more than 300,000 MT of olives annually, almost exclusively in the rainfed AEZ; the majority of them are processed into about 50,000 MT of olive oil per year.[73] These data are based on the most recent agricultural census data which provide the most comprehensive set of data across the sector.

Table 2.1 Major crops by area and volume in 2017[74]

See Annex A.1 – A.4 for additional detail

Crops	Hectares	MT
Field Crops		
Barley	56,458	48,954
Wheat	12,191	12,110
Clover	2,309	100,935
Chickpeas	464	1,509
Lentils	124	440
Vegetables		
Tomatoes	12,195	690,477
Potatoes	4,008	155,639
Squash	2,757	72,091
Eggplants	1,964	65,319
Cucumbers	1,654	190,847
Fruit Trees		
Olives	56,214	145,332
Citrus Fruit	6,421	108,385
Dates	3,223	25,419
Grapes	2,894	53,509
Peaches	2,750	69,473

Jordan is self-sufficient in olives, olive oil, tomatoes, goat meat, fresh milk, and eggs. Additionally, it produces a significant portion of the poultry and some vegetables consumed domestically. In contrast, local diets rely heavily on imported cereal, legumes, fruits, and some vegetables. Jordan produces only about 3-4% of the wheat and barley it consumes. Nearly all barley is dedicated to livestock feed.

Agriculture accounts for about 16% of the total export (US$ 1.2 billion) and 19% of total imports (US$ 4 billion), making Jordan a net importer.[75] Both imports and exports are highly diversified; the top five exports account for just 6.2% of total export value, and the top five imports account for 5.3% of import value.[76] Nevertheless, general trends indicate net imports of field crops, fruit, and value-added agricultural products, and net exports of vegetables and raw livestock, including live sheep. The top agricultural exports by value in 2017 included tomatoes, live sheep, peppers, livestock forage, and cheese (Table 2.2), and the top imports were wheat, barley, oil cake, sheep and goat meat, and bovine meat (Table 2.3).[77] Medjool dates have considerable export value per volume, although their total contributions in terms of area, volume, and export remain small.

Table 2.2 Major agricultural exports, 2017[78]

See Annex A.2 – A.5 for additional detail

Commodity	,000 US$	MT unless otherwise noted
Tomatoes	223,054	282,271
Live sheep (number)	161,827	497,091 head
Peppers	56,068	47,970
Livestock forage	36,395	30,857
Cheese	28,034	6,436
Squash	23,372	27,693
Sweet melon	15,034	35,417
Cucumbers	11,545	19,024
Watermelons	10,424	19,095
Poultry meat	9,998	5,034
Cauliflower	9,717	14,414
Eggs (number)	7,187	34,055,400 eggs

Table 2.3 Major agricultural imports, 2017[79]

See Annex A.2 – A.5 for additional detail

Commodity	,000 US$	MT unless otherwise noted
Wheat	232,654	1,103,029
Barley	177,170	960,360
Oil cake	164,726	437,773
Sheep and goat meat	144,992	24,528
Bovine meat	133,118	33,090
Cheese	106,470	23,981
Powdered milk	100,544	31,203
Live sheep and goats (number)	93,627	703,523 head
Poultry meat	92,072	59,636
Live bovine (number)	75,948	78,209 head
Apples	62,135	50,813
Fish	43,424	13,686
Chickpeas	43,383	37,712
Bananas	25,520	32,236

2.4 Farmer livelihoods

The agricultural sector is increasingly productive in Jordan, and there are significant gender and nationality disparities among agricultural employees. Of the approximately 107,700 farm operations in Jordan, around 34% are less than 0.2 ha, and only 94 farms (0.09%) are larger than 200 ha (Table 2.4).[80] Agricultural productivity in Jordan has been on the rise thanks in part to increasing labor productivity.[81] Agriculture employs 3.7% of the population; 1.7% of Jordanian nationals and 6.9% of non-Jordanians. The livestock sub-sector employed a total of 50,300 individuals in 2017, composed primarily of household members (69%), followed by permanent employees (25%), casual employees (5.2%), and finally seasonal employees (<1%).[82] Among agricultural workers, non-Jordanians and

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women are most strongly represented among casual laborers, who dedicate less than 4 months annually to agriculture. Non-Jordanian and Jordanian males are also strongly represented among permanent agricultural employees (Table 2.5). Less than 1% of total agricultural workers nationwide and about 2.3% of rural agricultural workers are women, but rural women often engage in unpaid agricultural work, such as seeding, weeding, thinning, and harvesting. Women are also often charged with post-harvest and value chain activities, such as sorting, grading, and bagging cereals, as well as producing cheese, yogurt, and butter.[84] Even though primary agriculture represents a small share of formal employment, along with agro-processing it accounts for about 14% of formal employment. Jobs are created not only in the production stage but also all along the value chain, including in processing, packaging, distribution, and related sectors such as services, transport, and communication. The agricultural sector also stimulates other economic sectors, including input supplies, transport, food processing, logistics, and financial services, so agricultural growth can have an economy-wide multiplier effect.

Table 2.4 Size distribution of farm holdings in 2017[85]

Size (ha)	Number	Percentage
0-10.0	104,221	96.7%
10.1-200.0	3,392	3.1%
>200.0	94	0.1%
TOTAL	107,707	99.9%

Table 2.5 Number and percentage of agricultural employment by nationality and gender in 2017[86]

Type (months)	Non-Jordanian				Non-Jordanian				Total
	Women		Men		Women		Men		
Casual (0-4)	7,729	9.6%	25,039	30.1%	6,776	8.4%	11,288	14.0%	50,832
Seasonal (4-8)	1,730	2.1%	3,292	4.1%	321	0.4%	978	1.2%	6,321
Permanent (>8)	158	0.2%	17,150	21.2%	176	0.2%	5,833	7.2%	23,677
TOTAL	9,617	11.9%	45,841	56.7%	7,273	9%	18,099	22.4%	80,830

2.5 Water use and allocation

Jordan's extremely scarce water resources have heavily informed its national systems. The country has always used its water resources extraordinarily judiciously; the country withdraws only a fraction of the water supply its neighbours consume per capita (Figure 2.2). Jordan consumed around 100 m^3 per capita in 2010, versus over 1,500 m^3 per capita in the United States and around 900 m^3 per capita in neighbouring Egypt, Saudi Arabia, and Syria.[87] Even so, Jordan has managed to reduced its per capita withdrawal by half over the past 40 years while still providing over 97% of its growing population with improved drinking and sanitation services.[88] This is thanks in large part to Jordan's innovative leadership in the reuse of waste water; nearly 91% of treated waste water is reused for agriculture.[89] The country is equally advanced in greenhouses, water conveyance, irrigation systems, and other techniques for optimizing water-efficiency. A full 47% of the 310 million m^3 of water dedicated to irrigation annually is treated wastewater. As such, Jordan now allocates far less of its total water withdrawals to agriculture than other middle-income or even high-income countries (Figure 2.3). The agricultural sector consumes 40% of groundwater resources and 55% of surface water resources.

Figure 2.2 Water withdrawal per capita[90]

For municipal, industrial, and agricultural use (m³)

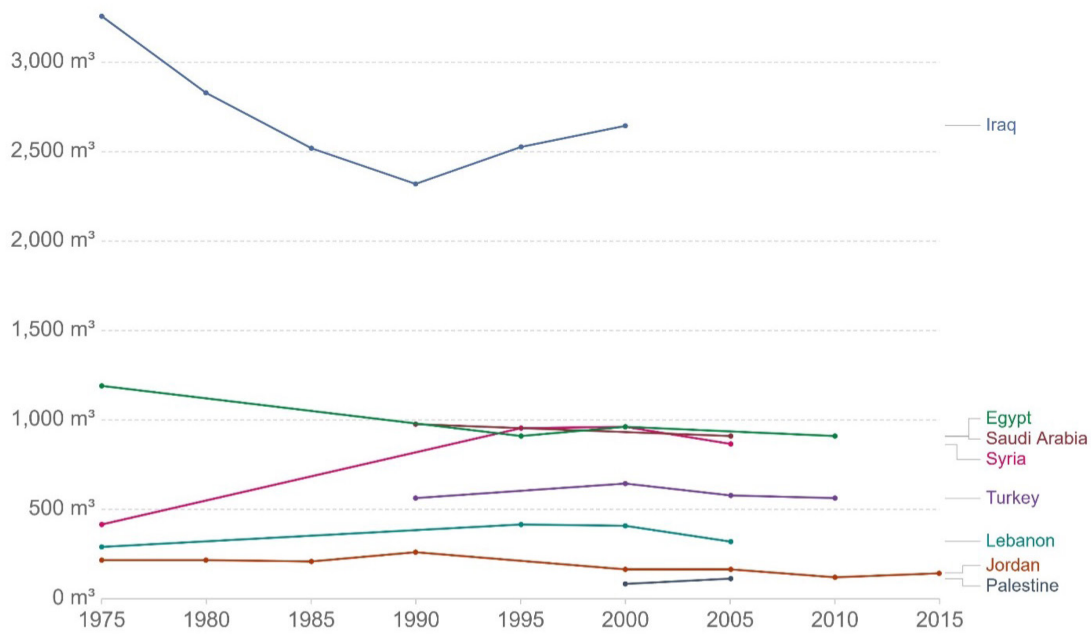
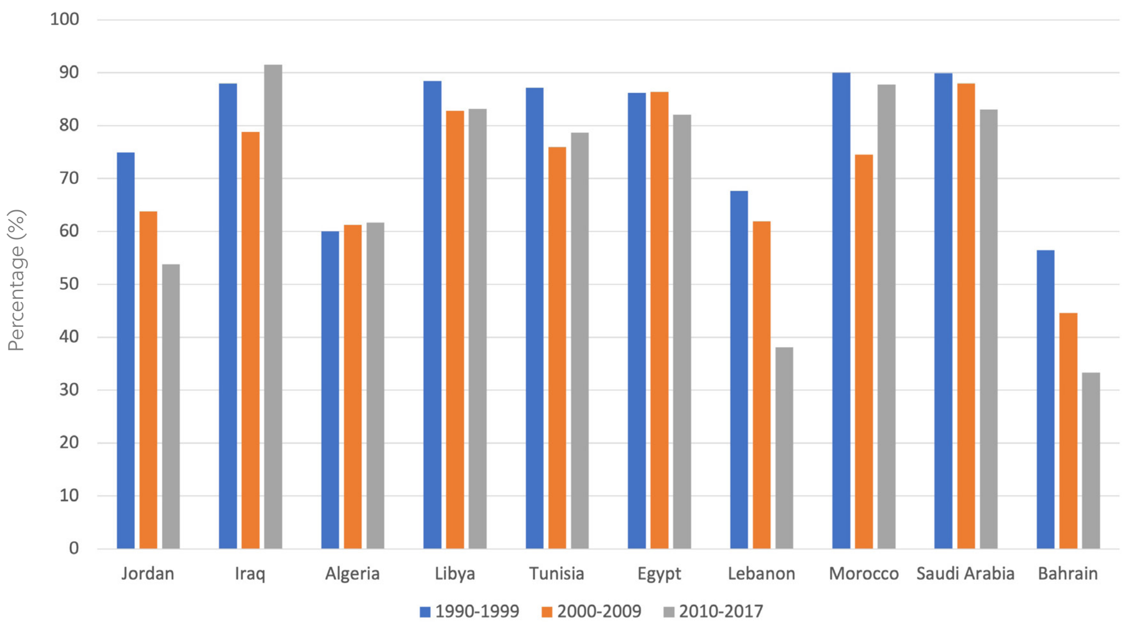


Figure 2.3: Change in water allocation to agriculture from overall withdrawals[91]



2.6 Greenhouse gas (GHG) emissions

The Jordanian energy sector produces the bulk of the nation's GHG emissions (73%), followed by waste (13%) and industry (9%).[92] Jordan's agricultural sector produced about 1.15 MT of GHG CO_2eq in 2017. This represents both a decrease in total emissions since 2006 (1.32 MT CO_2eq or 4.6% of total national emissions), as well as a 30% decrease in GHG intensity (MT/ha). Primary agricultural GHG emissions sources include enteric fermentation, manure left in pasture, nitrous emissions from agricultural soils, and secondary and tertiary emissions related to the agricultural sector, including portions of value chains, processing and the associated electricity production, industry, and transport.[93] The forestry sector reported 0.87 MT CO_2eq emissions in 2014 as a result of soil organic carbon loss in the rangelands.[94] This phenomenon is closely linked with unsustainable livestock practices, including overgrazing and the consequent land degradation. It represents an important area of mitigation potential in Jordan's agropastoral systems.

2.7 The institutional setting

The MoA is the primary actor charged with developing the agricultural sector. The MoA's mandate, including goals, rules, and responsibilities, is articulated in Agriculture Law 13 (2015). Within the MoA, the Agricultural Credit Corporation is in charge of financing agricultural activities, and the NARC is responsible for applied research.[95] The Ministry of Environment oversees the legal framework around climate change efforts, and the National Committee on Climate Change includes representatives of various ministries, civil societies, private enterprises, and academic institutions.[96] The Ministry of Water and Irrigation is responsible for all water resources, including those dedicated to irrigation, and supervises the Jordan Valley Authority, which oversees the irrigated AEZ. The Ministry of Water and Irrigation also hosts the National Drought Committee, which remotely monitors drought conditions.[97] The Ministry of Industry and Trade, the Ministry of Planning and International Collaboration, and the Department of Statistics also interact with the agriculture sector in terms of their respective fields.[98] Several universities offer higher degrees and research programming in crop science, animal science, and natural resource science.[99]

The private sector in Jordan has made important investments in date palms, but strong potential remains for private-sector involvement in other areas, such as financial services. This sector includes exporters, input traders, and farmer groups. Farmer groups are generally organized under five well-developed associations: the Veterinary Association, the Agricultural Inputs Traders' Association, the Agricultural Outputs Traders' Association, the Agricultural Engineers' Association, and the Vegetable and Fruit Producers' and Experts' Association.[100] Nevertheless, private-sector activity in Jordan remains far below potential. Activity in the rainfed AEZ is focused to olive oil production. Private-sector engagement is somewhat higher in the irrigated AEZ and includes imported inputs such as saplings, fertilizers, pesticides, seed varieties, equipment, and irrigation systems. Particularly high opportunity for private-sector engagement exists in the realm of financial services; there is only one agricultural credit institution in Jordan.[101] There is also significant opportunity for the private sector in poultry production, post-harvest management, value-addition, improved seeds and saplings, irrigation technology, and research.[102] The massive population of highly educated unemployed women represents huge potential for kick-starting Jordan's private sector economy.[103]

Most non-profit activities in Jordan center around the Syrian humanitarian crisis. Nevertheless, the country has received more than US$ 100 million since 2015 for climate-change related programming from World Bank, GEF-6, the Clean Technology Fund, the Green Climate Fund, and the Adaptation Fund.[104] Most notable among the resulting initiatives is the "Increasing the resilience of poor and vulnerable communities to climate change impacts in Jordan through implementing innovative projects in water and agriculture in support of adaptation to climate change" project. This US$ 9.2 million initiative, approved in 2015, is funded by the Adaptation Fund and hosted by the Ministry of Planning.[105]

Research is provided primarily by the MoA's NARC, while extension services - which used to be under NARC – is now a department under the MoA directly.[106] NARC's 8 regional centers and 13 research stations operate across 10 departments, ranging from Horticulture to Bees and from Field Crops to

Socioeconomic Studies.[107] Water management is a strong focus of NARC's research. NARC interfaces with farmers via service centers. The national extension has undergone multiple reforms over the past 30 years, and most recently has been struggling with the challenges of regional conflict and trade blockages.[108] Farmers have also reported a shift from mentoring to monitoring of agricultural activity; farmer unions have attempted to fill this gap with limited success.[109] Gender is an important aspect of the extension system, particularly in light of the growing focus on social welfare and community-based organizations.

The Jordan Valley Authority and the Water Authority of Jordan represent potentially valuable models for expanding and improving extension services in Jordan. In addition to their primary focus on water management, these self-governing groups of farmers also work together to provide extension and a wide variety of other services to their members, including business start-up support and agricultural road maintenance.[110]

2.8 The policy context

Jordan's National Economic Growth Plan has laid out several objectives in alignment with the SDGs and Millennium Development Goals that hold great potential impact for rural agricultural livelihoods. These include balancing production and consumption (SDG 12), doubling economic growth and job opportunities (SDG 8), promoting industry and innovation (SDG 9), improving energy security and affordability (SDG 7), and eliminating hunger (SDG 2) and poverty (SDG 1). Although the impact of the Economic Growth Plan is not yet evident, Jordan has generally demonstrated strong progress and expects to achieve SDG 2 by 2030. Nevertheless, the Syrian crisis, stagnating national growth, the COVID-19 pandemic, and the concomitant increases in investment needs have posed significant threats to continued progress toward these goals.[111]

Jordan is party to the Paris Agreement, and submitted its NDCs in November 2016 detailing the country's intent to reduce GHG emissions by 14%, with 12.5% reduction conditional on international financial support. [112] Jordan joined the NDC partnership in 2018, and in 2019 approved its NDC Action Plan, led by the Ministry of Environment and the Secretary General of the Ministry of Planning and International Cooperation. This action plan identifies priority areas for mitigation and adaptation. It also sets objectives for transitioning to a low-carbon climate-resilient economy, including bolstering the resilience of water resources and agriculture to climate change and mainstreaming climate change in local and regional development planning. Jordan is also party to several regional strategies, including the Arab Food Security Programme, Arabic Sustainable Agricultural Development, and the Food Security Strategy for Arabic and African Countries.[113]

There is currently no comprehensive policy for the protection of natural resources in Jordan.[114] Nevertheless, Jordan has historically been very active in international climate treaties, and the country's national climate policies demonstrate generally good alignment with these international commitments.[115] The National Climate Change Policy (2013-2020, slated to extend to 2030) is a key piece of legislation that informs various subsequent strategies and plans for a climate-resilient, low-carbon Jordan; the Third National Communication on Climate Change (2014) builds on the National Climate Change Policy with specific objectives, proposed actions, and projected impacts.[116]

The Green Growth National Action Plan also supports the NDC Action Plan and SDGs.[117] Additionally, in 2016 the Jordan Ministry of Agriculture launched its third National Strategy for Agricultural Development for 2016 to 2025 (updated to 2020-2025) as part of general national development efforts under Jordan Vision 2025. The National Strategy for Agricultural Development aims to increase agriculture's share of the GDP from 5.6% to 6.5%, increase agriculture's share of exports by from 16% to 21.3%, and increase irrigation efficiency by expanding the land area under drip irrigation and hydroponics.[118] The National Water Strategy 2016 – 2025 of the Jordan Ministry of Water and Irrigation sets non-revenue water (NRW) rate reduction – that is, lowering the percentage of water that is lost or unaccounted for in the system – as one of its highest priorities. Achievement of this goal would strongly inform Jordan's continued resiliency in the face of extreme water scarcity.[119] Other relevant policies include the Special Programme for Food Security, the Forest Strategy, the National Strategy and Action Plan to Combat Desertification, Comprehensive Food and Nutrition, Drought Mitigation, Poverty Alleviation, and the National Agenda.[120]

Jordan's national policy, however, does not a dequatrly support the sustainable growth of the agricultural sector. Agricultural investment overall is about half that of the regional average.[121] Irrigation water and pumping are incentivized, and the import tariff scheme encourages domestic production of crops that require significant water resources.[122] For example, barley imports have been subsidized for decades, discouraging domestic production and inflating the livestock sector beyond sustainable rangelands' carrying capacity.[123] Most land is public, and land partitioning legislation has led to significant fragmentation of privately owned land.[124] The country's overall Ease of Doing Business score for all sectors sat at 69.0/100 in 2020, versus Israel's 76.7, Saudi Arabia's 71.6, and Egypt's 60.1.[1125] This represents an 8 point increase from 2019.

2.9 Challenges in the agricultural sector

Jordan's agricultural sector is facing growing challenges as population pressures increase, including (i) production area, (ii) self-sufficiency and trade, (iii) natural resources, and (iv) the enabling environment.[126]

Production area

Crop production area in Jordan has been extraordinarily volatile over the past 40 years, varying from 11,270 km² in 1980 through peaks and valleys to an all-time low of 9,633 km² in 2007, and back up 10,670 km² as of 2016.[127] These drastic changes from one year to the next are associated with extreme annual variations in rainfall, and had an outsized impact in the rainfed AEZ, including the Amman, Balqa, and Irbid governates. Land fragmentation, which changes and limits potential land uses, may be one contributing factors to these fluctuations.[128] Low land tenure, which tend to stabilize land use patterns, and large influxes of refugees in need of settlement space may also be important factors. Such extreme variation in production implies inconsistent impacts across crop types; for example, the total area under vegetable production increased by over 10% between 1975 and 2007, the year in which total crop area hit an all-time low. By contrast, the area under barley production dropped by 59% from 2016 to 2017 alone, and wheat and legumes (including beans, chickpeas, and lentils) also saw decreases.[129] Such drastic changes in productivity have important implications for domestic food security and international trade.

Self-sufficiency and trade

Jordan depends heavily on imports for its staple foods, and import value exceeds exports by threefold.[130] Despite governmental efforts to build and maintain strategic stock and general storage facilities, the country has not and may not achieve self-sufficiency in wheat and barley, its two primary grain crops. This has been further exacerbated by a substantial increase in cereal as a portion of total food consumed since 2014.[131] At the same time, import prices have increased steadily as a result of various factors, including reduced trade routes, rising demand, high production costs, high import tariffs, the strong purchasing power of Gulf Cooperation Council visitors, and Jordanians receiving remittances from abroad.[132] Remittances source primarily from Gulf Cooperation Council countries, and comprised around 11% of the national GDP as of 2017.[133]

In addition, various regional and national factors have kept import and export trends in significant flux. Jordanian fruit and vegetable exports to Syria fell by more than 50% from 2011 to 2013, and the ISIL presence in Iraq caused a loss of more than 75% in exports to Iraq from 2011 to 2017. These regional crises also created opportunities for Jordan to occupy export marketed previously held by Syria and Iraq; thanks to a rapid re-orientation, total agricultural exports from Jordan to Gulf countries more than doubled from 2011 to 2017.[134] At the same time, refrigerated transport, post-harvest facilities, and airfreight options, which were already costly and disjointed, have been further weakened by the Syrian and Iraqi crises. This, along with a significant influx of refugees, robust national population growth, highly variable production, low crop diversification, inadequate food safety standards, and loss of productive land area, have certainly contributed to the expanding export-to-import gap ratio.[135] The COVID-19 pandemic has entrenched and exacerbated existing trade challenges.[136]

Natural resources

Jordan is ranked among the most water-scarce countries globally, along with nearly all its neighbours.[137] About 92.5% of Jordan's rainfall evaporates – this includes transpiration in rainfed and rangeland areas (green water); 5% recharges the groundwater, and 2.5% runs off to bodies of water. Jordan residents currently have access to an average of 61 litres/capita/day, with consumption rates ranging from 25 litres/capita/day in informal settlements to around 66 litres/capita/day in urbanized areas. These figures represent a significant reduction in water access since the beginning of the Syrian refugee crisis. Per capita water access could be significantly higher in Jordan; as of 2015, NRW rates in Jordan were around 65 litres/capita/day, which exceeded water provision. Only two thirds of groundwater withdrawal were safe yield, with the remainder exceeding natural recharge rates to tap non-renewable resources.[138] National water shortages averaged around 853 million m3 annually as of 2010. Demand is expected to increase by more than 26% by 2025 and reach an estimated 2,276 million m3 annually by 2040.[139] These figures imply an annual shortage of around 2,088 million m3 by 2040. Similar shortages are expected in the broader global region, largely eliminating the potential for water import and increasing the likelihood of water conflict.[140] Both water requirements and shortages would be significantly less without climate change.[141] Treated wastewater will continue to provide significant opportunities to reduce the water shortage; the wastewater system generated about 140 million m^3 in 2015, and as improved sanitation continues to expand, is expected to produce about 240 million m^3 annually by 2025. There are, nevertheless, health and quality concerns in using treated wastewater.[142]

Loss of vegetative cover is accelerating land degradation and desertification in Jordan. Besides overgrazing by livestock, land clearing associated with urbanization and quarrying is the most apparent driver of vegetation removal, and also catalyses erosion. Increasing climate variability, and particularly droughts and floods, exacerbate the loss of soil and vegetation. The increasingly frequent transport of livestock in vehicles on unpaved roads also contributes to this phenomenon. Excessive groundwater pumping and the associated salinization of groundwater further aggravates natural resource degradation in Jordan.[143]

The enabling environment

CSA in Jordan is challenged by a dearth of funding and weak institutional coordination among ministries and between the public and private sectors.[144] There are many public institutions charged with different aspects of the agricultural sector, and duplication, interference, and even policy conflicts frequently arise. The government needs a clear and well-coordinated policy approach incorporating food production, imports, and subsidies, among other key factors, to ensure Jordan's food system becomes and remains fit to endure repercussions of climate change and global emergencies. Similarly, there is a lack of comprehensive policy and planning for the protection of resources. Jordan's public spending on agriculture is far lower than that of most countries; Jordan's agricultural investment ratio hit an all-time low in 2010, and remains about half the regional average.[145] Despite declining public funds (and hence a growing plausible impact of private-sector investment), the potential role of the private sector and communities in rural development, innovation, finance, and resource management is systematically underestimated, and there is little or no engagement between public and private institutions. The government's Agricultural Council has aimed to coordinate public-private sector work with limited success.[146]

The Jordanian regulatory environment is particularly distortionary in terms of the ease of doing business. It generally inhibits business, particularly small businesses, foreign businesses, and women-led businesses.[147] Private-sector agricultural finance especially is compromised by current policy and remains virtually non-existent in the country. Along with weak land tenure, this dearth of financial services places extreme restrictions on opportunity for agricultural sector growth. The Syrian refugee crises and the COVID-19 pandemic have exacerbated this situation even further.[148] Concomitantly, the Jordanian government does not leverage the private sector's potential for addressing national issues such as water scarcity, food security, and climate resiliency.[149]

Chapter 3

Climate change and Jordanian agriculture

Highlights

- By 2030 temperatures are projected to increase 1–2°C and there will be a significant increase in the number of crop heat stress days throughout Jordan.
- Precipitation reductions of approximately 10% will be seen throughout the country by 2030, with the largest precipitation reductions occurring in the more fertile areas of the Jordan Valley and the rainfed zone.
- These changes will likely have negative effects on crop production by decreasing irrigation water availability and diminishing the suitability of key crops, such as potatoes.
- Crops such as wheat and barley, which are essential to sustaining livelihoods in rainfed and agropastoral zones, are and will remain only marginally adapted to Jordan's climate.
- Olives will remain suitable, while desert-adapted date palms are expected to increase in suitability, therefore creating a potential high-value market opportunity.
- Virtually all the agropastoral areas of Jordan will experience moderate livestock heat stress by 2030.

3.1 Climate impacts on agriculture to date

The degradation of Jordan's drylands is accelerated by climate change. There has been a steady decline in average annual rainfall across West Asia for the past several decades.[150] Future climate modelling indicates (i) further decreases in total precipitation, (ii) increasingly unpredictable and heterogeneous precipitation across the landscape, (iii) an increase in average temperatures of up to

4°C, (iv) increased rates of drought occurrence, length, and severity, and (v) more frequent extreme events, such as cyclones.[151]

The combination of declining average seasonal rainfall with increasing rainstorm intensity implies fewer and heavier rainstorms. This in turn creates conditions for greater frequency and severity of both major floods and droughts. Droughts of similar severity to the 1998-2000 drought, wherein 90% of the weather stations nationwide recorded severe or extreme drought, may double in frequency over the next 75 years.[152] Each one of these could be expected to bring the severe economic, environmental, and social losses commensurate with or greater than those of the 1998-2000 period. The resulting degradation of natural resources and agricultural losses could have grave implications for the national economy and food and nutritional security.

Decreased precipitation, increased temperatures, and more extreme drought conditions in tandem will markedly augment evapotranspiration and, consequently, plant water demands. This will increase Jordanian irrigated agriculture water demand by 5 to 20% by the 2070s.[153] Higher temperatures may also accelerate crop phenological phases, leading to reduced pollen viability, fertilization, grain filling, and fruit development, and crop yield loss.[154] These effects would have an outsized impact on Jordan's rainfed staple crops, including barley and wheat.[155] Indeed, an increase in average temperatures of just 2°C could decrease wheat production by around 10%.[156] The likelihood of crop failure will also rise, particularly when drought occurs during sensitive stages of crop development, such as the tillering and stem elongation periods of cereals.[157] Increased heat stress and extreme weather conditions may also limit the reproductive performance and increase the diseases and parasitic infection rates in livestock.[158]

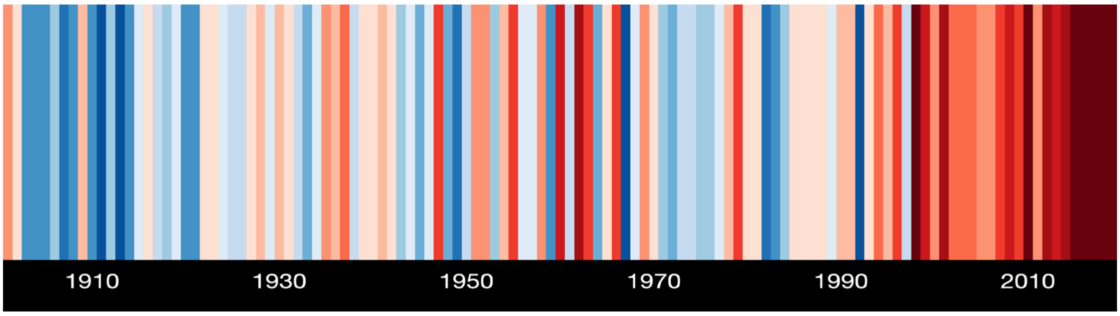
Occasionally, high pressure systems can lead to very cold conditions during specific parts of wintertime and cause widespread frost, affecting crops and fruit trees in the Jordan Valley and the highlands. Frost occurrence and impact are worst in the Joran Valley area as winter crops in the highlands are generally tolerant to frosts. The predictability of these weather systems and hence of frost is limited at seasonal to multi-decadal timescales. Hence, it is not possible to predict how frost dynamics in Jordan may change as a result of climate change. Nevertheless, these weather systems that lead to frost will keep occurring, although with changed intensity and frequency. Especially in the Jordan Valley, frost will remain a problem.[159]

3.2 Climate projections and risk

We assessed climate change in Jordan by first analyzing historical and projected changes in climatological mean temperature and precipitation. Historical climate trends since the 1960s indicate that annual maximum temperatures have increased by 0.3-1.8 °C, whereas minimum temperature have increased in the range 0.4-2.8 °C across the country (Figure 3.1). According to historical observations, there has been a decline in annual precipitation of about 5-20% across Jordan (6–27 mm per decade).[160] See Annex B for climate projections and risk methodology.

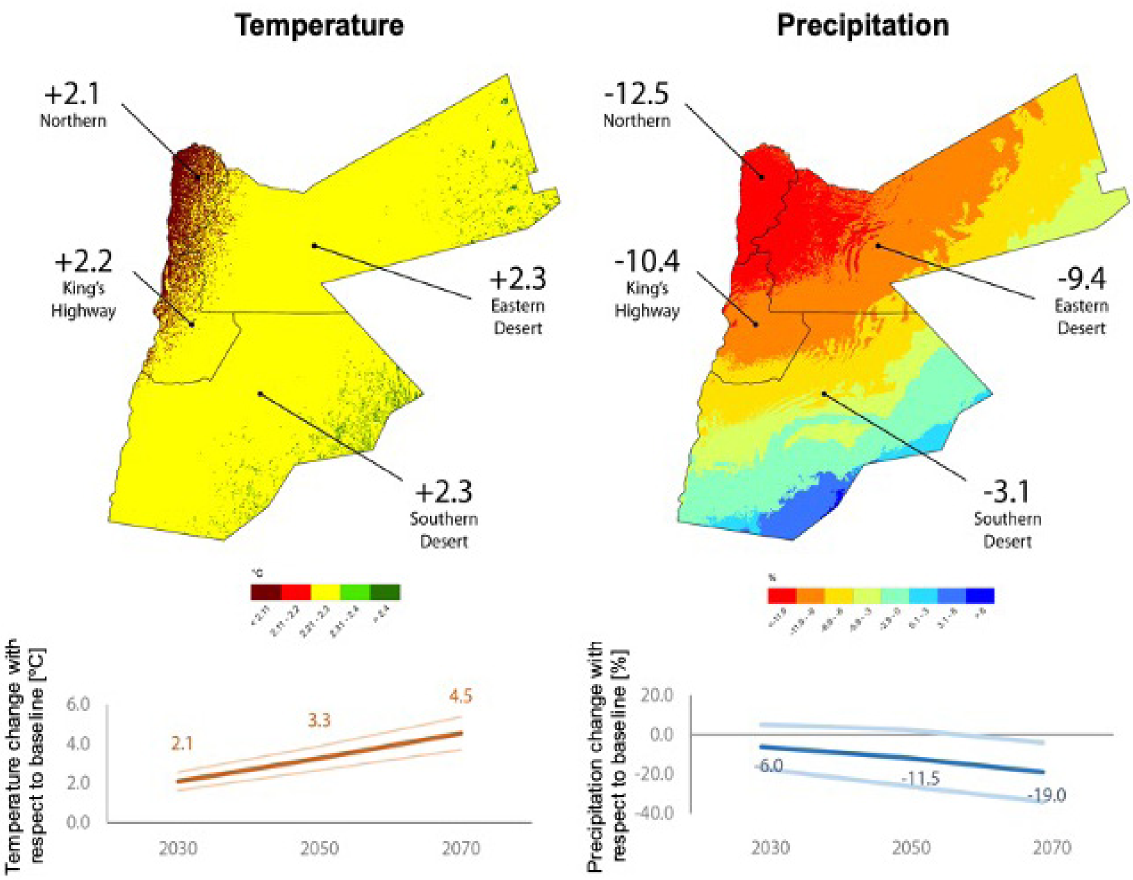
Figure 3.1 Annual mean temperature in Jordan[161]

Dark blue represents the coolest relative temperatures, dark red indicates the highest relative temperatures.



Total annual rainfall is projected to decline in the future. Climate models from the Coupled Model Intercomparison Project Phase 5 (CMIP5) ensemble project changes of precipitation in the future, with a decline of 6%, 11.5%, and 19% by 2030, 2050, and 2070, respectively (RCP 8.5, Figure 3.2). The whole country is expected to experience a decrease of precipitation. The northern region (12.5%) and King's Highway (10.4%) are projected to experience the largest precipitation declines by 2030. Projected rainfall decreases in the Eastern and Southern desert are 9.4% and 3.1%, respectively. Jordan's Eastern and Southern Desert regions (primarily rangelands) are likely to experience more warming than the Northern region and the King's Highway (mostly rainfed and irrigated agriculture).

Figure 3.2 Projected changes in annual mean temperature and precipitation in Jordan



3.3 Climate hazards

Here the occurrence and severity of physical climate hazards were assessed for the three AEZs of Jordan. Jordan is one of the driest and most arid countries in the Middle East. It is characterized by very low annual rainfall and hot summer temperatures. Minimum temperatures over the winter season can be as low as 5°C, whereas maximum temperatures over summer can reach more than 40°C. We present the analysis focusing only on Representative Concentration Pathway (RCP) 8.5, the high emissions trajectory, since it is the most consistent with the current observed global emissions trajectory, and because differences with other RCPs are negligible by 2030.[162] We focus on 2030 since it is an adequate near-term target for adaptation planning purposes.

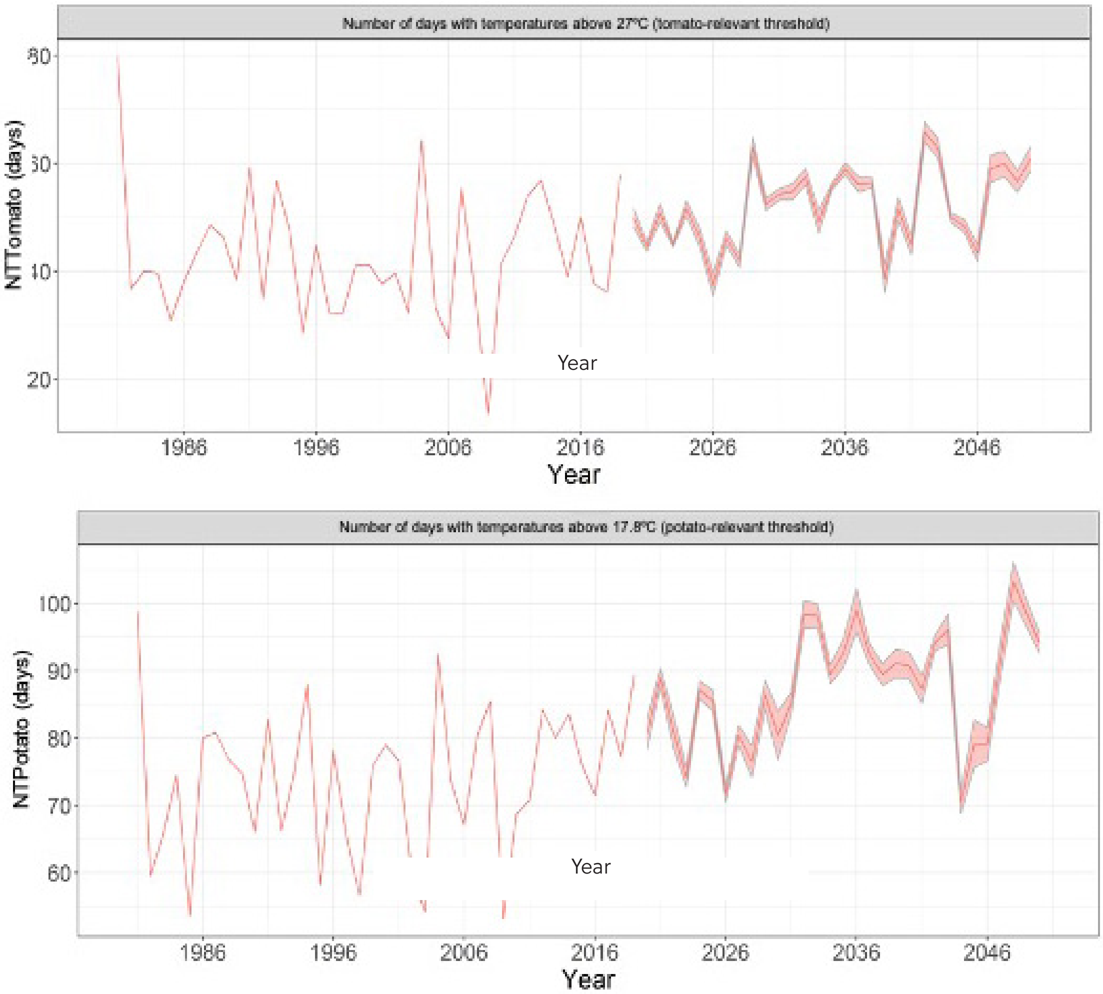
The climate hazards that are detrimental to agriculture include soil moisture stress with long dry spells and heat stress, both in terms of frequency and duration. These affect crops, livestock, and human labor, and therefore hinder agricultural production and development both directly and indirectly. The direct effects are mediated through physiological crop, pasture, and livestock responses to both heat and drought stress. The indirect effects manifest in many forms such as higher salinity; increased crop water needs, and hence declining ground water resources; the emergence of pests and diseases; and many other processes with feedback relationships.

The *irrigated* AEZ experiences a substantial number of hot days as well as long hot spells that affect a variety of fruits and vegetables grown in this area, including potatoes – a staple crop for Jordan. The average intensity of the wettest week, measured as the maximum amount of precipitation over a five-day period (P5D) for a season of interest, is relatively low both currently and in the future, suggesting that flooding is not an important hazard in Jordan. On the contrary, historically, there are instances when crops experienced many days with supra-optimal temperatures across the irrigated Jordan valley.

Tomatoes and date palms are two important food and cash crops in the irrigated AEZ. According to existing data, tomatoes have an upper optimum temperature of 27°C, whereas date palms grow well in temperatures of up to 45°C.[163] Data analysis indicates that date palm trees do not experience any heat stress throughout the year. Date palms can better tolerate very hot conditions, and though they are perennial and hence exposed to summer temperatures, our analysis shows that temperatures never exceed 45°C in summer in the irrigated AEZ. Hence, date palm cultivation, based on our analysis, is not expected to experience negative impacts from higher temperatures. Currently and under future scenarios, however, tomatoes likely experience at least 20–60 heat stress days distributed both at the start (October–November) and towards the end (March–April) of the rainy season. Hence, crops planted very early or very late could experience significant heat stress.

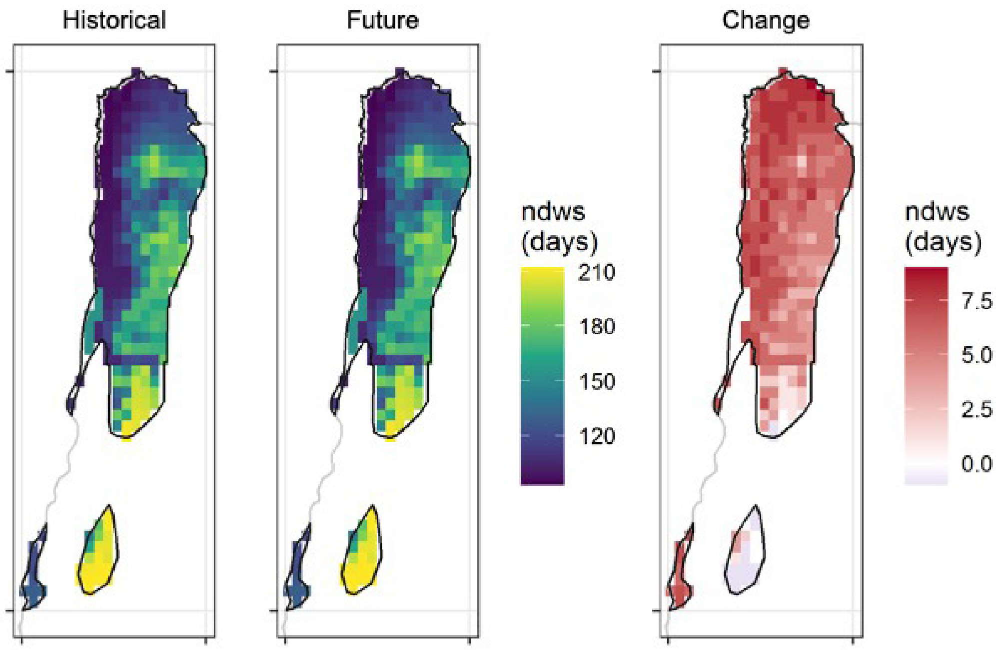
Future climate projections indicate that potatoes will be acutely affected by the increasing number of hot days in the growing season as well as by the increasing hot spells. Potatoes have a maximum optimum temperature of 17.8 °C.[164] On average, the winter season experiences around 70 hot days for potatoes, ranging from 50 to 100. These are concentrated especially towards tuber filling and harvest, around spring (Figure 3.3). Climate projections indicate that by 2030s, there could be an additional 10 hot days during the growing season. Many of these hot days occur toward spring, when potato crops are still in the field. Without adaptation, warm temperatures may dramatically reduce tuber formation and tuber weight. Similar results were projected for long hot spells. Hot spells can be on average up to 60 days long for potatoes and are projected to become on average ~10 days longer. Long hot spells can cause heat damage to potatoes and reduce tuber yield.

Figure 3.3 Historical and future projected trends of heat stress for tomatoes (top) and potatoes (bottom) for RCP 8.5



Moisture stress is an important hazard in the rainfed AEZ, where key crops such as potatoes, wheat, barley, and olives can experience wilting due to low moisture levels in the growing season. Previous studies have reported an increase in drought stress and hence of irrigation water requirements for olive-suitable areas in Jordan.[165] Historically the country has a high number of days with moisture stress in the growing season of rainfed areas (winter), and this trend is likely to continue until 2050 (Figure 3.4). Whereas the more fertile Jordan Valley shows a moderate-to-high number of water stress days (on average 90–100 days), the highland areas, especially towards the south, can be extremely dry, with almost the entire winter season experiencing soil moisture stress. Future climate projections indicate that the number of water stress days will increase by an average of 2–8 days, depending on the specific location and the climate change scenario or RCP.

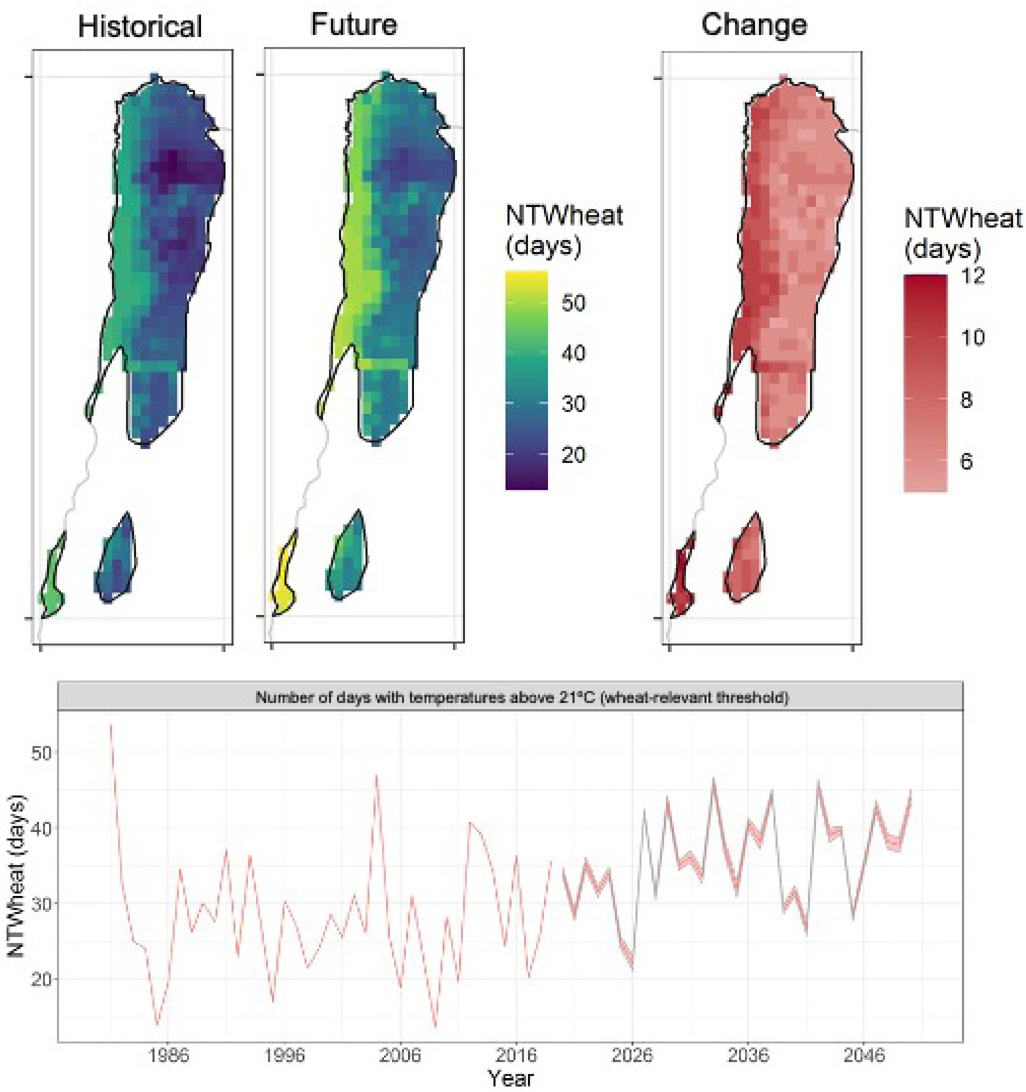
Figure 3.4 Historical and future occurrence and geographic distribution of moisture stress in the rainfed AEZ for RCP 8.5



Heat stress is also a major hazard across the ***rainfed AEZ***, affecting crop growth. Figure 3.5 shows the increasing number of days with heat stress for wheat. The results for barley are similar, since the optimal temperatures for barley are similar to those of wheat (~20°C). For potatoes, on the other hand, there are generally a greater number of days with heat stress across the AEZ. For olives, for which the reported upper-bound temperature is 34°C, heat stress during the winter season is not of concern, though the perennial nature of the crop means that it is exposed to summer temperatures. During the summer, olives can be exposed to high temperatures upwards of 35°C, though these conditions do not lead to any negative impacts.[166] A potential concern for olives, which we did not assess here, pertains to the systematic advancement of flowering, which might expose flower buds and flowers to high temperatures and hence decrease yield or fruit quality, even while the vegetative part of the crop continues to grow optimally. Previous studies suggest that flowering could occur up to 10 days earlier in Jordan, and this could reduce crop yield and farmer profits.[167] A second potential concern for olives is the prevalence of pests, and especially of the olive fly. In Jordan, however, the prevalence of the olive fly seems not to increase under future climate scenarios.[168]

For wheat, barley, and potatoes, supra-optimal temperatures are a hazard throughout the entire rainfed areas with 20–50 hot days on average for wheat and barley, and around 40–90 for potatoes during the winter season. Lower-elevation areas show the greatest exposure to heat stress, with as many as 50 days reaching hot temperatures for wheat and barley, and as many as 80 for potatoes. These heat stress days are typically concentrated towards spring, when grain filling and maturity occur for wheat and barley. These supra-optimal temperatures can accelerate crop senescence, reduce grain filling rates, and generally lower field crop productivity.[169] Future projections indicate that, on average, by the 2030s, crops could experience an additional 3–12 days with supra-optimal temperatures. Results also indicate relatively lengthy heat spells that are projected to increase in future climate scenarios.

Figure 3.5 Historical and future occurrence and geographic distribution of wheat heat stress in the rainfed AEZ for RCP 8.5



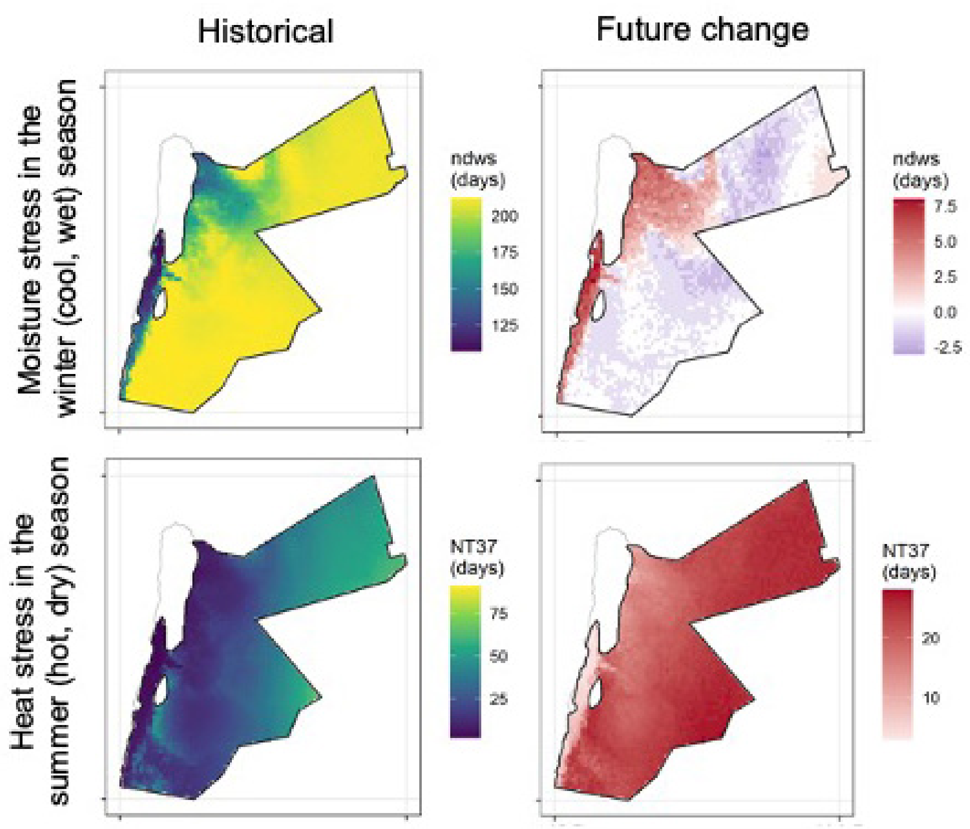
In general, for both the irrigated and the ***rainfed AEZs***, warming and drought stress can severely impact agricultural production. Temperatures, especially during spring, are already supra-optimal for wheat and potato growth on many days. Changes in the physical climate likely imply yield reductions, which are particularly worrisome for staple crops such as wheat and barley in rainfed areas. Some of these results have been reported previously, including by the Intergovernmental Panel on Climate Change (IPCC).[170] Jordan's barley yield may undergo reductions in the range of 25–50% by 2050, depending on the climate scenario used, with such reductions linked to declining precipitation and the co-occurrence during the reproductive period of many hot days (>34 °C).[171] Similar results are probable for winter wheat, with yield reductions of up to 40% by 2050.[172] Without adaptation, these projected changes and impacts are likely to reduce food availability and, for barley, also feed availability for livestock, thus leading to major impacts on agricultural livelihoods in Jordan.

The rangelands, or agropastoral AEZ (Badia), take up the vast majority of Jordan's land area. Jordan's rangelands are the driest and hottest areas of the country. The wet winter season is very dry, averaging

25 mm or less of rain per month and many moisture stress days (Figure 3.6, top). The summer is also dry, with no rainfall and many days (up to 60–80) with temperatures above 37°C, a threshold chosen to indicate livestock and human discomfort from heat (Figure 3.6, bottom). In the rangelands, rainfall is hardly enough to grow any crops, and livelihoods are primarily supported by livestock production. Indeed, the major economic use of the Badaia is pastoralism, and the most common animals herded are goats and sheep.[173] This livestock is raised on crop-residue, planted fodder, and grain-based systems with the rangeland contributing one to two months of livestock feeding per year.

The extent and intensity of water stress in the rangelands will remain severe throughout the entire agropastoral AEZ. Future climate projections indicate that the wetter areas will become generally drier, with an average 2–10 more moisture-stressed days in winter. Dry areas are projected to experience slightly less water stress. While winters are projected to also become hotter in the future, heat stress is a greater problem in the summer, where there are currently up to 80 days on average in some areas with temperatures above 37°C. These temperatures can hinder livestock productivity, and also affect human labor.[174] These stresses put the livestock sector at risk in terms of available grazing area and fodder. Currently, the livestock sector is already experiencing shortage of feeds, and climate change is projected to exacerbate this situation.

Figure 3.6 Soil moisture stress during the cool, wet winter season and heat stress during the hot, dry summer season for historical and future scenarios (2030s, RCP8.5)



Generally, the findings reported here indicate that Jordan is projected to become hotter and drier. The picture for Jordan is thus one of major challenges for agriculture and livestock production in the 2030s, and likely thereafter. These results generally agree with experts' perceptions of important risks (see Chapter 5, Figure 5.1), whereby heat and drought stress, including drought spells, water stress, and changing rainfall patterns, are identified as a risk by around 50% of respondents. Whereas other risks exist and were highlighted by experts, especially in relation to salinization and pests and diseases in irrigated areas, those were not assessed in our modelling work.

3.4 Climate change impacts on crop and livestock production

We modeled the suitability of important crops for the different AEZ. For the irrigated AEZ we modeled tomatoes, potatoes, and date palms; for the rainfed AEZ we analyzed potatoes, wheat, barley, and olives; and for the agropastoral AEZ we only analyzed barley. Crop parameters used are shown in Table 3.1, taken either from the Food and Agriculture Organization of the United Nations (FAO) EcoCrop database or from existing literature.[175]

Table 3.1 Crop ecological parameters used for the EcoCrop suitability model analysis

Crop	Growing season	Tkill (°C)	Tmin (°C)	Topmin (°C)	Topmax (°C)	Tmax (°C)	Rmin (mm)	Ropmin (mm)	Ropmax (mm)	Rmax (mm)
Potatoes	Oct–Mar	–0.8	3.8	12.4	17.8	24	150	251	326	785
Tomatoes	Oct–Mar	0	7	20	27	35	400	600	1300	1800
Date palms	All year	–4	5	15	45	52	100	500	2500	3500
Olives	All year	0	5	20	34	40	200	400	700	1200
Wheat	Oct–Mar	0	5	15	23	27	300	750	900	1600
Barley	Oct–Mar	–4	2	15	20	40	200	500	1000	2000

*Tkill: crop's cold killing temperature; Tmin: minimum temperature at which the crop grows; Topmin: minimum optimum temperature for crop growth; Topmax: maximum optimum suitability for crop growth; Tmax: maximum temperature for crop growth; Rmin: minimum rainfall required to sustain crop growth; Ropmin: minimum optimum rainfall for crop growth; Ropmax: maximum optimum rainfall for crop growth; and Rmax: maximum rainfall level at which the crop will grow.

For irrigated areas, results suggest that by 2030s, potatoes will become less suitable, whereas the suitability of tomatoes will increase (Figure 3.7). Potatoes are relatively heat-sensitive, and projected temperature increases by 2030s in the range 1–2°C, along with the significant increases in temperatures especially during the spring and autumn, mean that potatoes are likely to experience reduced suitability.[176] These changes can also potentially affect yield. Furthermore, although not assessed here, further warming, e.g., in the range of 2.5–3.5 °C by the 2050s, may lead to even greater suitability loss. According to EcoCrop model simulations, tomatoes are currently marginally suitable because temperatures are on average low in the middle of the winter months. Moderate warming is projected to increase tomato suitability from marginal to moderately suitable, representing continued opportunities for tomato cultivation under irrigation in Jordan.

Suitability model outputs for date palms (Fig. 3.8) indicate that, under irrigated systems, date palms either maintain their current levels of suitability, or, in the southern part of the Jordan Valley, their suitability increases from suitable to highly suitable. This result is partly due to the adaptation of date palms to hot and dry climates, but also due to the fact that these systems are irrigated and that our analysis assumes that irrigation water availability is not a constraint currently or in the future.

Figure 3.7: Potato and tomato suitability in the irrigated AEZ for historical and future scenarios (2030, RCP 8.5)

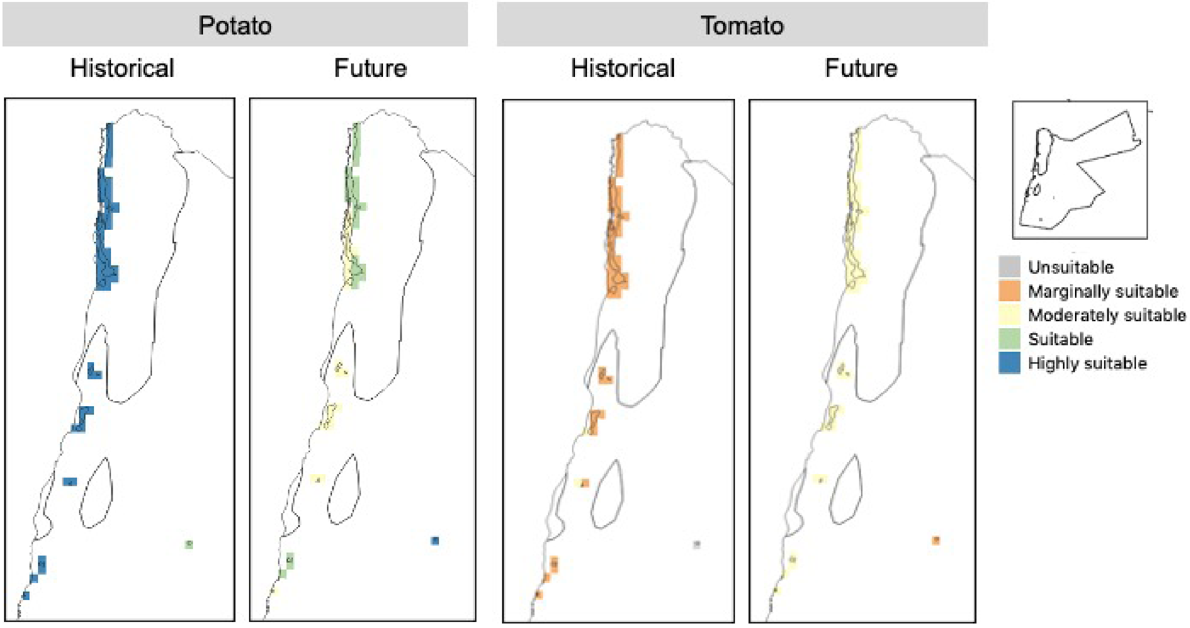
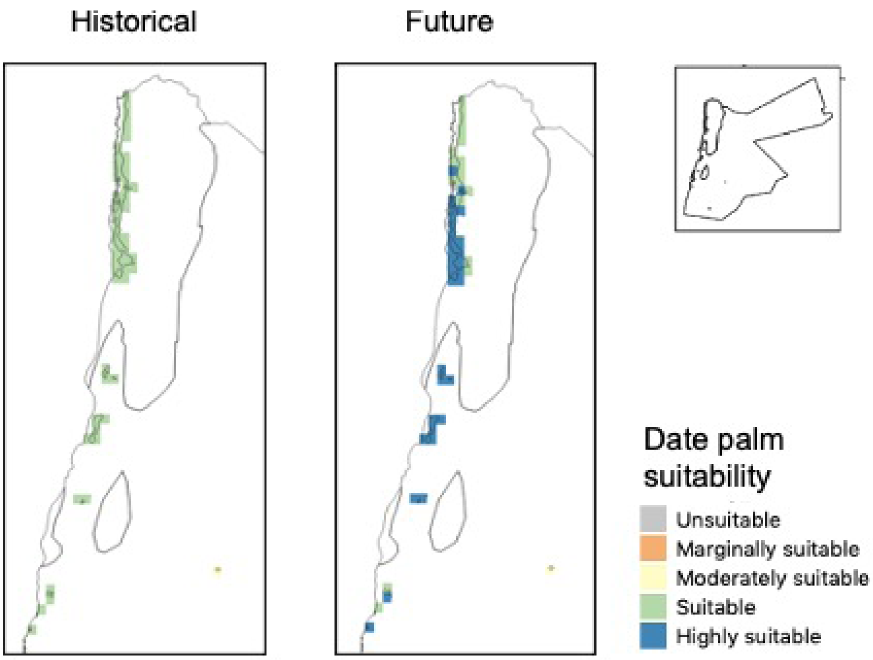
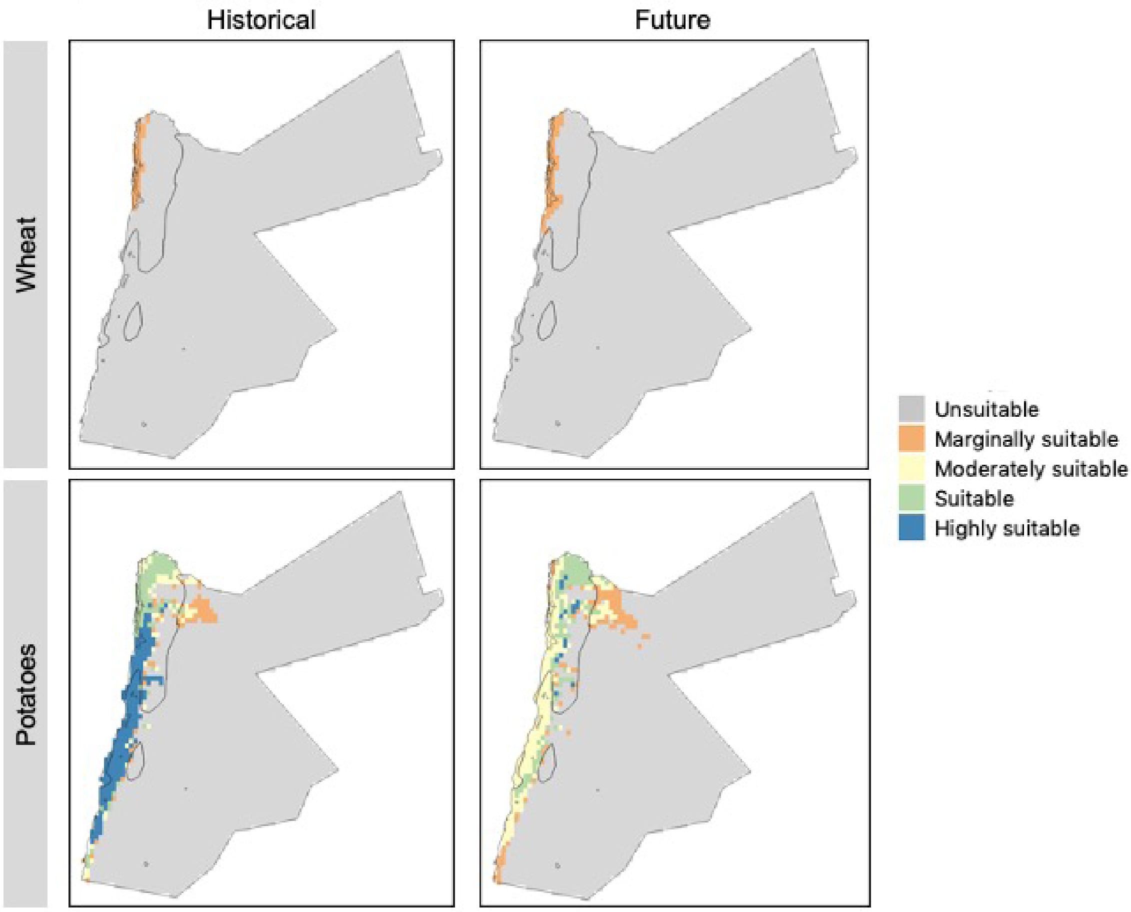


Figure 3.8: Date palm suitability in the irrigated AEZ for historical and future scenarios (2030, RCP 8.5)



In the ***rainfed AEZ***, wheat remains marginal and potatoes experience reduced suitability (Figure 3.9), while olive will remain suitable (Figure 3.10). For potatoes, these reductions are larger compared to the irrigated AEZ because of the projected decreases in seasonal rainfall during winter combined with numerous hot days during spring. Warming may make earlier planting in winter possible, offsetting some of the negative impacts observed here. Model results indicate that olives are moderately suitable in part of the rainfed zone (Fig. 3.10), and future projections suggest that the crop will remain suitable in 2030, though yield reductions may still occur in certain areas.[177] Investing in CSA practices that support wheat, olive, and potato production in the rainfed zone will be required to adapt to these changes.

Figure 3.9 Wheat and potato suitability in Jordan for historical and future scenarios (2030, RCP 8.5)



Areas in the east of the ***rainfed AEZ*** and the ***agropastoral AEZ*** **remain either marginally or moderately suitable, given the scarcity of rainfall water and the high temperatures.** In the west of the rainfed zone, crop distribution models show that the suitable area for barley will marginally increase (Figure 3.10). The rangeland is in fact hardly suitable for barley or any other of the crops analyzed here. Like any other grain crop, barley's limiting factor is water. Although, planting barley is not advised under rangeland conditions given the years of below-average rainfall,[178] water harvesting techniques can substantially increase productivity. Besides the potential impact of climate change on crops, direct physiological effects from heat stress for livestock are also expected (Fig. 3.11).

Figure 3.10 Barley and olive suitability in Jordan for historical and future scenarios (2030, RCP 8.5)

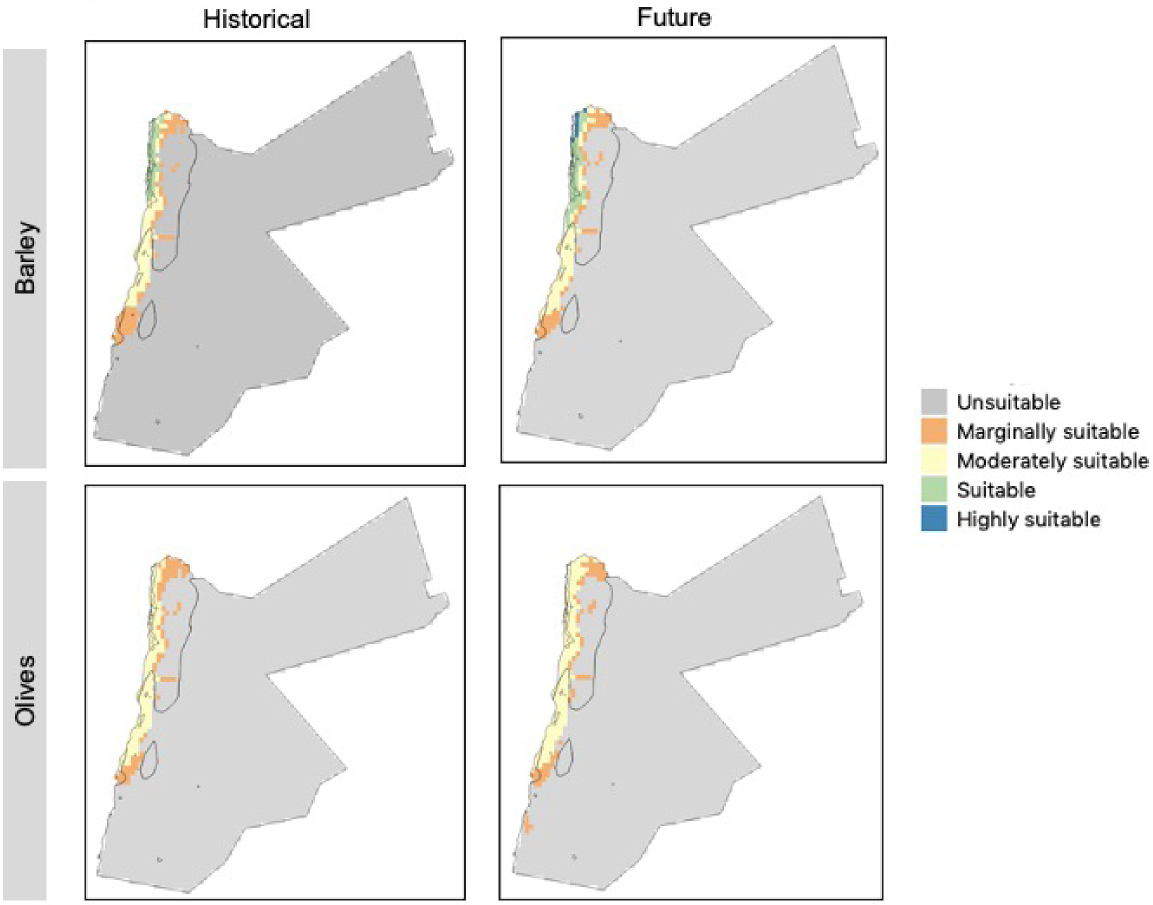
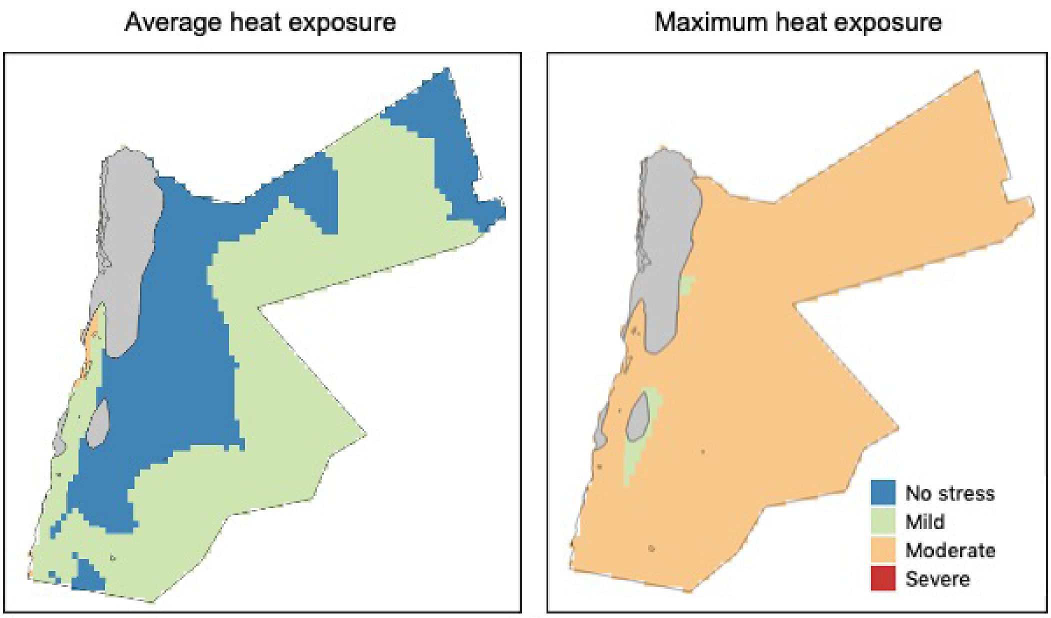


Figure 3.11 Thermal humidity index for cattle presented as average of the 12 months of the year (left) and for the warmest month of the year (right) (2030, RCP 8.5)



Covering a relatively wide range of key crops for the three AEZs of Jordan, our suitability analysis indicates that there will likely be "winners" and "losers", with rainfed agriculture and rangeland production taking the hardest hit. To better understand some of these climate impacts, we underscore the importance of conducting more comprehensive assessments that evaluate crop productivity using process-based models.[179] Furthermore, we have focused here on a relatively near time horizon (2030) because it is appropriate for adaptation planning. Many of the impacts identified here will likely worsen later in the century, as temperatures reach even more dangerous levels for crops and livestock

The impacts of climate change on agriculture in Jordan also include yield and crop losses due to less rainfall, reduced water available for irrigation, and increased water demand because of rising temperatures, shortened growing seasons, and desertification. These impacts are particularly relevant given that 65% of the country's harvest is grown under irrigation. Jordan's staple cereals, wheat and barley, are very sensitive to changes in climate. Barley yield is expected to decrease 25-50% by 2050 in Jordan due to increasing temperatures and reduced rainfall, which would have a significant impact on the availability of livestock feed. Declining rainfall and increasing temperatures will also continue to diminish water and pastureland for livestock.[180] Such marked reductions in crop and livestock productivity could further increase the country's reliance on imports and further reduce food security (see Chapter 4 on economic analysis for additional detail).

Chapter 4

Economic impact analysis

Highlights

- The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) simultaneously considers climate, socioeconomic, and crop scenarios to characterize each crop's response to climate change in terms of its performance in local and global markets.
- The model assumes an adequate supply of irrigation water, which in reality is expected to decline in the near future – a factor to take into account when interpreting the results.
- The yield of barley, tropical fruits, vegetables, and wheat is predicted to increase despite climate change.
- The area under crop cultivation increases slightly by 2050, while production increases more sharply. As such, competition for land among the different crops will likely heighten.
- Livestock numbers remain stable under climate change by 2050, and may prove essential to ensuring food security; the prices of lamb and dairy are projected to increase minimally by 2050 under all scenarios.
- Vegetables yields and prices will increase, thus decreasing overall food availability and increasing export; the impact on domestic consumption should be minimal.
- Potatoes, a regionally important crop, will see decreases in yield, area, availability, and demand, and production prices will rise by 2050.
- Jordan is expected to become more import-dependent, with 6 of the 8 regionally important commodities tending towards increased imports between now and 2050.
- Increased investment in climate-smart agriculture (CSA) would support both increased yields and water productivity, thus bolstering national food sovereignty and export within the abiotic boundaries of Jordan's natural resources.

4.1 Economic impacts of climate change

The economic analysis presented here uses the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT), an exploratory tool for assessing linkages between agricultural policy, climate change, and technologies in agricultural systems.[181] The IMPACT is scenario-driven in that different parameters may be specified using different scenarios (see also Annex C, including Table C.1.). The basis of the scenarios presented in this chapter is Shared Socioeconomic Pathway 2 (SSP2), a progression of population growth and changes in income that is widely seen as a "business-as-usual" scenario in that its characterization of socioeconomic trends is consistent with current global trajectories (less perturbations from COVID-19).

Model results are aggregated at the country level for a wide range of parameters such as price, food security, area, yield, and demand. Collectively, model results simultaneously consider climate, socioeconomic, and crop scenarios. With these results, we can illustrate potential regional differences in the impact of climate change and related policies and technologies both on local crops and on the same crops and their substitutes and complements traded at the global scale.

For the purposes of this study, we identify regionally important crops and the corresponding production systems based on criteria such as the nutritional value of the commodity, its economic value, and the area under production. For Jordan, a series of priority crops were identified, some modeled directly as part of the IMPACT methodology and others more generally represented under broader groupings of non-specific crops. In IMPACT, approximately 60 different commodities are represented with varying levels of fidelity. The list of priority crops that can be modeled in IMPACT is included in Annex C, Table C.2.

Key priority commodities for Jordan include vegetables, potatoes, barley and wheat, date palm and olive, as well as lamb, poultry and dairy. Eggplants, cucumbers, tomatoes, squash, and peppers are regionally important crops and are modeled under the category of vegetables. Dates are modeled under tropical fruits. Olives are a regionally important crop but are not modeled in IMPACT, neither as a specific category nor under a broader category. IMPACT does not currently include a dynamic livestock model, and model results thus serve as an indication of possible changes in the production of meat rather than as a precise response of animal models. Barley, potatoes, and wheat, on the other hand, are modeled using process-based crop models to simulate their responses relative to an ensemble of expected future climates.

Key supply-side variables relevant to Jordan's crops, livestock, and commodities include yield, area harvested, and numbers of animals. Other important variables are the price of commodities and local and international trade. Any of these variables has the potential to grow or shrink over time depending on factors such as the influence of climate, international markets, and internal investment in agriculture.

4.2 Changes in yield, area, production, and animal numbers

IMPACT characterizes each crop's response to climate change relative to its performance in its local economic context and, simultaneously, how it is faring in the global market. Thus, when IMPACT reports that a crop is expected to perform better or worse in the future, that projection takes into account not only the local impact of climate change on the crop and the corresponding yield but also, how the same crop is responding worldwide. Thus, for crops that perform well in the Jordanian context, Jordan has a comparative advantage relative to other producers of the same commodity.

Except for potatoes, all the selected crops experience a relative increase in yield, which is defined as production per unit of area, under conditions of climate change (CC). That is, yields improve when considering the relative productivity of these crops as compared to other local crops, as well as how these crops perform in the global marketplace. Factors that may influence yield include additional investment, better input prices, and expected increases in productivity through either genetic gains or improved agronomic practices.[182] By 2050, increases in yield tend to range between 10-20 percentage points (Table 4.1). The difference between RCP4.5 and RCP8.5 is minimal, with impact under the two carbon concentration pathways differing by less than 1 percentage point.

Table 4.1 The impact on yield of two CC scenarios (RCP4.5 and RCP8.5) compared to NoCC scenario by 2050

Commodity	NoCC (%)	CC RCP 4.5 2020-2050 (%)	RCP4.5 impact (percentage points)	CC RCP 8.5 2020-2050 (%)	RCP8.5 impact (percentage points)
Barley	62.1	78.6	16.5	78.8	16.7
Potato	25.8	19.7	-6.1	13.7	-12.1
Tropical fruit	50.3	63.8	13.5	63.0	12.7
Vegetables	49.5	62.1	12.7	61.4	11.9
Wheat	77.2	96.4	19.2	97.1	19.9

The area under cultivation for the key crops (see Chapter 2, Table 2.1 for an overview) is projected to remain relatively stable under conditions of climate change (Table 4.2). Barley and potatoes show lost area under CC compared to no climate change (NoCC), while vegetables and wheat see modest increases in area, and tropical fruit a slightly higher increase. Once again, the difference between the two climate scenarios appears to lack a clear signal. Overall, increases in area under scenarios of both CC and NoCC are less accentuated than increases in production, as evident in both RCP4.5 (Figure 4.1) and RCP8.5 (Figure 4.2).

Table 4.2 The impact on area of two CC scenarios (RCP4.5 and RCP8.5) compared to NoCC by 2050

Commodity	NoCC (%)	CC RCP 4.5 2020-2050 (%)	RCP4.5 impact (percentage points)	CC RCP 8.5 2020-2050 (%)	RCP8.5 impact (percentage points)
Barley	9.6	7.9	-1.7	8	-1.6
Potato	1.7	-0.6	-2.3	-2	-3.7
Tropical fruit	13.9	18.7	4.8	18.7	4.8
Vegetables	30	32.5	2.6	32.3	2.4
Wheat	12.9	14.7	1.8	15.8	2.9

Figure 4.1: The impact of CC RCP4.5 on yield, area, and production of crops by 2050

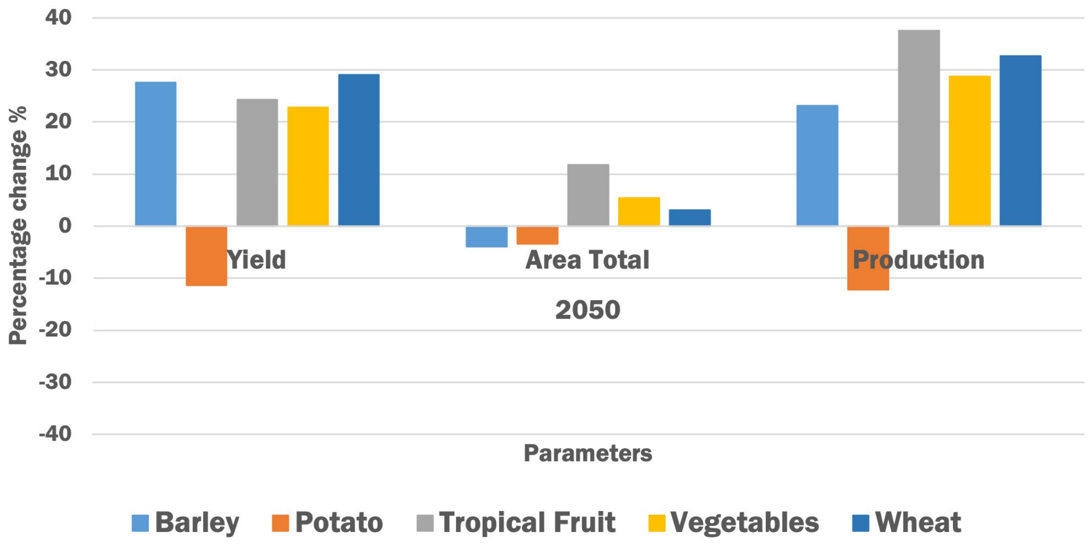
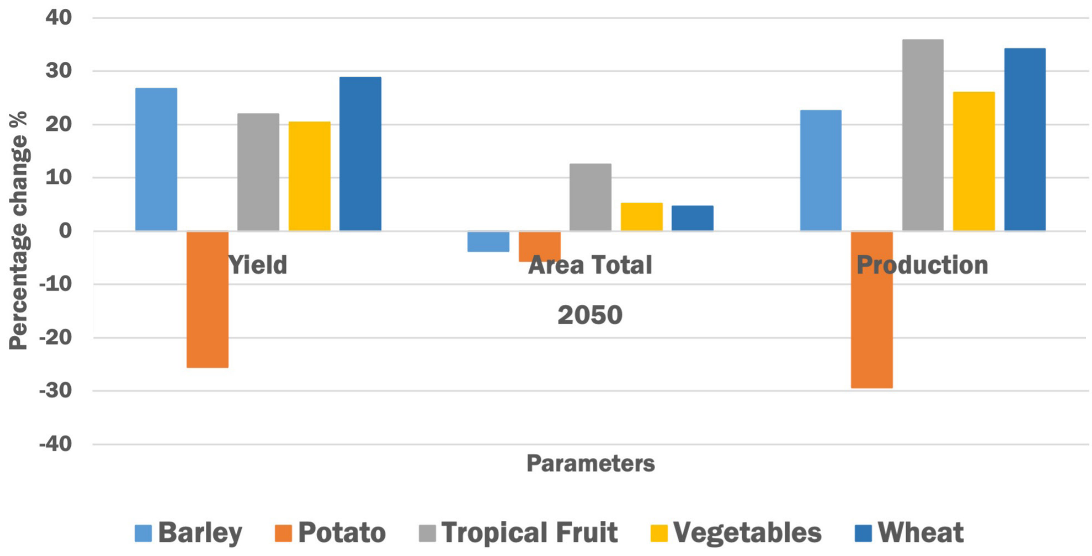


Figure 4.2: The impact of CC RCP8.5 on yield, area, and production of crops by 2050



The projection that the area of land under cultivation will not increase at the same rate as production indicates that agricultural practices will intensify through improved practices and technology rather than by using more land (Table 4.3). Though small, there will be an increase in the area under cultivation for tropical fruits, vegetables, and wheat, which may drive competition for land in a country that already has limited arable land.

Production is projected to increase under both CC scenarios for barley, tropical fruit, vegetables, and wheat. Negligible increases are expected for dairy, poultry, and relative decreases in production are expected for potatoes and lamb under conditions of climate change.

Table 4.3: The impact on production of two CC scenarios (RCP4.5 and RCP8.5) compared to NoCC by 2050

Commodity	NoCC (%)	CC RCP 4.5 2020-2050 (%)	RCP4.5 impact (percentage points)	CC RCP 8.5 2020-2050 (%)	RCP8.5 impact (percentage points)
Barley	77.8	92.8	15.1	93.2	15.4
Potato	27.9	19.9	-8	11.8	-16.1
Tropical fruit	71.3	94.5	23.2	93.5	22.3
Vegetables	94.3	114.9	20.6	113.6	19.3
Wheat	100	125.3	25.2	128.2	28.1
Dairy	145.9	146.4	0.6	146.2	0.3
Lamb	159.6	159.5	-0.1	159	-0.6
Poultry	190.1	191	0.9	190.5	0.5

Model results also indicate that climate change will have a relatively small impact on livestock numbers (Table 4.4). Lamb populations decrease by 0.1 percentage points and 0.4 percentage points under CC RCP4.5 and 8.5 respectively. Dairy and poultry experience slight increases between 0.2-0.4 percentage points under CC compared to NoCC by 2050. There is effectively no shift in these commodities relative to climate change, suggesting that they are relatively stable and resistant to climate change given the demand and quantities produced.

Table 4.4 The impact on livestock populations of two CC scenarios (RCP4.5 and RCP8.5) compared to NoCC by 2050

Commodity	NoCC (%)	CC RCP 4.5 2020-2050 (%)	RCP4.5 impact (percentage points)	CC RCP 8.5 2020-2050 (%)	RCP8.5 impact (percentage points)
Dairy	46.1	46.4	0.3	46.2	0.2
Lamb	52.3	52.2	-0.1	52	-0.4
Poultry	21.3	21.7	0.4	21.5	0.2

4.3 Changes in food availability, household demand, and food prices

The expected food availability of all crops and livestock will experience a small negative impact from climate change of less than 1 percentage point for most commodities (Table 4.5). For these projections, food availability is measured as the number of kilocalories available to each person, each day, from both local production and international trade. The exceptions are barley, whose food availability undergoes a modest increase under CC scenarios in comparison to NoCC, and potatoes, which will experience a negative impact between 3-4 percentage points for both CC scenarios compared to NoCC by 2050. Overall, the impact of climate change on food availability appears to be small, likely due to the relatively limited areas under cultivation and to with Jordan's dependence on imports.

Table 4.5 The impact on food availability of two CC scenarios (RCP4.5 and RCP8.5) compared to NoCC by 2050

Commodity	NoCC (%)	CC RCP 4.5 2020-2050 (%)	RCP4.5 impact (percentage points)	CC RCP 8.5 2020-2050 (%)	RCP8.5 impact (percentage points)
Barley	1.7	2.3	0.7	2.3	0.6
Potato	18.5	15.4	-3.1	14.6	-3.9
Tropical fruit	42.3	39.4	-2.9	38.9	-3.4
Vegetables	44.7	44.1	-0.6	43.8	-0.9
Wheat	-0.2	-0.3	-0.1	-0.8	-0.6
Dairy	16.6	16.6	0	16.4	-0.1
Lamb	66.1	66.1	0	66.0	-0.1
Poultry	43.8	43.7	-0.2	43.4	-0.4

The total demand for food derives from simulated consumer behavior in response to food price and income among other factors. For instance, when the production of a commodity decreases, the price typically increases, resulting in lower demand by consumers for the commodity in question. This is a simplified example, however; real-world trends are complex and depend on interactions with a variety of other aspects, including the corresponding prices for both substitute and complementary commodities.

In comparison to the NoCC scenario, conditions of climate change result in slight declines in total demand for the selected crops and livestock, with the exception of barley and wheat (Table 4.6). Negative impacts are minimal except for potatoes and tropical fruit, which again show a larger decrease of between 5 and 8 percentage points under CC. In a middle-income country such as Jordan, such slight declines in food supply do not adversely affect overall access to food given existing surpluses and the capacity for importation.

Table 4.6 The impact on food demand of two CC scenarios (RCP4.5 and RCP8.5) compared to NoCC by 2050

Commodity	NoCC (%)	CC RCP 4.5 2020-2050 (%)	RCP4.5 impact (percentage points)	CC RCP 8.5 2020-2050 (%)	RCP8.5 impact (percentage points)
Barley	142.6	150.5	7.9	154.4	11.8
Potato	117.1	110.8	-6.3	109.1	-7.9
Tropical fruit	136.0	131.2	-4.8	130.3	-5.7
Vegetables	141.6	140.5	-1.1	140.1	-1.5
Wheat	65.5	71.6	6.1	74.9	9.4
Dairy	93.3	93.3	0	93.1	-0.2
Lamb	175.5	175.5	0	175.3	-0.2
Poultry	138.5	138.2	-0.3	137.8	-0.7

While the declines in food supply do not adversely affect access to food, they will influence food prices. Under conditions of climate change, prices will increase across the board, with the exception of barley. These price increases are most pronounced for potatoes and tropical fruit, followed by vegetables, and wheat, and this trend is consistent with the corresponding declines in the projected food availability associated with these crops (Table 4.7).

Table 4.7: The impact on producer prices of two CC scenarios (RCP4.5 and RCP8.5) compared to NoCC by 2050

Commodity	NoCC (%)	CC RCP 4.5 2020-2050 (%)	RCP4.5 impact (percentage points)	CC RCP 8.5 2020-2050 (%)	RCP8.5 impact (percentage points)
Barley	9	4.2	-4.9	5.4	-3.7
Potato	7.2	17.1	9.9	20.2	13
Tropical fruit	10.6	17.9	7.3	19.8	9.2
Vegetables	28.5	32.1	3.7	33.9	5.5
Wheat	11.3	12.5	1.2	15.5	4.2
Dairy	4.2	4.4	0.3	4.8	0.6
Lamb	-10	-9.6	0.4	-9.2	0.8
Poultry	4.6	6.3	1.7	7.8	3.2

4.4 Changes in trade

From 2020 to 2050, a subset of the priority commodities shows increasing differentiation in trade over time, irrespective of the climate change scenario. As illustrated in the previous sections, climate change can propel production in both positive and negative directions which, in turn, drives the associated surplus or deficit of commodities. These surpluses and deficits can then be alleviated through international trade.

Changes in net trade are calculated in IMPACT by a function of domestic production, domestic demand, and changes in stock. A positive net trade indicates a trend towards exportation of a commodity, while a negative net trade indicates a trend towards importation. Figures 4.3 and 4.4 below show commodity trade trends over time, illustrating changes in imports and exports in terms of millions of tons. Under both CC scenarios, the model projects increasing export of vegetables; this result is consistent with recent trade studies reflecting an average of 11% growth per year and over 80% growth of total exported commodities in some years.[183] Under both the RCP4.5 and RCP8.5 CC scenarios, there a tendency toward increasing imports of both barley and wheat, illustrating that demand will outstrip domestic supply in spite of the fact that these crops tend to fare well in both CC scenarios.

Figure 4.3 Impact of CC RPC4.5 on net trade of key commodities from 2020 to 2050 (millions of tonnes)

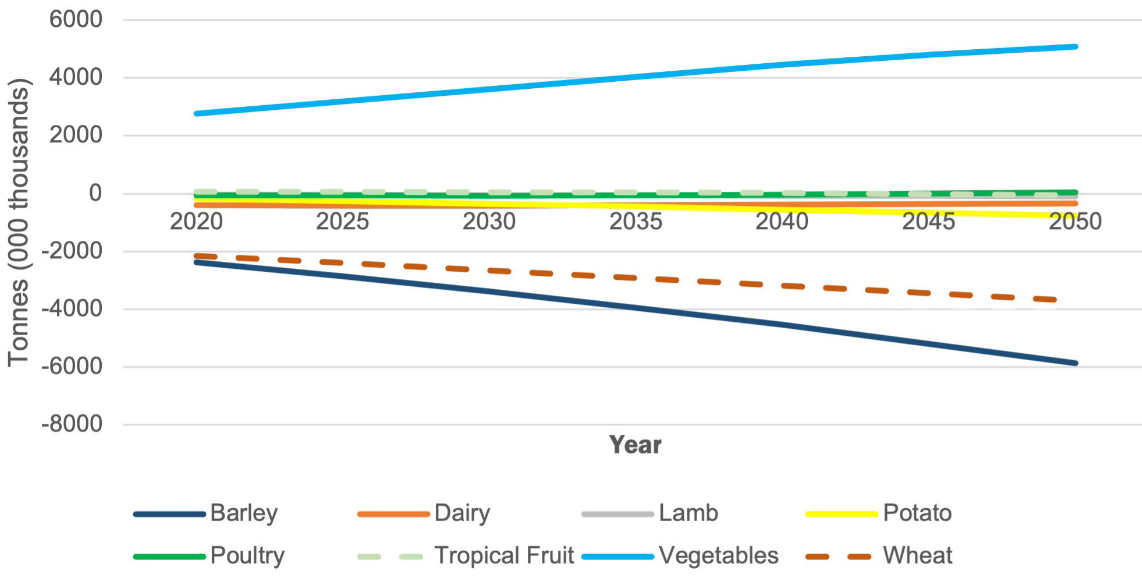
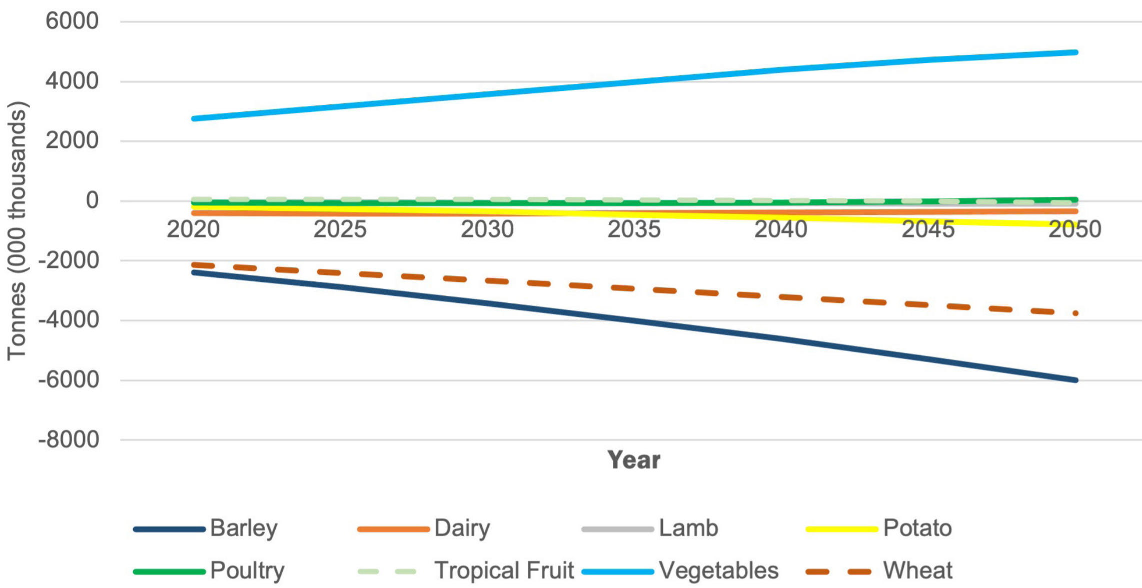


Figure 4.4 Impact of CC RPC8.5 on net trade of key commodities from 2020 to 2050 (millions of tonnes)



Rates of change of imports and exports are relative, so it is useful to examine the net change in imports both over time and across the climate change scenarios. Table 4.8 demonstrates that, with the exception of tropical fruit and dairy, imports are expected to increase over time. CC scenarios tend to favor tropical fruit, lowering import dependence over time, whereas imports of potatoes are expected to increase substantially more under RCP8.5 than in conditions associated with RCP4.5.

Exports of vegetables are projected to increase in all scenarios. Vegetables comprise the only commodity in this study that is characterize by a substantial surplus and associated exports. It is notable that vegetable exports are expected to increase substantially more under CC conditions than NoCC, nearly doubling in both CC scenarios. Vegetable exports rise slightly less under RCP8.5 than under the milder RCP4.5 scenario (Table 4.9).

Poultry is not present in Tables 4.8 or 4.9 because the trends for this commodity are unclear. From the data, it is apparent that under both CC scenarios, poultry shows an initial, slowing trend towards importation from 2020 to 2045, but then reaches equilibrium and begins to show an increasing trend towards exportation between 2045 and 2050.

Table 4.8 Crops and livestock that show negative net trade (import) trends under two CC scenarios (RCP4.5 and RCP8.5) compared to NoCC by 2050

Commodity	NoCC (%)	CC RCP 4.5 2020-2050 (%)	RCP4.5 impact (percentage points)	CC RCP 8.5 2020-2050 (%)	RCP8.5 impact (percentage points)
Barley	144.3	152	7.8	156	11.7
Potato	331.3	330.6	-0.8	349.6	18.2
Tropical fruit	-1474.4	-289.7	1184.8	-296.3	1178.1
Wheat	64.6	70.1	5.5	73.4	8.8
Dairy	-30.1	-31.5	-1.4	-31.2	-1.1
Lamb	200.5	200.8	0.3	201	0.5

Table 4.9 : Crops and livestock that show positive net trade (export) trends under two CC scenarios (RCP4.5 and RCP8.5) compared to NoCC by 2050

Commodity	NoCC (%)	CC RCP 4.5 2020-2050 (%)	RCP4.5 impact (percentage points)	CC RCP 8.5 2020-2050 (%)	RCP8.5 impact (percentage points)
Vegetables	46.3	90.5	44.3	88.3	42.1

Chapter 5

Prioritization of Climate-Smart Agriculture (CSA) interventions in Jordan

Highlights

- Climate-smart agriculture (CSA) investments were chosen through a multistep prioritization process involving nearly 50 experts from various fields.
- National documents were reviewed to first identify 46 practices with potential for CSA; these were narrowed down to 16 packages.
- Experts considered the important policy objectives when prioritizing packages, including food security, reduced price volatility, value chain development, and youth employment, but priorities differ between AEZs.
- Experts assessed the packages against the three CSA pillars – adaptation, mitigation, and productivity – and considered their potential for scaling, then evaluated their scores to select the most promising.
- Expert panels were organized within each AEZ to discuss key challenges, business models, and policy incentives. Two CSA packages were selected for each AEZ, at least one of which has a clear commodity value chain focus.
- For the irrigated AEZ, high-value date palm development and protected vegetable production was prioritized. For the rainfed AEZ, enhanced olive production and processing and improved field crop management was prioritized. Enhanced small ruminant production and Badia restoration were the optimal investment packages for the agropastoral AEZ.

5.1 Process to prioritize CSA investments

CSA aims to achieve adaptation, mitigation, and productivity outcomes, but doing so requires understanding what "climate-smart" means in different locations and designing projects suited to the diverse contexts. The prioritization process of investment options generally follows the CSA Prioritization Framework and builds on the initiatives and work of government agencies and local institutions.[184]

The first step in developing this CSA investment portfolio was a review of national documents including policies, strategies, and plans, in order to identify practices with potential to be applied in the context of CSA. A longlist of 46 CSA practices was enumerated based on key commodity groups, namely vegetables, fruits, field crops, and animals, as well as on soil and water conditions. After an initial screening by a small group of experts, some practices were eliminated, while others that complemented each other or pertained to the same commodity or process were combined into 16 CSA packages: 6 for irrigated areas, 4 for rainfed areas, 3 for agropastoral areas, and 3 that could be applied in all areas. The shortlist of CSA packages is summarized in Table 5.1, with an extensive description for each package in Annex D.

Table 5.1 Shortlist of CSA packages assessed by national experts

CSA package
Irrigated AEZ
1. **High-value date palm development**, processing, and marketing using modern irrigation systems and improved cultural practices
2. Expanding/upgrading **protected vegetable production** with drip irrigation and improved greenhouse technologies
3. Advancing inland **freshwater fish productio**n for local nutritional food security through improved breeds/practices
4. Upgrading **irrigation water productivity** by modernizing systems, shifting to high-value cash crops, and applying precision agriculture
5. Strengthening the **energy-water-food nexus** in irrigated agriculture by replacing fossil fuel for pumps and local desalination units with renewable solar energy
6. Decentralizing **treatment of sewage water** in agriculture at the community level, supporting greywater treatment at the household level, and managing integrated treated sewage with rainwater in supplemental irrigation systems
Rainfed AEZ
7. Upgrading **olive production and processing** by introducing low-cost, modern technologies for collection, cold pressing, and pickling, and through alternative use of waste
8. **Soil health improvement** through increased infiltration and greater soil-health storage capacity through the adoption of contouring, terracing, appropriate plows, polymers, and the use of organic matter
9. **Agroforestry packages** to reforest most of the suitable marginal lands in 10 years by planting trees and shrubs and creating development programs for follow-up
10. Enhanced **the management and effictivness of rainwater for field crop** and value addition, upgrading the durum wheat value chain for higher income, and expanding barley production for animal feed with rainwater harvesting
Rangeland AEZ
11. Enhancing **small ruminant production** and quality with concentrated farming, including byproduct processing, fattening, and advanced breeding
12. Strengthening the **dairy value chain** at industry and community levels through collective cold storage powered by renewable energy and through training with a proper institutional setup
13. **Badia restoration** with micro-catchment water harvesting and improved grazing management

All AEZs

14. **Rainwater harvesting** for domestic and agricultural use
15. Expanding **hydroponic and aeroponic practices** for high-value vegetables using groundwater
16. Upgrading the **poultry industry and value chai**n with local feed production and collective cold storage powered by renewable energy

As a second step, an online survey was shared among 200 experts to evaluate the CSA packages for each AEZ. In total, 48 experts completed the survey, of which 38, 40, and 23 completed the sections for irrigated, rainfed, and agropastoral areas, respectively. Participants included mainly men (79%) but also women (21%) and predominantly hailed from academia (46%), government ministries (29%), and research organizations (19%); some came from non-governmental organizations (NGOs) or were independent consultants. Most participants were between 45-54 years of age (44%), followed by 35-44 years (25%), 55-64 years (19%), and 65 years of age and older (13%).

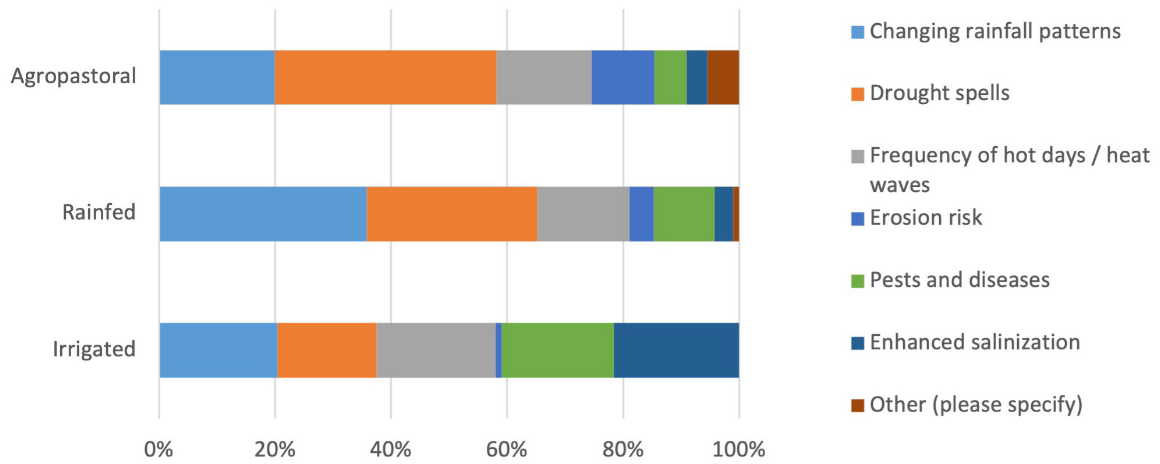
The third step in the prioritization process was panel meetings with experts from within and outside the government, complemented by experts from financial institutions and the private sector. These experts contributed to the final section of CSA investments.

5.2 Assessment of climate hazards, other risks, and policy objectives

Before evaluating the CSA packages for each AEZ, experts were consulted about climate-related hazards, other risks, and policy objectives that needed to be considered in each area.

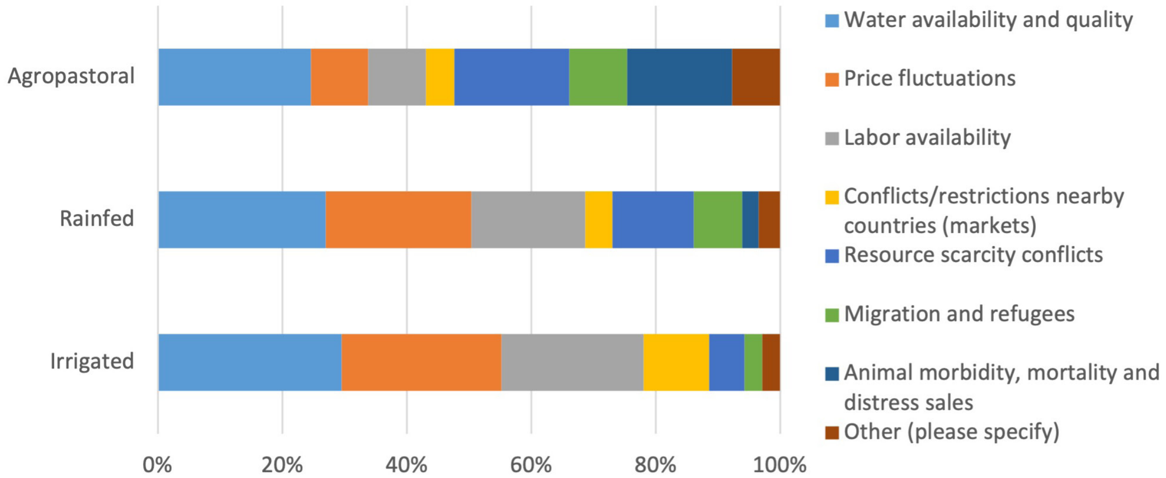
Various climate hazards were perceived as risks across the three AEZs, such as water stress, the frequency of hot days, droughts, and changing rainfall patterns. However, there were also important differences (Figure 5.1). Changing rainfall patterns stood out as a risk for rainfed areas, while irrigated areas are less vulnerable. The amounts of precipitation in agropastoral areas are already very low. The perceived risk of drought spells, therefore, was also higher in rainfed and agropastoral areas than in irrigated areas. Erosion risk was perceived as a risk for agropastoral areas. On the other hand, pest and diseases and increased salinization were perceived as particular risks for irrigated areas.

Figure 5.1: Stakeholder perceptions of climate-related risks for different AEZs



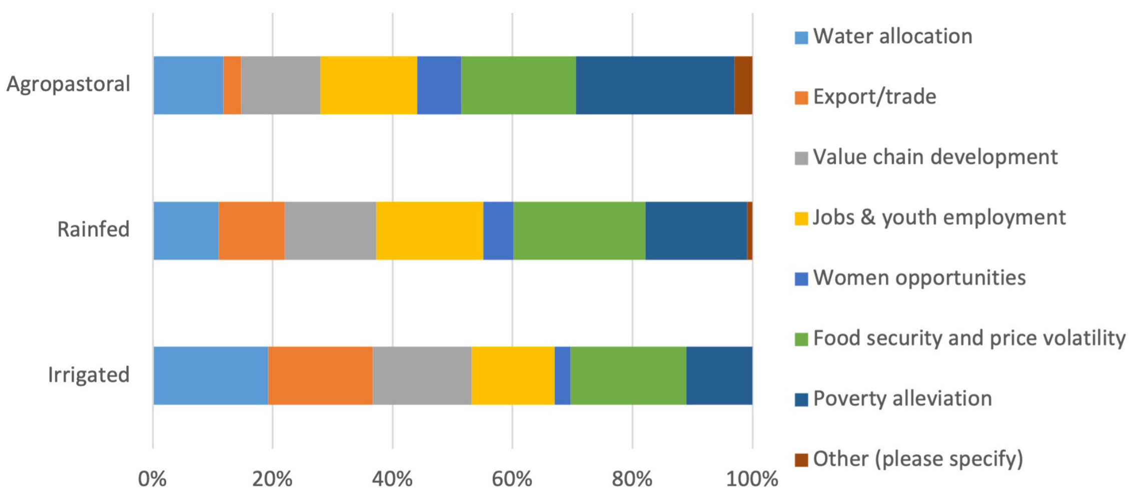
Experts were also consulted about other risks (Figure 5.2). Water availability and quality were a general concern among all experts across the AEZs. Price fluctuations and labor availability were perceived as acuter risks for irrigated and rainfed areas than for agropastoral areas. Conflicts in nearby markets in other countries were mainly regarded as a risk for irrigated areas with more developed commodity value chains for export markets. Conflicts due to resource scarcity were accorded higher importance in rainfed and agropastoral areas than in irrigated regions, while animal morbidity and mortality and distress sales were considered a heightened risk for agropastoral areas. Migration and refugees were seen as a more urgent risk in rainfed and agropastoral areas than in irrigated areas.

Figure 5.2 Other risks relevant to the evaluation of CSA packages for different AEZs



Finally, we asked experts which policy objectives should be considered in different areas (Figure 5.3). Greater food security and reduced price volatility are considered vital policy objectives for all AEZs. Value chain development and youth employment are also widely prioritized. There are, however, distinct differences among the AEZs. Water allocation, export, and trade have a high profile in irrigated areas, while poverty alleviation is more critical in rainfed areas and most pressing in agropastoral areas. Opportunities for women were mentioned less often, although their perceived importance increased when moving from more affluent irrigated areas to rainfed and agropastoral areas.

Figure 5.3 Policy objectives relevant to evaluation of CSA packages for different AEZs



5.3 Evaluation of CSA investments

Participants in the online survey were asked to make an initial selection of CSA packages based on their potential to address climate hazards, other risks, and policy objectives; these were then further assessed in terms of the three pillars of CSA, namely adaptation, mitigation, and productivity, as well as in terms of scalability and pertinent investment risks.

- **Adaptation** refers to actions that lessen vulnerability to climate change, e.g., increased water use efficiency, reduced soil disturbance, climate risk prevention and management, and diversification.
- **Mitigation** refers to actions that diminish and curb GHG emissions, e.g., reduced energy use, carbon storage through biomass or soils, lower methane emissions, manure management, and nutrient use efficiency.
- **Productivity** refers to an increase in yield or income in the context of climate change, e.g., through higher production, better product quality, new markets, reduced post-harvest losses, and improved efficiency.
- **Scalability** refers to the potential of CSA packages to be applied for impact at scale, understood in terms of geographic area, number of beneficiaries, volume, or value.
- I**nvestment risk** refers to the degree of uncertainty or potential financial loss inherent in an investment decision.

The irrigated AEZ (mainly Jordan Valley)

For the irrigated AEZ, nine CSA packages were assessed by 38 experts. First, experts were asked to make an initial selection based on climate hazards, other risks, and policy objectives (see the response rate in Table 5.2). The CSA packages (1) "High-value palm development" and (4) "Upgrading irrigation water productivity" were most often selected, closely followed by (2) "Expanding protected vegetable production," and then (5) "Strengthening the energy-water-food nexus" and (15) "Hydro- and aeroponic practices." The following packages were less often selected to deal with the particular context of irrigated areas: (6) "Decentralized treatment and use of sewage water," (3) "Inland freshwater production," and (14) "Rainwater harvesting for households." Package (16), "Upgrading the poultry industry and value chain," was not selected at all.

The selected packages were then assessed against the three pillars of CSA: adaptation, mitigation, and productivity. The assessments of their potential contributions were translated into an average score on a scale from 1 (low) to 5 (high) (see Table 5.2). Scores were relatively high for the different CSA criteria. The best packages for adaptation were the following: (2) "Expanding protected vegetable production" and (4) "Upgrading irrigation water." The best options for mitigation, meanwhile, were packages (4) "Upgrading irrigation water productivity" and (5) "Strengthening the energy-water-food nexus." The highest-scoring packages for productivity included the first four packages, (1) "Date palm development," (2) "Expanding protected vegetable production," (3) "Inland freshwater production," and (4) "Strengthening the energy-water-food nexus," as well as package (15), "Hydro- and aeroponics." In terms of their average score for climate-smart potential based on the three criteria, the highest scorers were packages (2) "Expanding protected vegetable production," (4) "Upgrading irrigation water productivity," and (15) "Hydro- and aeroponics." Package (16), "Upgrading the poultry industry and value chain," was not selected and therefore not assessed.

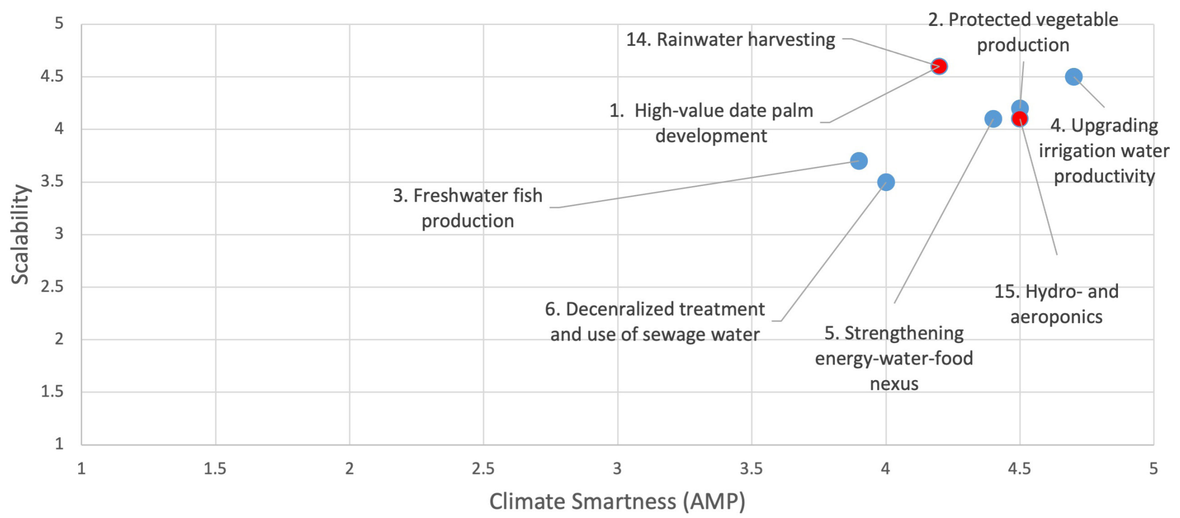
Table 5.2 Evaluation of CSA packages in irrigated areas based on CSA criteria

CSA packages	Responses	A	M	P	Average
1. High-value date palm development	28	4.2	3.9	4.6	4.2
2. Expanding protected vegetable production	23	4.7	3.9	4.9	4.5
3. Inland freshwater fish production	11	3.7	3.4	4.5	3.9
4. Upgrading irrigation water productivity	27	4.8	4.5	4.9	4.7
5. Strengthening the energy-water-food nexus	19	4.4	4.6	4.1	4.4
6. Decentralized treatment and use of sewage water	15	4.2	4.2	3.7	4.0
14. Rainwater harvesting for households	10	4.2	4.2	4.1	4.2
15. Hydro- and aeroponics for high-value vegetables	19	4.4	4.3	4.7	4.5
16. Upgrading the poultry industry and value chain	0	0	0	0	0
Answered	38				

*Average score for adaptation (A), mitigation (M), and productivity (P), with 1=low and 5=high.

When the average value for climate-smart potential was compared with the average evaluation of scalability on a scale from 1 (low) to 5 (high) (Figure 5.4), two packages score relatively lower: (3) "Inland freshwater fish production" and (6) "Decentralized treatment and use of sewage water." The remaining packages all demonstrate high climate-smart potential and high scalability: (1) "High-value date palm development," (2) "Expanding protected vegetable production," (4) "Upgrading irrigation water productivity," (5) "Strengthening the energy-water-food nexus," (14) "Rainwater harvesting," and (15) "Hydro- and aeroponics." The latter two – (14) "Rainwater harvesting" and (15) "Hydro- and aeroponics" – were considered a medium to high investment risk, however.

Figure 5.4: Assessment of CSA packages in irrigated areas based on climate-smart potential and scalability



*Packages with perceived investment risk are indicated in red.

The rainfed AEZ (mainly highlands)

For the rainfed AEZ, seven CSA packages were assessed by 40 experts. Just as they were for the irrigated areas, experts were first asked to make an initial selection based on climate hazards, other risks, and policy objectives (see the response rates in Table 5.3). The CSA packages (7) "Upgrading olive production and processing" and (14) "Rainwater harvesting for households" were the most frequently selected, followed by (8) "Soil health improvement" and (10) "The durum value chain and barley production." Options (9) "Agroforestry packages" and (15) "Hydro- and aeroponic practices" were selected slightly less often. Only a few experts chose package (16), "Upgrading the poultry industry and value chain."

The selected packages were then assessed against the three pillars of CSA, namely adaptation, mitigation, and productivity. Their potential contributions were translated into an average score from 1 (low) to 5 (high) (see Table 5.3). Again, scores were relatively high for the CSA criteria. The highest scoring packages for adaptation were the following: (9) "Agroforestry packages" and (10) "The durum wheat value chain and barley production." The former also scored high on mitigation, and the latter scored well for productivity. In terms of their average score for climate-smart potential encompassing all three criteria, option (9) "Agroforestry packages" stood out, closely followed by (8) "Soil health improvement" and (10) "The durum wheat value chain and barley production."

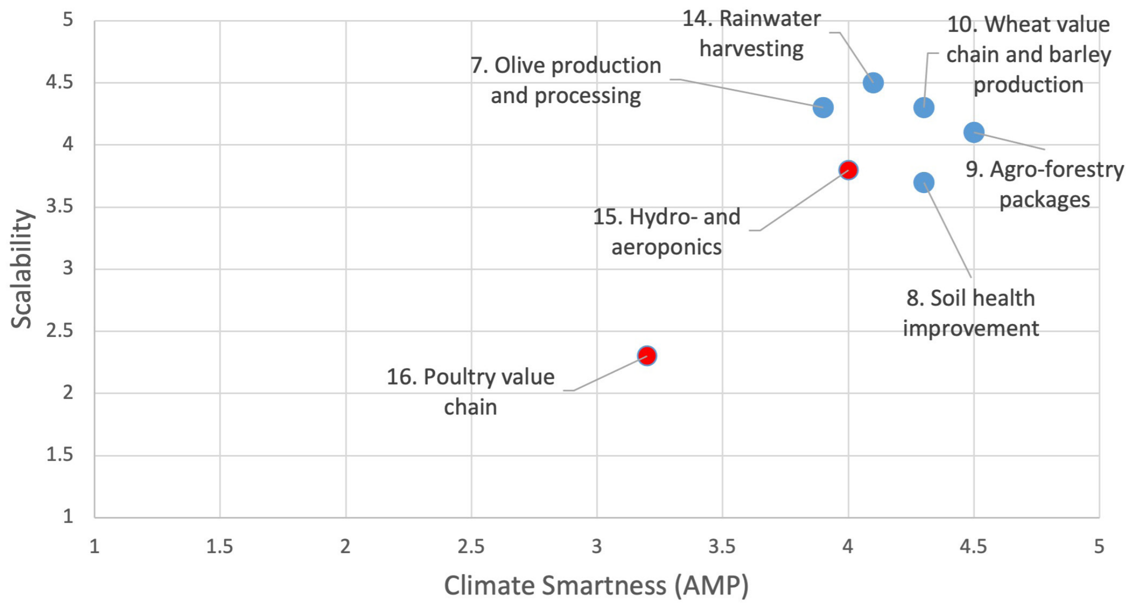
Table 5.3 Evaluation of CSA packages for rainfed areas based on CSA criteria

CSA packages	Responses	A	M	P	Average
7. Upgrading olive production and processing	28	4.0	3.4	4.2	3.9
8. Soil health improvement	19	4.4	4.2	4.4	4.3
9. Agroforestry packages	14	4.7	4.7	4.1	4.5
10. Durum wheat value chain and barley production	17	4.6	3.8	4.6	4.3
14. Rainwater harvesting for households	25	4.4	4.2	3.8	4.1
15. Hydro- and aeroponics for high-value vegetables	13	4.1	4.2	3.8	4.0
16. Upgrading the poultry industry and value chain	4	3.7	3.0	3.0	3.2
Answers	40				

Average score for adaptation (A), mitigation (M), and productivity (P), with 1=low and 5=high.

The average value of climate-smart potential of the different packages was compared with scalability, again using a scale from 1 (low) to 5 (high) (Figure 5.5). Package (16), "Upgrading the poultry industry and value chain," was a clear outlier for its low scores. Package (15), "Hydro- and aeroponics," fared better, but overall, it was less positively assessed than others. These two packages were also considered a medium to high investment risk. The remaining packages scored better in climate-smart potential, in scalability, or in both categories.

Figure 5.5: Assessment of CSA packages in rainfed areas based on climate-smart potential and scalability



*Packages with perceived investment risk are indicated in red.

The agropastoral AEZ (mainly Badia)

For the agropastoral AEZ, six CSA packages were assessed by 23 experts. As for the other two AEZs, experts were asked to make an initial selection based on climate hazards, other risks, and policy objectives (see the response rates in Table 5.4). Four packages stood out: (11) "Small ruminants' production," (13) "Badia restoration," (14) "Rainwater harvesting for households," and (12) "The dairy production value chain." The other two packages were chosen by only 3 experts: (15) "Hydro- and aeroponic practices," and (16) "The poultry industry and value chain."

The packages were then assessed against the three pillars of CSA, namely adaptation, mitigation, and productivity. Again, assessments were translated into an average score from 1 (low) to 5 (high) (see Table 5.4). Scores were relatively high across CSA criteria. Packages (13) "Badia restoration" and (15) "Hydro- and aeroponic practices" scored best for adaptation. The latter also scored high in terms of mitigation and productivity, but since it was only selected by 3 experts, these results should be evaluated with caution. In terms of productivity, package (12) "The dairy production value chain" also scored very high. Overall, two practices stood out for their average climate-smart potential: (13) "Badia restoration" and (15) "Hydro- and aeroponic practices"; the latter, however, only received a low number of responses.

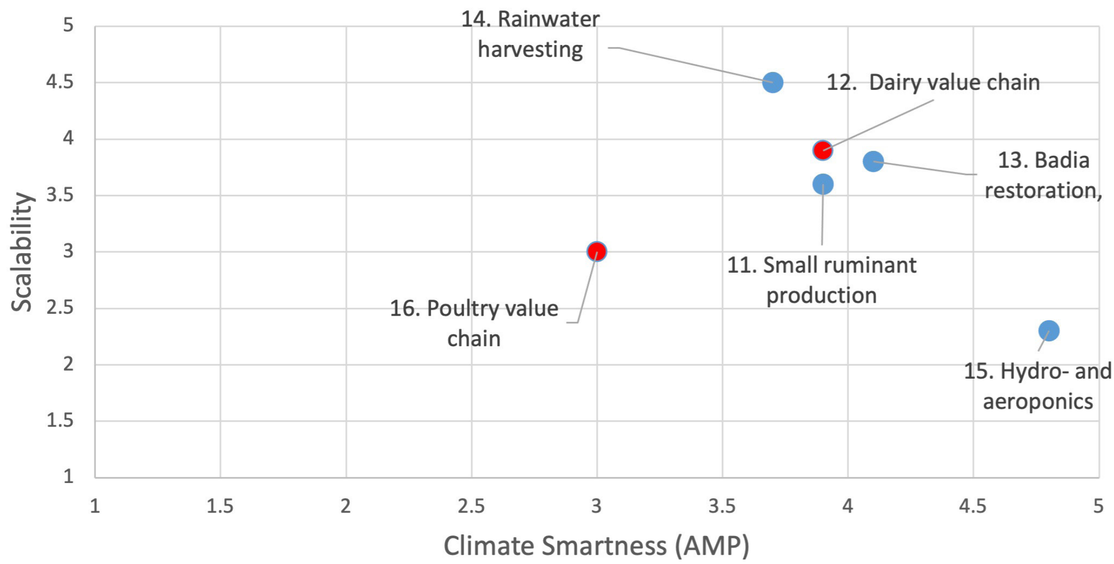
Table 5.4: Evaluation of CSA packages in agropastoral areas for CSA criteria

CSA packages	Responses	A	M	P	Average
11. Small ruminants' production	18	4.1	3.3	4.2	3.9
12. The dairy production value chain	14	4.1	3.1	4.6	3.9
13. Badia restoration	16	4.5	3.9	4.0	4.1
14. Rainwater harvesting for households	15	4.2	3.1	3.8	3.7
15. Hydro- and aeroponics for high-value vegetables	3	5.0	4.3	5.0	4.8
16. The poultry industry and value chain	3	3.0	2.3	3.7	3.0
Answers	23				

*Average score for adaptation (A), mitigation (M), and productivity (P), with 1=low and 5=high.

Figure 5.6 compares the average value for climate-smart potential of these different packages with their scalability score ranging from 1 (low) to 5 (high). Package (16), "The poultry industry and value chain," is again a clear outlier for its low scores. Package (16) "Hydro- and aeroponics," meanwhile, scores well in terms of climate-smart potential, but its score for scalability in agropastoral areas is very low. The other four packages are closely clustered with high average values for both climate-smart potential and scalability. Package (12), "The dairy value chain," is considered a medium to high investment risk.

Figure 5.6 Assessment of CSA packages in agropastoral areas based on climate-smart potential and scalability



*Packages with perceived investment risk are indicated in red.

5.4 The selection of CSA investments

As a final step in the prioritization phase, expert panels were organized for each AEZ. Meetings were held with 8-10 experts from government ministries, research organizations, academia, and NGOs, and also including independent consultants and representatives of the private sector and finance institutions. Participants discussed the results from the online survey and proposed CSA packages.

In principle, two CSA packages were selected for each AEZ, of which at least one has a clear commodity value chain focus. In certain cases, the experts decided to recombine some of the options. The prioritized options were as follows:

1. High-value **date palm** development, processing, and marketing using modern irrigation and improved cultural practices (CSA-1) (irrigated areas)
2. Expanding and upgrading protected **vegetable** production with advanced technologies and processing and marketing options (CSA-2, 4, 15) (irrigated areas)
3. Upgrading **olive** production and processing by introducing low-cost modern technologies for collection, cold pressing and pickling, and alternative waste use (CSA-7) (rainfed areas)
4. Enhancing **barley** production through rainwater harvesting and improved management (CSA-10) (rainfed areas and the Badia)
5. Enhancing **small ruminant** production through intensive farming systems and dairy chain

development (CSA-11, 12) (agropastoral areas)

6. **Badia restoration** with micro-catchment water harvesting and improved grazing management (CSA-13) (agropastoral areas)

These packages were adapted slightly based on discussions within each expert panel about key challenges, business models, and policy incentives. The redefined packages' geographic scope, target populations, and key activities are further addressed in the program design.

Chapter 6

Using CSA investment concepts as a foundation for programming

Highlights

- Climate-smart agriculture (CSA) practices can help strengthen farmers' resilience to climate change. They are highly context-specific and dependent upon careful planning, the right enabling conditions, strong capacity building, and robust stakeholder involvement mechanisms.
- Primary constraints include access to quality information, capacity, finance, and markets, and often stem from or are aggravated by policy issues and socio-cultural factors.
- Repositioning the language framework among national policies to explicitly include CSA objectives will help enable cross-institutional alignment, integration, and collaboration.
- The proposed CSA investments align with and support Jordan's national priorities, the Sustainable Development Goals (SDGs), the Paris Agreement, and the Nationally Determined Contributions, and furnish excellent opportunities for further policy alignment.
- Increasing water productivity through these CSA investments in conjunction with appropriate water policies to restrict the rebound effect would relieve agricultural pressure on groundwater.
- Adopting broader international definitions of key terms may create opportunities to meet international commitments, unlock supportive international funding, and more easily compare national statistics to other countries in the region.
- Blended finance models would help mobilize public and private finance to scale up successful, sustainable, high-potential CSA investments.

6.1 What does CSA investment planning have to offer?

CSA is highly context-specific. Best-bet adaptation, mitigation, and productivity activities that will strengthen farmers' resilience to climate change vary from one community, geography, and production system to the next. Thorough context-specific innovation is necessary to maximize benefits, but its scalability through simple replication is not possible. CSA investment planning requires ensuring that enabling conditions are right and that strong capacity-building and stakeholder involvement mechanisms are clearly identified.

Decision makers at all levels must understand the purpose, rationale, and required conditions for CSA investment. Promoting CSA in Jordan should be understood as an approach for integrating and evaluating climate change scenario planning, economic analysis, priority setting of regional areas, and potential barriers and opportunities. In this chapter, we will continue to explore key elements needed for project design and implementations for the priority investments, in order to identify opportunities, constraints, and financing opportunities. The information presented is based on short concept notes developed for each investment package with support of expert consultation and stakeholder interviews (see Annex E). These concept notes and therefore this chapter together propose an initial design for a series of programs and projects and a basis for a cost-benefit analysis and GHG emissions assessment. Further study will be necessary to develop project and program design based on market and value chain analyses

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6.2 CSA packages and the rationale for investment

Table 6.1 below demonstrates for each of the investments why that commodity was selected, what the climate change impact will be for the commodity, and the objective of the CSA investment.

Most investments have important economic value with export potential for date palm, vegetables, olive oil, and small ruminants. While the country depends on imports for many staple foods, Jordan is self-sufficient in some crops (e.g., olives, tomatoes, goat meat), and can achieve greater food and feed security through the investment programs. Dates have considerable export value per volume and production area has expanded to over 4,000 hectares in recent years. Olives, vegetables, and barley comprise the largest landscapes of planted acreage, with vegetables earning the highest export value of US$ 223M, followed by small ruminants at US$ 170M.

Adaptation and growth are key objectives for all the CSA investments. Date palms are heat-tolerant and able to grow well in irrigated areas, with scope for increased production when well managed. Vegetables grown in open fields are sensitive to heat stress and vulnerable to post-harvest losses; they need protection and better management technologies to increase quality and expand export opportunities. Olive trees are generally well suited to rainfed conditions but are vulnerable to post-harvest losses; adaptive measures will be required to maintain this important production system. Barley, small ruminants, and Badia restoration are all related and critical to ensure livestock feed and sustainable management of grazing areas while supporting rural livelihoods. Barley is sensitive to climate-change impacts but is critical as livestock feed; measures will be needed to ensure water availability to secure and grow production. Investments focused on small ruminant farming systems and Badia restoration in general are critical for rural households in the Badia.

Table 6.1 Gains from CSA implementation: Rationale for investments

CSA Investment	On-Farm Value	Jordanian Importance[185]	Projected CC-response	Scenario without investment	Main investment Objective
Date Palm	Economic, Nutrition	Export and local consumption. Estimated 25,000 metric tons annual production over approximately 4,000 hectares.	Increase in suitability. Thrives in higher temperatures, tolerant to water stress.	Stable production	Growth
Vegetables	Economic, Nutrition and Food Security	Export and local consumption. Estimated 1.7 million metric tons produced on over 37,000 hectares. Tomatoes alone contribute 280,000 metric tons to export markets valued at US$ 223M.	Increase in suitability for tomatoes, decreased suitability for potatoes. Growing season of fruiting vegetables extends with increased number of warm days, though high temperatures stress plants. Hot spells dramatically reduce tuber formation, weight, and yields.	Decreased (open field) production; Increased post-harvest losses	Adaptation and growth
Olive	Economic, Nutrition	Major production system in rainfed areas; potential to increase processed quality for export. Over 56,000 hectares producing more than 145,000 metric tons, of which over 1,000 metric tons are exported.	Moderately suitable in rainfed zone; tolerates heat and water stress,	Increased post-harvest losses; Exacerbated environmental degradation	Adaptation and growth
Barley	Economic and Food / Feed Security	Essential livestock feed during periods of fodder shortage. Domestic production contributes nearly 50,000 metric tons while 960,000 metric tons are imported annually.	Poor response to climate change. Lengthier and more common heat stress days concentrated towards spring reduce grain filling and maturity. Warming and drought stress.	Yield expected to be substantially affected; Increased imports	Adaptation and growth
Small Ruminants	Economic and Food Security	Reliably high demand, key sector for women. Annual export nearly 500,000 sheep and goats with value nearly US$ 170M.	Small ruminants are well adapted to climate change, although higher summer temperatures may hinder livestock productivity and affect human labor. Increased heat and moisture stress reduce grazing and fodder sources, limiting livestock health.	Increased land degradation; Decreased feed security	Adaptation and growth
Badia Restoration	Ecosystem services, including feed security for livestock	Mitigating and preventing desertification. Supports barley and small ruminant investments along with several national policies.	Hotter summers and drier winters reduce the soil's ability to support vegetative growth, hindering opportunities for livestock or crop production.	Continuing loss of arable land; Decreased productivity	Adaptation and mitigation

6.3 Prioritized CSA packages: region, beneficiaries, and development outcomes

The investments were selected to cover the different AEZs in Jordan, focusing on date palms and vegetables in irrigated areas, olives and barley in rainfed areas, and small ruminants and Badia restoration in agropastoral areas. Table 6.2 provides an overview of the package per region, including the number of beneficiaries and proposed development outcomes, which were based on expert consultations.

Table 6.2 CSA investment priority by zone, beneficiaries, and proposed development outcomes

CSA Investment	Agro-ecological zone	Beneficiaries	Proposed development outcomes
Date Palms	The Jordan valley Irrigated areas	500 new small/medium and existing large farm owners	Expand current date palm area by 800 ha in small landholdings and increase economic return of current plantations by 50% over 5 years.
Vegetables	The Jordan Valley and highlands irrigated areas currently using groundwater	500 Small and medium size farmers currently cultivating in open fields and 200 existing protected agriculture farmers; 40 farmers will be specifically targeted for hydroponics	Expand protected vegetables cultivation by 25% and economic water productivity by 40% over 5 years.
Olives	Northern and central Jordan rainfed areas	1000 olive farmers will benefit from one or more components of the package. Environmental benefits of olive waste processing impact numerous communities in hot spot zones	10% of current conventional olive growing farmers adopt advanced olive growing, collecting, processing, and packaging technologies over 5 years of implementing the project
Barley	Rainfed areas and the western Badia	Essential livestock feed during periods of fodder shortage. Domestic production contributes nearly 50,000 metric tons while 960,000 metric tons are imported annually.	Poor response to climate change. Lengthier and more common heat stress days concentrated towards spring reduce grain filling and maturity. Warming and drought stress.
Small Ruminants	Agropostoral areas, the Badia	3 major communities with 900 farmers (total population of 6000 people with potential indirect benefits through out-scaling elements of the development to other communities	Building and running 3 collective *awasi* pilot community farms in the north, middle and south Badia adopting latest technologies of feed and milk processing and marketing
Badia Restoration	Agropastoral areas, the Badia	250 landowners	Restoring 5,000 hectares with shrubs and grasses using micro catchment water harvesting and improved grazing management in 5 years

The investment in date palm aims to expand its area by 800 ha and to replace less suitable and low-value crops in the Jordan Valley irrigated areas. The package would include a program for supporting 500 new small, medium, and existing large farm owners during the establishment phase, including credit and technical assistance, formulation of cooperatives that can consolidate land for small date palm fields, plant protection programs especially against red palm weevils, and aggregate processing and marketing facilities. This investment package offers significant employment opportunity in product processing, marketing, retail, and information and communications technology (ICT) platforms. The project will also facilitate investment and public support for large farming and the development of e-extension and e-advisory to improve service provision.

The package on protected vegetables includes a program for converting open field and low tunnel vegetable production in Jordan valley and highlands irrigated areas to greenhouse production systems with modern highly efficient irrigation systems. It will target 500 small and medium farmers currently cultivating open field vegetables and 200 existing protected vegetable growers. It includes the use of enhanced technologies including greenhouses, improved varieties, and pest and disease control, for higher-quality products; precision agriculture such as using sensors in improved water management and nutrient management; building temporary cold storage facilities that help avoid market flooding; using renewable energy; and the establishment of grading and processing facilities for added-value production, processing, and export, with the support of e-extension and e-advisory. The project also supports the introduction of hydroponic production of high value vegetables in irrigated highlands with groundwater resources for 40 additional farmers. The investment package also offers significant employment opportunities in sales and construction of building infrastructure, renewable energy, and inputs; product processing, marketing, and customer service; and development of ICT platforms. This technology will replace open vegetable fields and forages, rather than expanding current planting.

Olive production will target advanced production and processing technologies and conservation, while improving the quality of processed oil. This package would focus on 1000 olive farmers in Jordan's northern and central rainfed areas and includes improved harvest through low-cost modern technologies that increase quality and reduce harvesting time, strengthen farmer linkages with other value chain actors, and introduce a modern and alternative (cold) pressing process for high quality oil extraction. Despite investments in low-cost harvesting technologies, the production of olives continues to provide important employment opportunities during harvesting, as well as in inputs and sales, building infrastructure and maintenance, manufacturing and technology, product processing, marketing, transportation, retail, and green energy. The project will also reduce the environmental impact of current processing methods on local water resources.

To be able to increase ***barley production***, investment will need to be made in rainwater harvesting combined with the selection and management of suitable lands. Hence, this package targets 1000 farmers and their communities in the western Jordan rainfed areas and the western Badia aiming at expanding barley production with rainwater harvesting for animal feed, the introduction of high productive drought tolerant barley varieties (risk-reducing combination) and application of integrated cultivation packages. This investment package offers employment opportunities connected to inputs, seed multiplications, product processing, marketing, and customer service.

Concentrated farming systems for ***small ruminants*** will be piloted in three communities in the Badia, with adoption of balanced feed for fattening, and milk processing technologies and marketing. This package targets 900 farmer families and will include investment in training and advisory for production and processing of sheep, developing small ruminant cooperative groups based on (traditional) community structures, improvement of by-product processing, and strengthening dairy processing and marketing. Value-added facilities would include by-product processing at local and community levels (including product diversification and marketing), and improvement of cold storage using renewable energy. This investment package offers employment opportunities related to manufacturing and sales of inputs (eg. improved feed supply, veterinary services, vaccines), building infrastructure and maintenance, milk and by-product processing, pasteurization, cold chain infrastructure, milk and by-product marketing, transportation, retail, and green energy technology infrastructure.

Finally, 5,000 ha will be restored using micro-catchment water harvesting and improved grazing management. This package on *Badia* restoration includes providing micro catchment water harvesting units (*Vallerani*) to constructlarge-scale bunds and counter ridges and nurseries to produce millions of seedlings of indigenous shrubs, directly benefiting 250 landowners. The project also endeavors to change grazing management of the restored areas from open to controlled, training of local communities and restoration staff on the package implementation, and an M&E program to assess the impact of restoration on ecosystem services. This investment package offers employment opportunities related to inputs and sales (nurseries), retail and customer service, landscaping services, education and research.

6.4. Overarching barriers and enabling factors

The specific context of Jordan entails circumstances that manifest as general barriers to investment; this applies even more strongly in the context of agriculture and CSA. Some of these are difficult-to-control risks with serious consequences related to political and security issues, conflicts of resources, climate risks, and financial markets. However, there are also many factors that can be managed and that have a direct impact on CSA design and implementation. Table 6.3 below summarizes the main challenges, as well as some opportunities for each of the prioritized investment packages based on expert consultations. Many challenges referred to information, capacity, finance, organization, markets, and socio-cultural aspects; and these often stemmed from, or are aggravated by, policy issues. We gathered this information initially through expert panels, and group interviews with various stakeholder representatives enabled us to explore these constraints and opportunities more fully. These experts were selected for the knowledge and experience they could bring about related commodities or investment packages. In addition, we reviewed the main findings of recent projects, studies and initiatives in Jordan relevant to the investment packages to ensure that findings were aligned (see Annex F).

Table 6.3 Key constraints and opportunities to design and implementation of CSA interventions

CSA Investment	Constraints	Opportunities
Date Palms	- Land area of small/medium farmers is generally too low for viable business - Small/medium farmers face problems accessing credit - Lack of institutional support for processing packaging and marketing - Timely and accurate information lacking for production, processing and marketing - Small/medium farmers not integrated into larger value chain - Need for improved cultural practices and red weevil handling	- Date palm relatively well adapted to anticipated climate impacts - Sector relatively well organized with potential for e-extension and e-advisory - Private advisory services - Young entrepreneurs can be attracted through ICTs - Initiatives exist for using smart applications for e-extension and e-technology transfer (platforms for farmers to get direct info), offering investment and scaling opportunities - Leverage policies to use finance and business services - Implement policy that facilitates export and promotes domestic consumption

CSA Investment	Constraints	Opportunities
Vegetables	- Investment costs for converting to protected vegetable production - Reliable markets are critical due to perishability - High quality standards of export markets - Over-flooding of markets if processing or storage and/or markets not well organized (less organized than some other sectors) - Lack of timely and accurate information for production, processing and marketing. - COVID-19 is affecting export	- Sector with particularly good export opportunities, and which is expected to increase under climate change scenarios. - Greenhouses are expensive, but existing farms can be upgraded (tunnels, etc.) for protected farming - Protected vegetable production (off-season, high prices) with improved processing and storage facilities can alleviate price fluctuations and enable compliance with strict regulations for export (food safety) and traceability - Implement policy for premium/certification standards - Policy incentives for private sector involvement and access to business services
Olives	- High production costs (especially labor) - Need quality improvement for export market standards (cold pressing 'extra' virgin oil), while satisfying domestic markets - Lack of information on production, pest control, marketing, improving quality (also for traceability) and coordination with processers - Weak value chain integration, especially for small/ medium farmers - Access to finance, business, and extension services	- Jordan olive oil is of high quality and popular in local market (olive production is entranced in local culture) - Some farming leaders exist, can be example for others - Farmer groups/cooperatives can help reduce production costs, mitigate risks, and strengthen value chain to reach new markets - Cooperation/cooperatives at local level that add value (e.g. packaging and enabling certification) can attract farmer participation - Policy incentives for private sector involvement to improve products' quality and develop markets - Implement policy for premium/certification scheme
Barley	- Access to new technologies and extension/ business services to improve production under rainfed conditions - Weak linkages with input suppliers - Subsidies to reduce price for barley (to support farmers) distorts market for barley production, favoring international producers	- Farmer groups/cooperatives can help reduce production costs, facilitate information sharing, and strengthen linkages to input suppliers and other actors throughout the value chain - High demand for barley as livestock feed, which is expected to further increase due to climate change - Policy incentive to improve access to extension and business services - Improve access to finance, possibly in combination with tax incentives or change in subsidy on Barley
Small Ruminants	- Lifestyle changes may conflict with long-held socio-cultural values in the Badia - Limited financial means for inputs and/or technology - Processing and marketing of by products, especially milk, is underdeveloped - Current subsidies support herders with barley (feed) and wheat bran, encouraging farmers to increase herds (not intensify), causing overgrazing	- Land degradation makes nomadic lifestyle difficult to maintain; younger generation interested in business opportunities - Women play key role in husbandry of small ruminants, providing opportunities to involve women more strongly - Farmer groups/organizations can improve financial access to inputs and structures; with supply and production integration, processing/marketing, and gender respect - Incentivize private sector support

CSA Investment	Constraints	Opportunities
Badia Restoration	- Restoration requires variety of role players for endorsement and support. - Initial area protection, benefiting farmers only in medium-long term (challenging values linked to open access to grazing) - Low capacity among restoration staff and farmer (communities) to implement restoration practices; community trust in own people forces locals to play key role in sustainable management - Unfamiliarity with ICTs outside of social purposes; new habits and protocols will need to be learned	- Previous program on Badia restoration can serve as a model for follow up (existing gaps, what people look forward to doing); While women have a generally limited role in decision-making, there have been positive experiences with women's stronger roles in meetings/ cooperatives. - ICTs can enable monitoring across large distances - Public-Private partnerships may fulfil gaps in technical capacity - Implement policies to improve access to extension services and payments for ecosystem services

Issues with the provision of information and information sharing emerged as one of the main overarching constraints. Many experts noted that information is lacking or not well organized. This is a particular problem for the investments that require timely and accurate information (i.e., date palm, vegetables, olive) to promote production and to link production effectively with processing and marketing. Mechanisms for information provision and exchange do not seem to work effectively. These barriers will impact policy making and extension services that could otherwise support CSA. However, there may be opportunities for the development of digital services through e-extension and e-advisory, which may further attract young entrepreneurs. These services require substantial investment in building databases with reliable and accurate information to enable decision making. Such platforms can attract private investment, especially in sectors with growth potential and (export) market opportunities such as the date palm, olive, and vegetables sector.

There is a need for capacity strengthening and access to financial services. While broadly applicable, these will be most prominent for those investments requiring high transition or labor costs and investment in modern technologies (i.e., date palm, vegetables). Poor access to extension, business and financial services can be a major hindrance to the uptake and scaling of CSA practices. Capacity building among all actors, including restoration staff and the broader farming communities is critical for the long-term success of the investments, particularly in the Badia. Short-term credit and risk reduction instruments are crucial for smallholders to transform their farming into a viable business. However, commercial banks are hesitant to invest in agriculture and are generally only interested in working with large companies with clear business plans. A supportive policy environment for the provision of well-developed extension and business services, and the development of credit and financial mechanisms, potentially with the involvement of the private sector, will be essential.

The development of farmer organizations and better value chain integration are needed to enable growth of these sectors. Alignment through farmer organizations or cooperatives is essential for reducing costs of production, mitigating risks, accessing economies of scale, and adding value in terms of processing and improved technologies that can open export markets. At present, the effectiveness of cooperatives in playing these roles in Jordan is limited due to institutional constraints that could be ameliorated. Nonetheless, other forms of group alignment besides cooperatives may also be productive. Organizations that link farmers with other actors, especially processors, are particularly important for investments in date palm, vegetables, olives, and small ruminants, and to a lesser extent barley. Contract farming could be a viable way to integrate smallholders with bigger businesses to reach new markets. Lack of coordinating entities between vegetable farmers, processing and storage, and markets can cause over-flooding that lowers prices and exacerbates food loss, while a similar deficit in coordination of processing and marketing of animal by-products has prevented the development of a small ruminant milk industry. Integration and strengthening of value chains between small and medium farmers and larger companies will expand market access and facilitate quality improvements, and is essential for vegetables, date palm and olive sectors.

Socio-cultural aspects are key to any investment, and are particularly relevant to investments in the Badia. The small ruminants and Badia restoration project will thus require very robust local community engagement. Trust will be important here, and the use of participatory approaches, taking into account people's livelihoods and lifestyles, gender norms, and power structures will be critical for success. Particular attention needs to be paid to the involvement of women who play an important role in the management of small ruminants and processing of by-products and milk products, but it will also be challenging considering traditional hierarchies.

Most of these challenges or constraints are embedded in the policy environment. Hence supportive policies will be required to develop appropriate public service and encourage participation of the private sector where possible. This is most striking in the case of barley as the main livestock feed. Huge political and financial support is provided to herders through barley subsidies, which has increased livestock numbers with overgrazing of the Badia and further degradation. Hence, it is of strategic importance to produce more barley locally and organize small ruminants in concentrated farming systems in the Badia. Policies addressing quality standards should also be considered, for example a certification scheme for processing and marketing of olive oil that incentivizes CSA practices and private sector investment. Subsidies should be designed to help people without harming the environment, e.g., by linking subsidy to technology and outputs instead of inputs. Policies that consider the key barriers for each investment are key to achieving robust CSA.

6.5. Alignment of CSA investments with national policies and key priorities

Numerous national policies support climate change action and adaptation, while very few explicitly support CSA. Table 6.4 illustrates how recent policies, discussed further below, have increasingly supported agricultural resilience.

Table 6.4 Recent Jordan plans, policies and frameworks supporting climate change, adaption, mitigation or CSA

Policy, plan, or framework	Abb.	Date	Climate Change	Adaptation	Mitigation	CSA
Sustainable Arab Agricultural Development [186]		2005-2025	Low	Medium	Low	Low
National Climate Change Policy[187]	NCCP	2013-2020, ext. to 2030	High	High	High	Low
Jordan Poverty Reduction Strategy[188]		2013	High	Medium	Low	Low
Third National Communication on Climate Change[189]	TNC	2014	High	High	High	Low
National Strategy and Action Plan to Combat Desertification[190]	NAP	2015- 2020	High	Medium	Low	Low
Climate Change Policy for a Resilient Water Sector[191]		2016	High	High	High	Low
National Strategy for Agricultural Development*	NSAD	2020-2025	High	Low	Low	Low
National Water Strategy[192]		2016-2025	High	High	Low	Low
Green Growth National Action Plan[193]	GGNAP	2021-2025	High	High	High	Medium
National Economic Growth Plan[194]	JEGP	2018-2022	Low	Low	Low	Low
NDC Action Plan		2019	High	High	High	High

*Publication forthcoming.

There exists a robust opportunity to further align national policies with the NDCs in terms of CSA objectives. Climate change and adaptation are strongly recognized throughout many national policies while mitigation is less frequently mentioned (though highly acknowledged when included). However, most of the plans and policies fall short of explicitly including climate smart agriculture, creating a misalignment with the NDC Action Plan. Repositioning this language framework will help enable cross institutional alignment and integration, ensuring collaboration across departments and preventing loss of support for initiatives that are otherwise aimed in the same direction.

The National Climate Change Policy reflects the priorities and objectives of both environmental and development sectors with linkages to global responsibilities. This commitment identifies policy priorities and guidelines, instruments for addressing climate change, and provides a legal framework for future elaboration of national climate change policy. The policy sets the stage for international support, multi-stakeholder coordination and public-private partnerships in achieving CSA objectives. Components of the NCCP, along with the Third National Communication on Climate Change, Climate Change Policy for a Resilient Water Sector, and Green Growth National Action Plan align most closely with the NDC Action Plan.

Table 6.5 Links between CSA investments and national priorities

CSA investment	Poverty reduction	Food security	Jobs and youth employment	Women opportunities	Value Chain development	Export/ trade	Water allocation	Environmental Conservation
Date palms								
Vegetables								
Olives								
Barley								
Small ruminants								
Badia restoration								

Most of the CSA investments are aligned with Jordan's national priorities, both in terms of high-level objectives and specific investment activities (Table 6.5). Five of the investments (i.e., date palm, vegetables, olive, small ruminants, and to a lesser extend barley) are directly linked to multiple national priorities (i.e., poverty reduction, food security, jobs and youth employment, value chain development, and water allocation). The CSAs facilitate national priority activities that harmonize with the SDGs. The CSAs are directly attached to goals including poverty reduction (SDG 1), hunger (SDG 2), employment and economic growth (SDG 8), sustainable communities (SDG 11), and climate action (SDG 13). CSA activities supporting the national priorities upholds Jordan's commitment to the 2030 Agenda for Sustainable Development[195] to ensure a resilient, prosperous, and inclusive economy.

Badia restoration aims to address national goals related to environmental conservation and water allocation, a key priority of several national policies and plans. Mitigating water issues is highlighted in the National Strategy to Combat Desertification, the National Water Strategy, and the Third National Communication on Climate Change. These policies aim to guide management of water resources and sustainable water and sanitation services considering climate imperatives. The Badia restoration package directly contributes to these goals by increasing water availability through rainwater harvesting and specific water conservation structures.

Climate smart agriculture and water access are increasingly recognized as national priorities of concomitant importance. Overall, there is widespread recognition among relevant ministries that water access and allocation play a critical role in the development of the agricultural sector and will likely become more urgent in the future due to climate change. Although fewer policies recognize the critical role CSA holds for supporting productivity of the agricultural sector, by adapting existing practices and technologies to address these challenges, there is scope to further develop these packages with strong involvement of relevant ministries and other partners. Jordan's stable and secure political environment in the Middle East is considered of critical importance by most other countries, providing opportunities for investments and cooperation with key donors, country delegations and private business.[196]

Since water availability for irrigation is expected to decrease by 20-25% as a result of climate change and increasing appropriation for human consumption[197], it will be critical that policies and programming facilitate the best use of water by considering the water productivity value for agricultural investments. Water productivity is not only the biophysical measurement of agricultural outputs per unit of water, but also with respect to economic returns, water productivity is a value representing benefit per unit of water in terms of, e.g., dollar value, nutrition, employment, or environmental resources.[198] Table 6.6 below shows the potential impact on water productivity and water savings for each investment package.

Table 6.6 Estimated crop water productivity under current practices and proposed CSA packages

Conventional practices	CSA packages	Yield kg/du*		Water use m³/du**		WP kg/m³		Mean producer price US$/kg†		WP gross US$/m³ ‡		Savings§ (%)‡
		Conv	CSA	Conv	CSA	Conv	CSA	Conv	CSA	Conv	CSA	
Open-field vegetables	Date palm Medjool	5000	1000	500	1400	10	0.71	0.4	7.0	4.0	5.0	+25
Open-field vegetables	Greenhouse vegetables	5000	15000	500	375	10	40	0.4	0.5	4.0	20.0	+400
Open-field vegetables	Hydroponic vegetables	5000	30000	500	150	10	200	0.4	0.5	4.0	100	+2400
Rainfed olives (fruits)	Improved olives (fruits)	300	400	500	500	0.6	0.8	1.0	1.2	0.6	0.96	+ 60
Rainfed olive oil (20% of fruits)	Improved olive oil (22% of fruits)	60	80	500	500	0.12	0.16	5.0	7.0	0.6	1.12	+87
Barley without water harvesting	Barley with marab WH	50	400	150	400	0.33	1.00	0.42	0.42	0.14	0.42	+200
	Barley with runoff strip WH	50	200	150	300	0.33	0.67	0.42	0.42	0.14	0.28	+100
Rangelands, ET 10% of total rainfall	Restored rangeland, ET 50% of total rainfall	Given constant rainfall, ET, biomass production (rangeland species), and, consequently WP, increase fivefold, from 10% to 50%.										+500

Note: ET = evapotranspiration; Conv = current conventional practices; WP = Water productivity; WH = Water harvesting
* Average yields per dunum (0.1 ha) of 2018 in Jordan
**Calculated evapotranspiration (ET)
† Mean producer sales prices as of 2018 in Jordan
‡ Based on gross sales, costs of production not included. As such, these are not net gains and should not be considered a comparison across investment packages, but rather a comparison of conventional vs. CSA production.
§ Water savings for same gross sales or increased gross sales for same water consumption.
Sources: date palm water use,[199] Badia restoration water use,[200] yields and produce prices[201]

Hydroponic vegetables show the highest water savings, followed by greenhouse vegetable production systems, indicating the CSA investment in protected vegetables provides the best value in terms of water productivity. Water productivity and savings calculations do not account for investment costs and thus reflect only water efficiency. Government incentives such as credit or low interest rates will be necessary to diminish barriers to entry for farmers to invest in hydroponic or greenhouse structures. In order to significantly reduce groundwater reliance in agriculture, hydroponics is recommended in the highlands, where groundwater is heavily relied upon for crop production and fruit trees.

Given the diminishing allocation of water to agriculture and increasing amount of groundwater designated for human consumption, these CSA investments would relieve agricultural pressure on groundwater.[202] Especially in the highlands, policies of replacing current water-inefficient agricultural systems with high-value vegetables in hydroponic systems would cut down pumping by at least 80% for the same returns. Water productivity and water savings are projected to increase in five of the six packages. Limitations did not allow for calculations pertaining to the small ruminants. While restoration of rangeland in the Badia cannot be evaluated to compare sales, the investment would contribute to a fivefold increase in biophysical water productivity that carries benefits in green water use for agricultural and environmental activities.

Current policies related to agriculture and water aim to improve irrigation efficiency and enhance land productivity (kg/dunum). Increasing land productivity generally requires more water than is available. Agriculture land is therefore no longer the most limiting resources; rather, water greatly limits agriculture in Jordan. As water availability continuously decreases, the only way to increase or at least maintain current production levels is by increasing water productivity. New policies therefore need to target water productivity in addition to land productivity. This priority requires directing subsidies and other policy instruments to encourage cropping patterns, irrigation systems and management, advanced technologies, and investment to maximize water productivity. The CSA packages indicated above are among the options that can increase biophysical and economic water productivity and nutrient-related, environmental water productivity, and social benefits.

6.6. Contribution of CSA investments to the NDC Action Plan

The aforementioned national priorities and policies heavily informed the NDC Action Plan approved in 2019. The national guidelines helped to identify practices with potential to be applied in the context of CSA. Many of the national priorities listed in Table 6.5 strongly support Jordan's NDC Action Plan submitted to the Paris Accord in 2016. The initiatives share similar goals including a climate resilient economy, a secure food system supported by adaptive measures to climate change in the water and agricultural sectors, and enhancing livelihoods through capacity building and opportunities for vulnerable communities, including rural smallholders, youth, and women.

The proposed CSA investments' contributions to the NDC Action Plan objectives are strong and stretch beyond the outcomes and outputs targeted to the agricultural sector. Table 6.7 presents an overview of the contributions of the CSA investments to the different aspects of each objective. The key elements listed here are relatively narrowly defined within the NDC Action Plan as compared to broader international definitions. Adopting the broader definitions of these elements may be a good opportunity for meeting international commitments, unlocking supportive international funding, and more easily comparing national statistics to others in the regions. This is particularly applicable to resilience of agricultural systems and sustainable farming practices.

Table 6.7: Alignment of CSA investments with NDC Partnership goals

NDC objective	Element	Date Palm	Vegetables	Olive	Barley	Small ruminant	Badia restoration
Low emission economy	Scale up energy efficiency						
	Use renewable energy						
	Mitigate methane gas emission						
Adapt to climate change	Reduction of water loss						
	Reduced water pollution						
	Increase water availability						
	Agricultural system resilience						
	Enhance resilience rural communities						
Enabling Environment	Protect natural eco-systems						
	Increase resilience vulnerable groups						
	Institutionalize capacity building						

Use of renewable energy is a component of several CSA packages that align with the NDC objective promoting a low emission economy. For the transition to a low emissions economy, the NDC Action Plan refers to energy efficiency measures, the adaptation of solar energy and other renewable resources and mitigation of methane gas emissions. While this mainly refers to the industrial, buildings and urban sector, it also targets the water and agricultural sector. Energy efficiency in the water sector highlights the importance of water utilities, and solar energy for water pumping and the use of solar PV systems are explicitly mentioned. Although mitigating emissions is not the main purpose of the CSA investments, several of the packages include mitigation as a co-benefit. Examples include relatively moderate energy use for irrigation and fruit processing of date palm; relatively low use of energy for protected vegetable and potential use of renewable energy for cold storage; use of alternative energy (solar) in pressing mills for olives and recycling of biosolids and liquid waste; and, renewable energy for processing of dairy products of small ruminants.

The adaptation of the water and agricultural sector to the impacts of climate change is at the heart of the proposed CSA investments. For water, the NDC plan refers to reduced loss of water, reduced pollution, and increased water availability. Investments on vegetables, date palm, and olives aim to reduce loss of water through the use of modern irrigation systems (vegetables) or soil-water-nutrient conservation (date palm, olive); indirectly Badia restoration also contributes to reduced rainwater losses through restored vegetation and halting soils degradation. The reduction of water pollution is addressed in the date palm sector through the reduction of date palm waste. CSA investments on barley and Badia restoration aim to increase water availability through rainwater harvesting and specific measure to conserve water. For the agricultural sector, the NDC Action Plan refers to strengthening the resilience of agricultural system and of rural communities. The former includes rehabilitation of rangeland and grazing reserves; forestation and afforestation projects; reclaiming land for productive use; conserving local landraces; adopting sustainable land use management; and improving cropping patterns and crop varieties. Rehabilitating natural landscapes is an integral benefit of the Badia restoration project, as well as CSA investments on small ruminants and barley. Increasing resilience of rural communities refers to the improvement of skills of rural women and rural households in livestock rearing, gardening, food production, and marketing; deploying community-based management of sustainable recreational parks; and launching ecosystem-based enterprises in forested areas. These elements resonate well with both the investment on small ruminants and Badia restoration.

CSA investments in the Badia contribute directly to the resilience of natural ecosystems. The NDC Action Plan refers to "improving conservation status of climate vulnerable ecosystems and strengthen adaptive capacities of key ecological hotspots", as well as the "integration of carbon sinks into mitigation & adaptation policies." The Badia's expansive lands hold both cultural and ecological significance that fits this definition, and restoration of the Badia contributes to both NDC goals. Indirectly, the expansion of barley production and concentrated farming systems for small ruminants may eventually also contribute to reduced land degradation and increased land carbon storage.

Enabling rural economic opportunities and poverty reduction is an objective of several CSA investments. Generally, the CSA Action Plan complies with building resilience of socio-economically disadvantaged (rural) communities and groups; more specifically the NDC action plans refers to enhancing income of rural families living below the poverty line and expanding income and agricultural productivity projects that target poor rural households (including gender responsive programs). Both goals apply to programs in the Badia (i.e., barley, small ruminants, and Badia restoration) as the region is primarily rural with fewer economic opportunities currently available. Other CSA investments (date palms, vegetables, and olives) aim to address similar goals as they encompass potential for employment opportunities.

Capacity building is a key element of strengthening resilience seen across all six investments. The NDC Action Plan refers to capacity building across the board, including the adoption of an M&E framework; incentivizing institutions to plan for mitigation and adaptation measures and to develop and deliver climate resilient services; providing training to conduct feasibility studies for selected projects; and raising awareness about climate change across institutions and sectors. These efforts align well with the CSA investments and the CSA Action Plan more generally. Overall, the CSA investments seem well aligned with the NDC Action Plan, proving scope for further policy alignment and support, as well as compliance with M&E frameworks to be able to account of progress made in terms of resilience, adaption and mitigation.

6.7. Financing opportunities for CSA programming

The NCD Acton Plan also mentions the importance of institutionalizing climate funding processes for raising and delivering climate finance. This is to be accomplished by strengthening the institutional capacity of Jordan Environmental Fund and create a revolving loan fund to support mitigation and adaptation efforts of farmers.

Greater effort needs to be placed on accessing international climate finance instruments while also ensuring availability of local-level public and private financing instruments for investments in CSA. Jordan strongly depends on international investments, although funding for the agricultural sector and especially CSA in the country has so far been limited. There is only one agricultural credit institution in Jordan; and private sector activity in Jordan remains far below potential as a result of restrictive policies. While there is scope for private-sector investment for CSA in high value commodity markets (date palm, vegetables, possibly olive) in general the private sector seems hesitant to invest in the agricultural sector. Moreover, it was noted that no commercial bank or finance institution will invest in agricultural production in the Badia (barley, small ruminants and especially Badia restoration). For this reason – in addition to the private sector's reluctance to get involved and the significant public benefits of restoring the region – the role of multilateral and bilateral development organizations will need to be significant. Also blended finance, in which public money is used to reduce the risk of the private sector, should be further explored.

There are many potential private, public and international funding sources and instruments. Some key public and private sources are summarized here.

- Public funding sources and tools:
  - National institutions: government budgets; state-owned enterprises; sovereign wealth funds, central and state banks
  - Public financial intermediaries: bilateral/multilateral aid agencies; national, regional, and multilateral climate funds; national, bilateral, regional, and multilateral development finance institutions; United Nations (UN) organizations

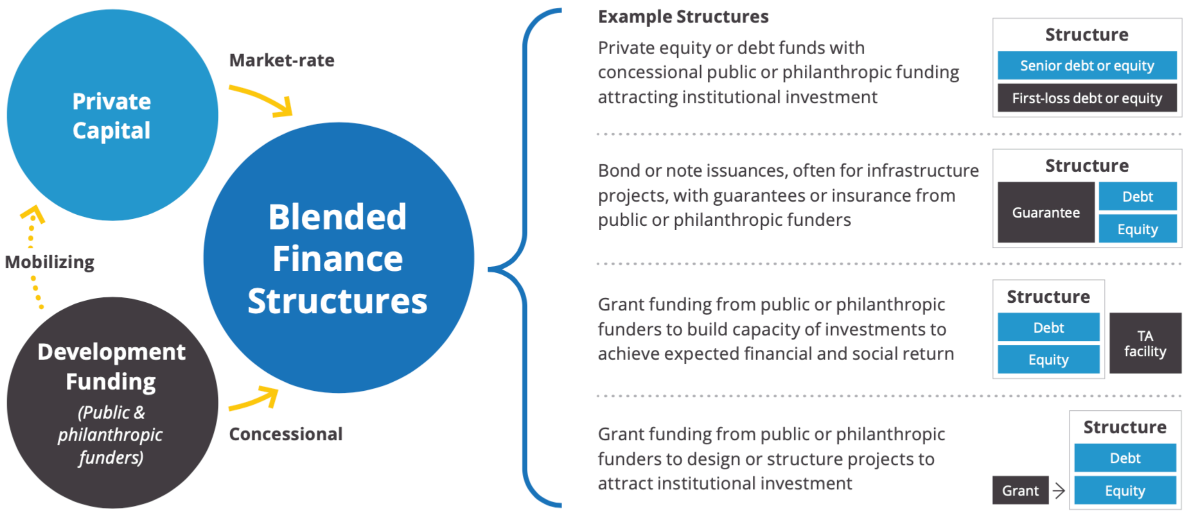
- Private funding sources and tools:
  - Private finance institutions: smallholder and community organizations; microfinance institutions; revolving funds; cooperative banks
  - Private sector: agribusinesses; corporations; private capital project developers; private national and multinational companies
  - Private financial intermediaries: domestic and international commercial financial institutions, venture capital, institutional investors, private equity funds

UNFCCC negotiations have mobilized opportunities for climate financing from both public and private sources to help reduce emissions and increase resilience against the detrimental effects of climate change.[203] Climate financing describes the flow of money from country to country and via international institutions (e.g., Green Climate Fund, African Development Fund, Strategic Climate Fund) to support climate change-related activities, programs, or projects, for mitigation or adaptation. Initially agreed upon at the Copenhagen Accord in 2009 and further reinforced In the Paris Agreement in 2015, wealthier nations have pledged to give poorer nations US$100bn annually to tackle climate change.[204] The type of finance provision varies (e.g development aid, private equity, loans, or concessional finance) and is tracked database collated by the Organisation for Economic Co-operation and Development (OECD).[205] Jordan has received in excess of US$100 million since 2015 for climate finance programming from World Bank, GEF-6, the Clean Technology Fund, the Green Climate Fund, and the Adaptation Fund.[206] Most notable among these is the "Increasing The Resilience

Of Poor And Vulnerable Communities To Climate Change Impacts In Jordan Through Implementing Innovative Projects In Water And Agriculture In Support Of Adaptation To Climate Change" project.[207] This US$ 9.2 million initiative, approved in 2015, is funded by the Adaptation Fund and hosted by the Ministry of Planning.[208]

There are different types of financing instruments to explore. Capital instruments can vary from public finance instruments such as direct investment, taxes, subsidies, and grants, as well as loans, bonds, public budget allocation, private equity, result based finance and purchases, etc. Further, risk instruments can be used, such as credit guarantees, insurance, and off-take agreement. Blended finance (Figure 6.1) could be particularly relevant in the context of Jordan and the investments proposed, and should be further examined.

Figure 6.1 Blended finance mechanisms and structures



Blended finance can be used to mobilize public and private finance to scale up successful, high potential CSA investments. Blended models that capitalize on public funding to offset risks of private finance are increasingly important and emphasize the key role of the private sector and leveraged investments. This does require an enabling context, involving policy and regulations to enact mandatory reporting. Increasing the ease of running a farm business can offer incentives for small/medium farmers to invest in technologies for CSA and reduce supply chain vulnerability.

Other financial sources could be tapped to distribute climate finance programming through innovative finance mechanisms that are already widely used in other sectors. Currently, climate funding seldom leverages capital from other players. Among these, examples include incentivizing payments for and increasing the variety of environmental services. Blended finance approaches offer high potential and include private sector technical assistance funds, concessional capital, guarantees or risk insurance, private finance design-stage grants, and/or results-based financing that comes from the public or philanthropic funds, which can make investments more attractive for commercial and institutional investors.

Making finance accessible at the farmer and SME levels can be achieved through the bundling of finance, productivity, and market access services.[210] For farmers, finance may be bundled with input provision, training, advisory, technology, off-taking, and market access services. For farmers and small and medium enterprises, finance services may be bundled with business development, advisory, technology, market, and partnership-brokering services. Local organizations, such as cooperatives, can be important platforms for increased access to finance through initiatives such as revolving credit, collective savings and finance mobilization, equipment sharing, and bulk purchasing and sales for improved bargaining power.

The proposed CSA investments provide opportunities for sustainable growth. This includes the transition to new practices and the adoption of new technologies. In addition to accessing credit that enables these changes, smallholder households want ease of payment, insurance, and savings to transact more effectively, manage risk, and smooth cash flows. By addressing these factors farmers can improve the quantity and quality of production, while at the same time addressing other risks and bottlenecks in supply chains and the food system more broadly. This creates an enabling environment for attracting private finance.

Chapter 7

Climate-Smart Analysis for CSA investments

Highlights

- At both the farm and aggregated levels, our cost-benefit analysis (CBA) shows a positive net present value (NPV) and internal rate of return (IRR) for all CSA packages, indicating a generally good return on investment.
- Using the Adoption and Diffusion Outcome Prediction Tool (ADOPT), we predict high maximum adoption rates for all CSA investments--93% to 98% within a 20-year period. Diffusion rates differ, presumably due to the diverse characteristics and learnability of the target beneficiaries of each package.
- The CSA investment packages have various levels of sensitivity to discount rate, climate change, and output price variability.
- All the investment packages proposed by this CSA Action Plan have a negative net carbon balance, with a total reduction potential of greenhouse gas (GHG) emissions of 823,665 tCO2-eq, representing a value of more than US$ 25 million based on a carbon price of US$30.65/tCO2-eq.
- Badia restoration contributes most to GHG emission reduction (64%), followed at a distance by small ruminant and date palm value chains (12-13% each) and then vegetable value chains (4.6%); investment packages on olive and barley contribute least (3.4% each).
- Overall, taking a value chain approach reduces the payback period for most CSA investments substantially, while increasing financing opportunities through private-sector involvement.

7.1 Cost-benefit analysis and greenhouse gas mitigation assessment

Within the context of program design, detailed modeling was conducted to predict the potential performance of selected CSA investments in terms of productivity, resilience, and mitigation, subject to expected cost, social and climate risks, and their potential impact on outcomes. The cost-benefit analysis (CBA) and GHG mitigation assessment presented in this chapter provide a quantitative evaluation of the CSA investments, complementing the broader qualitative assessment in the previous chapter. Together these quantitative and qualitative perspectives provide the ingredients for the overall design of a CSA program as part of this CSA Action Plan.

The chapter starts by assessing the profitability of the proposed CSA investments at the farm level and the aggregated investment-package level, followed by a GHG emission assessment. The CBA, includes input and production costs under on-farm analysis. For large scale investment we provide a value chain perspective, taking into consideration post-harvest, processing, storage, marketing, and institutional costs whenever possible – dependent on data availability. We discuss profitability under climate change for different CSA investments, and how sensitive or resilient these investments are under varying conditions. Along with the impact of climate change on productivity and resilience, GHG emissions were assessed for each CSA investment package compared to current practice, as well as the impact on GHG emissions at the program level. Table 7.1 provides an overview of the investment packages with key components along the value chain.

Table 7.1 Key components of investment packages across the value chain

NDC objective	Element	Date Palm	Vegetables	Olive
Date Palm	- High quality varieties -*Plant protection program*	- Improved cultural practices (soil-water-nutrient conservation) - Modern (drip) irrigation	- Collective post-harvest facilities (processing and storage)	- *Collective marketing infrastructure*
Vegetables	- Protected greenhouse	- Precision farming (with sensors) and modern (drip) irrigation - Hydroponics for high value vegetables (in highlands)	- Cold storage facilities (with renewable energy) - Grading and sorting facilities	- *Quality certification schemes (for high value export markets)*
Olive	Reduced water pollution	- Micro-catchment water harvesting - Modern harvesting technology - *Improved cultural practices (soil-water-nutrient conservation)*	- Cold pressing - Solar energy for mills - *Reducing solid/liquid waste of processing*	- Global GAP Certification
Barley	- Improved varieties	- Micro-catchment water harvesting - Precision farming		
Small ruminants	- Fencing	- Concentrated farming - On-farm fattening through balanced feed	- By-product processing (especially milk) - *Cold storage (renewable energy)*	- *Product differentiation and marketing*

NDC objective	Element	Date Palm	Vegetables	Olive
Badia restoration	- *Selection of suitable sites* - Nurseries for seedlings - Construction of bunds/ contour ridges at large scale	- Planting shrubs/ grasses with macro-water harvesting - Controlled grazing		

*Elements in *italic* could not be included in the CBA due to the lack of data

7.2 Farm-scale incremental profitability of CSA investments

We first employed a CBA to assess the financial profitability of different CSA packages at the farm level. CBAs are widely used to value and compare the costs and benefits of CSA interventions, in order to guide decision on whether an investment should be implemented given limited resources.[211, 212, 213] At the farm level, an ex post facto CBA was used because these CSA interventions have already been tried or implemented by several farmers or areas.

We used the two most common CBA indicators, net present value (NPV) and internal rate of return (IRR), to estimate the incremental net profitability of commodities produced under CSA and under the conventional farming (see Annex G). A positive NPV and IRR indicate a positive net incremental benefit, or profitability. The higher the NPV and the IRR are, the higher profitability of the CSA intervention. It should therefore be underlined that the NPV/IRR relate to the incremental impact of the CSA interventions compared to conventional practices and is not the NPV/IRR of a new investment using such practices. In other words, such NPV/IRR do not relate to the potential profitability of the agriculture sector but of a specific additional investment within the sector. Payback period is a measure for the number of years it takes for the investment to reach break-even.

In general, all CSA packages are profitable at the farm-scale level, as the NPV and IRR of incremental net-benefit are positive for all CSA packages (Table 7.2). Barley and Badia restoration bring the lowest benefit at the farm level. However, the IRR of these two packages is relatively high, and the payback period is also shorter than for other packages due to the low initial investment costs at the farm level. On the other hand, the vegetables package has a high NPV, but its IRR is low at 9% to 11% due to substantial farm-level investments, and the investments also take longer time to reach the break-even point (8 to 10 years). We discuss the farm-level CBA for each package below.

Table 7.2 Farm-level Cost-Benefit Analysis of CSA packages (20 years)*

CSA package**	Initial investment cost (JD)***	NPV@6% (JD)	IRR (%)	Payback Period (years)
Date palm	792	1,749	10	12
Vegetables (a)	42,743	9,064	9	9.8
Vegetables (b)	39,743	14,384	11	8.9
Vegetables (c)	44,743	7,177	11	10.3
Olive	1,682	4,521	58	3
Barley	47	655	41	4
Small ruminants	25,838	50,442	40	3
Badia restoration	1.79	60.67	117	3

* A farm-level CBA is scaled at 1 dunum (0.1 ha). For small ruminants, the CBA is for 150 heads.

**Vegetables: (a) open field to greenhouses; (b) low tunnels to greenhouses; (c) open field to hydroponics

***1 JD = US$ 1.41

Date palms. The NPV of converting open-field vegetables – squash in this case – to date palm is JD 1,749 per dunum at a 6% discount rate, and the IRR is 10%. The date palm package requires a shift from annual, open-field vegetables to a perennial crop. While annual crops bring yearly financial returns, perennial crops require several years until the first harvest. In the case of date palms, the harvest starts in year 3 and reaches maximum yield at year 10. As such, the payback period of this CSA package at the farm level is 12 years. During the first five years, farmers can intercrop annual crops such as onions when the date palms are still young. The initial investment cost for date palms is JD 792, higher than the annual cost of open-field squash production. The high investment cost for date palms, over and above the price of high-quality varieties like Medjool dates, results from the mechanized processes of land preparation, fertilizer application, and irrigation. When reaching maximum yield, date production generates JD 2,400 in revenue per dunum, higher than open-field squash. However, the cost of harvesting and post-harvest processing and storge of dates is also high, leading to a small incremental net benefit annually, from JD 792 to JD 1,132 per dunum.

Vegetables. Three options for transitioning to CSA were considered in the vegetables investment package: (a) open field to greenhouses; (b) low tunnel to greenhouses; and (c) open field to hydroponics; squash and tomatoes were used as representative crops. The incremental NPV and IRR of the second option were the highest among the three. In all the options, a substantial investment cost is required to establish a greenhouse or hydroponic system. The cost of setting up a greenhouse with a ventilator, an advanced drip irrigation system, and a sensor for precision farming is about JD 42 per square meter[214] and JD 44 per square meter for hydroponics.[215] When converting open-field production to a greenhouse or hydroponics, the cost is JD 3,000 to JD 5,000 higher than switching to a greenhouse from existing low-tunnel production. As result, the incremental NPV and IRR of the second option – shifting from low-tunnel to greenhouse production – are the highest among the three options. The high investment cost, however, arises only in the first year. From the second year, the revenue or income from vegetables produced using greenhouses or hydroponics is three times higher than the annual cost, and about seven times higher than the revenue of open-field vegetables in conventional farming. However, because of huge initial cost, investments in the different options for vegetable production require about 9-10 years to be paid back.

Olives. The CBA of this package shows a positive incremental NPV (JD 4,521) and high IRR (58%) per dunum over a period of 20 years. The positive incremental NPV stems from the higher yield and price of upgraded olive production and processing when compared to conventional practice. However, the initial investment cost per dunum of upgraded olive production is JD 1,682 higher than the standard annual production cost. This high cost is mostly spent on the harvesting machine, whose price is about JD 1,500, and on the batteries for the machine. While recognizing the importance of employment, investing in a harvesting machine helps to reduce labor costs significantly, as well as fruit loss during manual harvesting. As result, the net benefit of transitioning from manual labor to a harvesting machine is only negative in the first year and remains positive from the second year onwards. It only requires 3 years for the CSA investment in olives to reach the break-even point.

Barley. Introducing water harvesting techniques for barley cultivation brings a positive incremental NPV of JD 655 per dunum and an IRR of 41% over 20 years compared to conventional rainfed barley. The positive NPV and IRR of this package derive from water harvesting, which improves the yield of barley, and from the use of improved varieties rather than the rain-dependent local variety. The initial incremental benefit of CSA compared to conventional production is negative in the first two years due to the cost of setting up water-harvesting structures coupled with a 2-year waiting period without harvests to stabilize the strips. However, these small initial losses are worth the increased net benefit from year 3 onwards. The investment required for this package takes 4 years to pay back.

Small ruminants. By transitioning from open grazing to on-farm fattening or concentrated farming systems for small ruminants, the incremental NPV of 150 heads over a period of 20 years is estimated at JD 50,442, with an IRR of 40%. These high incremental benefits come from significantly elevated revenue – about 50% higher – from concentrated farming as opposed to open grazing. With this package, improved revenue is not only derived from increased yield, but also from the prices of meat, cheese, and milk as well as manure, culling, skin, and wool. However, the investment cost for concentrated farming systems is also high, at around JD 69,043, which is about 60% higher than the cost of open grazing in the first year. The investment cost for this package includes improved health and management of local sheep and goat breeds and the establishment of fencing; investment costs for milk and cheese processing and storage are considerable, although these investments contribute to better quality and prices; and finally, the cost to feed the livestock is also higher. However, from the second year onward, the annual cost of concentrated farming is only about 26% greater than that of open grazing, mostly due to the cost of feeding the livestock. Regardless of high investment cost, the payback period of this CSA package is only 3 years as a result of its substantial benefits.

Badia restoration package. At 1 dunum, Badia generates an NPV of JD 60.67 and an IRR of 117% over 20 years. However, at the farm scale, we only include the labor cost of planting shrubs. Other costs such as setting up the water-harvesting catchment and machinery including tractors and lasers were included at large scale level, since this is a landscape-scale investment package. At the farm level, benefits include avoiding the cost of planting barley, earning revenue from harvesting shrubs, and reducing the cost of soil erosion compared to barley. The payback period of this package at farm-scale is 3 years.

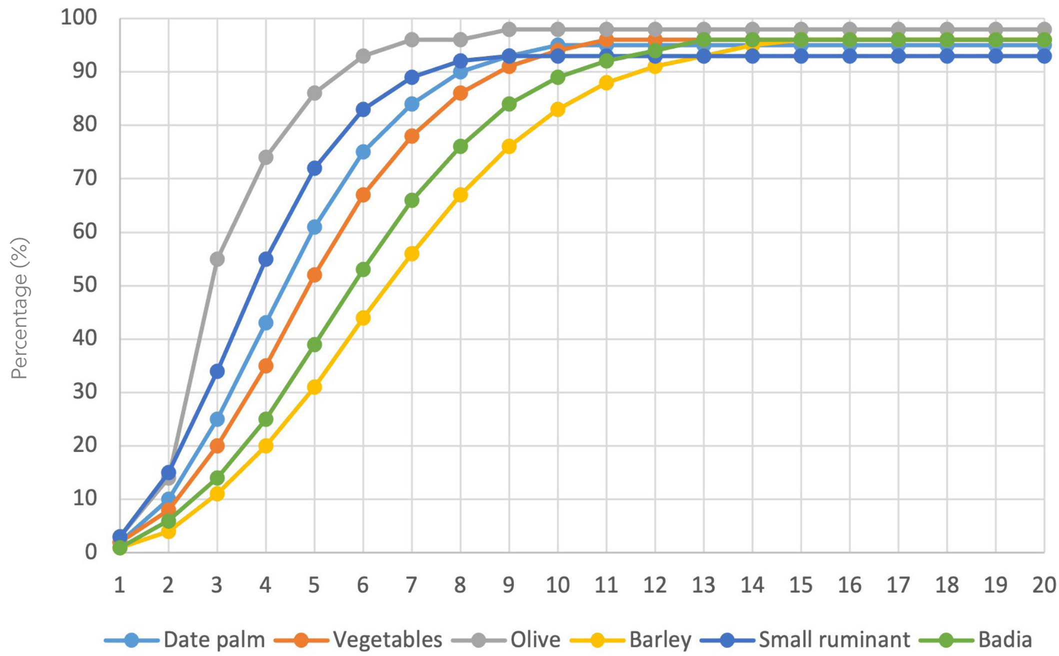
7.3 Adoption and aggregated economic profitability

We used the Adoption and Diffusion Outcome Prediction Tool (ADOPT) to predict the adoption rate for targeted beneficiaries. ADOPT is an online tool that has been developed to predict the probability of adoption and diffusion of an agricultural innovation for a specific population (see Annex G); factors that affect the maximum adoption rate and the time it takes to adopt an innovation include the characteristics of the innovation itself and the characteristics of the targeted population.[216]

Results generated by ADOPT tool show that the predicted maximum adoption rates for all CSA investments are remarkably high at 93% to 98%. However, each package has different adoption curves as shown in Figure 7.1, indicating different rates of diffusion. The speed of adoption is highest for the CSA package on olives, followed by small ruminants, date palms, vegetables, and then Badia restoration and barley. The CSA package for olives is predicted to diffuse the quickest among its target beneficiaries and reaches 86% in year 5 with a maximum adoption rate of 98% at year 10. The adoption of the small ruminants' package reaches 72% in year 5 and maxes out at 93% in year 9. Date palms and vegetables follow at 61% in year 5 and a 95% maximum at year 10, and 52% in year 5 and 96% maximum at year 11, respectively. The innovations for Badia restoration and barley are expected to spread at the slowest rate. For Badia restoration, the adoption rate reaches 39% in year 5 and a maximum rate of 96% at year 13, and for barley, 31% in year 5 and maximum of 96% at year 15.

The different rates of adoption might be best explained by the characteristics and learnability of the target beneficiaries of each package. As rated by the experts, the characteristics of each innovation, in terms of its relative advantages and learnability, are relatively equivalent for all the CSA packages. Based on expert interviews, the majority of the beneficiaries targeted for the olive package are oriented toward high profits, environmental considerations, and a long-term management horizon, with no short-term constraints. The total score for relative advantages of this target population was the highest of any CSA package; the learnability of the target population for olives is also high because the majority of producers have relevant existing skills and knowledge and are aware of the innovation. As such, the olive package is likely to be easily accepted and adopted. The barley and Badia restoration packages, in contrast, target a population group who almost all need to learn new skills and knowledge. Therefore, the adoption rate of these packages is slower. The adoption and diffusion rate within the small ruminant package seems rather high, given cultural practices of open grazing in the Badia. Those high rates assume substantial financial and technical support to the participating communities.

Figure 7.1 Predicted adoption rate of CSA packages



Aggregated economic profitability refers to the large-scale economic impact of each CSA investment package. The aggregated economic profitability of the six packages was estimated based on a combination of the net incremental benefit at the farm level (Table 7.2), the annual adoption rate (Figure 7.1); and, the large-scale investment costs beyond the farm level, such as for trainings and equipment for post-harvest storage and processing; and the number of targeted beneficiaries (see Annex G, Table G.2).

At the aggregated investment level (Table 7.3), date palms, vegetables, small ruminants, and olives are among the top packages that generate a high NPV, while barley and Badia restoration produce the lowest NPV. The higher the initial investment cost is compared to the annual incremental benefit flow, the lower the IRR and the longer the payback period are, and vice versa. Thus, at the farm level, the CSA packages for vegetables and date palms have the lowest IRR at 9-11%, and they require the longest payback period of 9-12 years. However, at aggregated investment level, the date palm and vegetable packages each generate a relatively high IRR: 74% for date palms, and 105-255% for vegetables. The high returns lead to a shorter payback period at the aggregated level.

Barley and Badia restoration generate a relatively low incremental net benefit at both the farm and aggregate scales. However, the investments required at the farm scale are significantly lower than the incremental benefits; thus, the packages have a high IRR. At large scale, the investment cost

Table 7.3 Economic profitability of CSA packages at aggregated investment level (20 years)

CSA package*	Area (ha)	Investments (costs)**			Aggregated NPV@6% (million JD)	Aggregated IRR (%)	Payback period (years)
		On-farm (million JD)	Large-scale (million JD)	Aggregated (million JD)			
Date palms	800	6.34	1.30	7.64	22.33	74	3.1
Vegetables (a)	250	106.86	0.37	107.23	38.91	255	1.6
Vegetables (b)	100	39.74	0.19	39.93	18.28	232	1.7
Vegetables (c)	20	8.95	0.09	9.04	2.91	105	2.6
Olive	1,000	16.82	2.12	18.94	36.83	93	2.6
Barley	1,000	0.47	0.60	1.07	3.73	34	5.5
Small ruminants	n/a	23.26	0.54	23.80	36.45	256	1.6
Badia restoration	5000	0.1	1.39	1.49	1.59	16	6.9

*Vegetables: (a) open field to greenhouses; (b) low tunnels to greenhouses; (c) open field to hydroponics

**1 JD = US$ 1.41

for barley is about 93% of the incremental net annual benefit at the maximum adoption rate, and that of Badia restoration is 4 times higher than the annual aggregate benefit of the package. This situation results in a low IRR and longer payback periods for these two packages.

The small ruminant and olive packages have a relatively high NPV and IRR at the farm scale. At aggregated scale, these packages produce an even higher IRR at 256% for small ruminant and 93% for olives. These results mean that these packages enable substantially high profitability both at the farm scale and at the aggregated investment package level, which can cover the investment cost within a short period of time.

7.4 Risks and sensitivity analysis

An analysis of risks and sensitivity was performed for farm-scale NPV (Table 7.4) and aggregated NPV (Table 7.5) under different climate change and discount rate scenarios. In general, the NPV of all CSA packages both at the farm scale and at the aggregated level is highly sensitive to the choice of discount rate. The impact of climate change and output prices, however, varies across CSA packages and scales of analysis. For example, climate change has a significant effect on the NPV results for date palms, vegetables, and barley, at both the farm and aggregated scales. In contrast, the NPV results of olive and small ruminant packages are not influenced much by climate change scenarios. Similarly, the variability of output prices leads to a wide distribution of NPV results for date palms, vegetables, and small ruminants but not for olives or barley. We discuss the sensitivity of each CSA package in detail below.

Date palms

Date palms are among the packages that are highly sensitive to all three factors: discount rate, climate change, and output price variability. Figure 7.2 shows the farm-scale NPV of date palms under NoCC and CC scenarios and under three different discount rates: 2.5%, 6%, and 9%. Converting from open-field vegetables like squash to date palms under NoCC is profitable at 2.5% and 6% discount rates, but not at 9%, because the mean farm-scale NPV at a 9% discount rate is negative (JD -105). However, under CC, the date palm package shows a positive NPV at all three discount rates. The mean of its NPV under CC is significantly higher than under NoCC because under CC, the yield of date palms increases more than the yield of squash, resulting in higher incremental net benefit at farm scale. At large scale, the date palm package is even more profitable under CC (Figure 7.3). The difference in the means of aggregated NPV between NoCC and CC is about 35%. This result highlights that date palms have the benefit of being comparatively more resilient to climate change than open-field squash.

Date palms are highly sensitive to price variability. In Figures 7.2 and 7.3, the length of the box plots indicates a wide distribution of NPV amounts at both scales under all CC and discount rate scenarios. This distribution results in part from the broad range of date prices from 1.5 JD/kg to 4 JD/kg. As a result of this sensitivity, there is a risk of a negative NPV at the farm level in some scenarios besides the 9% discount rate under NoCC. For example, if the date price decreases, the package is not profitable at a 6% discount rate under NoCC; the lower limit NPV is -491 JD. The package is also not profitable at a 9% discount rate under CC; in this case, the lower limit is NPV is -312 JD. At aggregate scale, the date palm package is profitable regardless of price variability. (Please note that the mean NPV of date palms at a 6% discount rate in this section is slightly different from the reported value in Table 7.2 and 7.3. This is because the mean NPV here is generated from simulations of output prices, while in the previous section it is estimated based on a single, static price.)

At the farm level as opposed to aggregate scale, the NPV of date palms is more sensitive to discount rates. At the farm level, under NoCC, the mean NPV at a 2.5% discount rate is 31% higher than the NPV at 6%, and 103% higher than the NPV at 9%. Under CC, meanwhile, the mean NPV at a 2.5% discount rate is 57% higher than at 6%, and 85% higher than the NPV at a 9% discount rate. At larger scales, discount rates have a smaller impact on the aggregate NPV. This is due to the high initial investment cost at the farm scale, whereas at the aggregated scale, the investment cost is low compared to the generated incremental benefit. At elevated discount rates, the significant investment costs at the farm level become more expensive, resulting in a lower NPV.

Figure 7.2 Sensitivity analysis of the NPV of the date palm package at the farm level

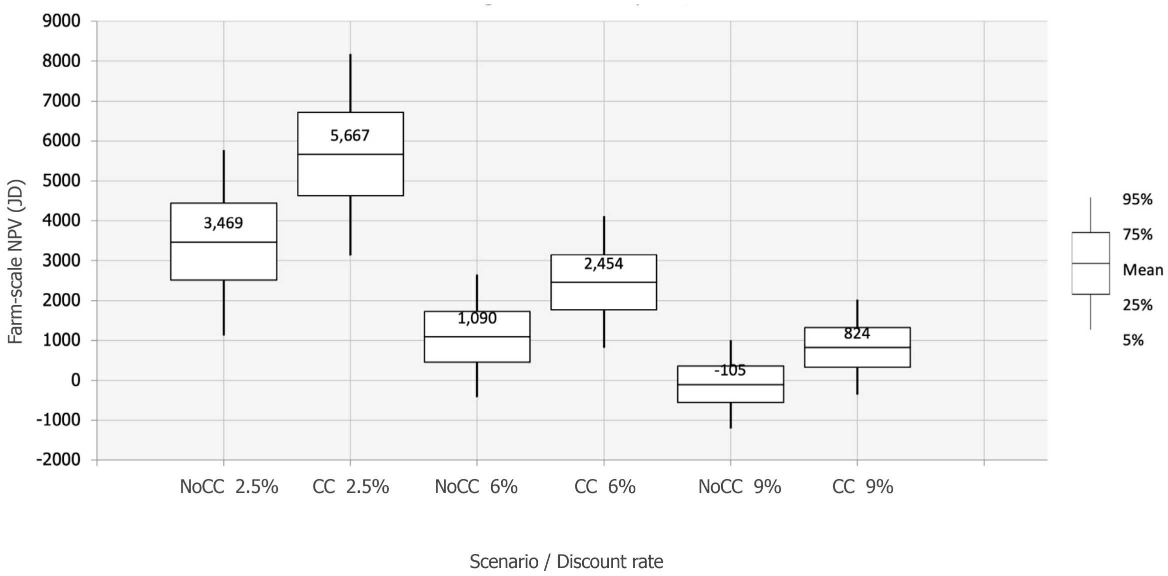
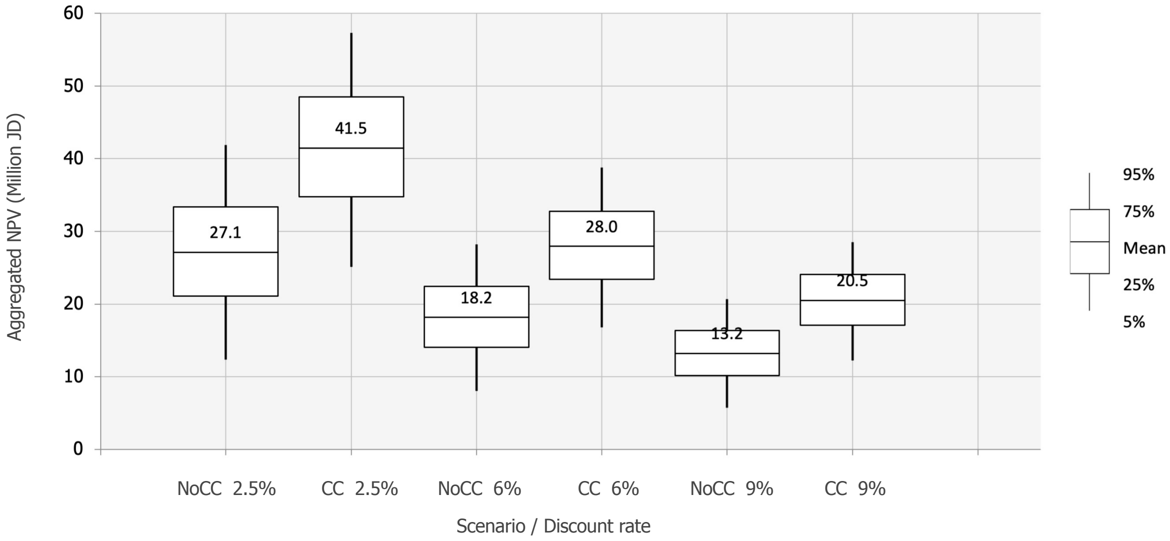


Figure 7.3 Sensitivity analysis of the NPV of the date palm package at the aggregated scale



Vegetables

The vegetables package, like the one for date palms, is highly sensitive to discount rates, climate change, and output prices. Sensitivity results for the vegetables package, with its different transition options, are presented via a series of box plots (Figures 7.4-7.9). Overall, across all three discount rates, the mean NPV at both the farm and aggregate scales is higher under CC than under NoCC . The difference in mean NPV between NoCC and CC scenarios is more obvious at low discount rates than at high ones, and at aggregate scale than at the farm scale. Therefore, regardless of the high initial investment costs involved, converting from open-field or low tunnel production to greenhouse or hydroponic production brings great profits particularly under CC.

There is considerable variability in vegetable prices. The maximum price of tomatoes is 50% higher than the average price and 75% higher than the minimum. This fact leads to large standard deviation of NPV results. However, as is the case for the date palm package, the aggregated NPV of the vegetables package is always positive regardless of price variability across all scenarios. At the farm scale, when converting from open-field to greenhouse or hydroponic production, low vegetable prices result in the risk of a negative NPV at a 9% discount rate under NoCC. In case of conversion from low tunnel to greenhouse production, the package shows a positive NPV across all scenarios and price ranges.

Figure 7.4 Sensitivity analysis of NPV for vegetables package (a) (open-field to greenhouse) at farm-scale level

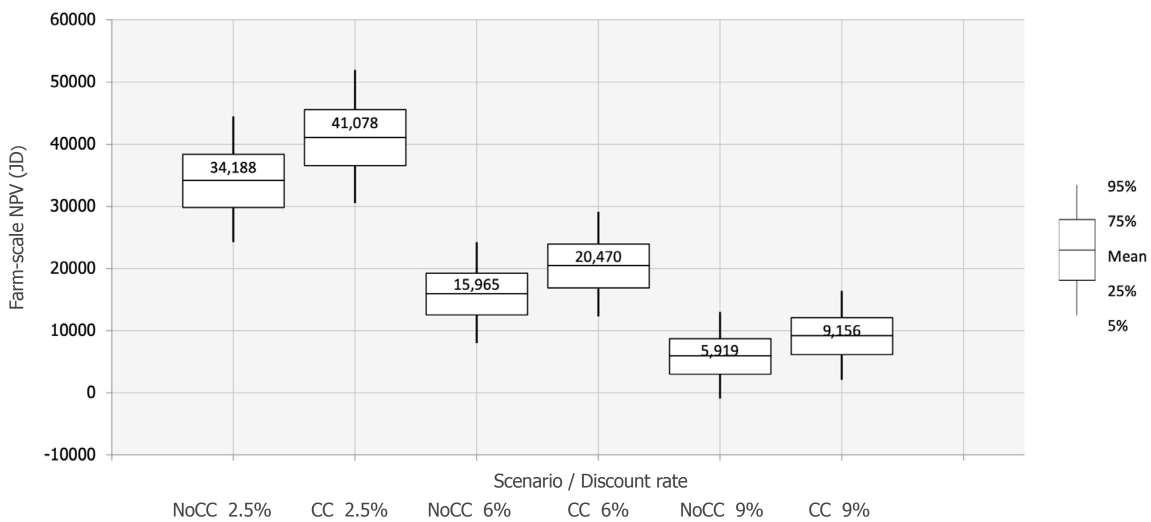


Figure 7.5 Sensitivity analysis of the NPV of vegetables package (a) (open-field to greenhouse) at the aggregated level

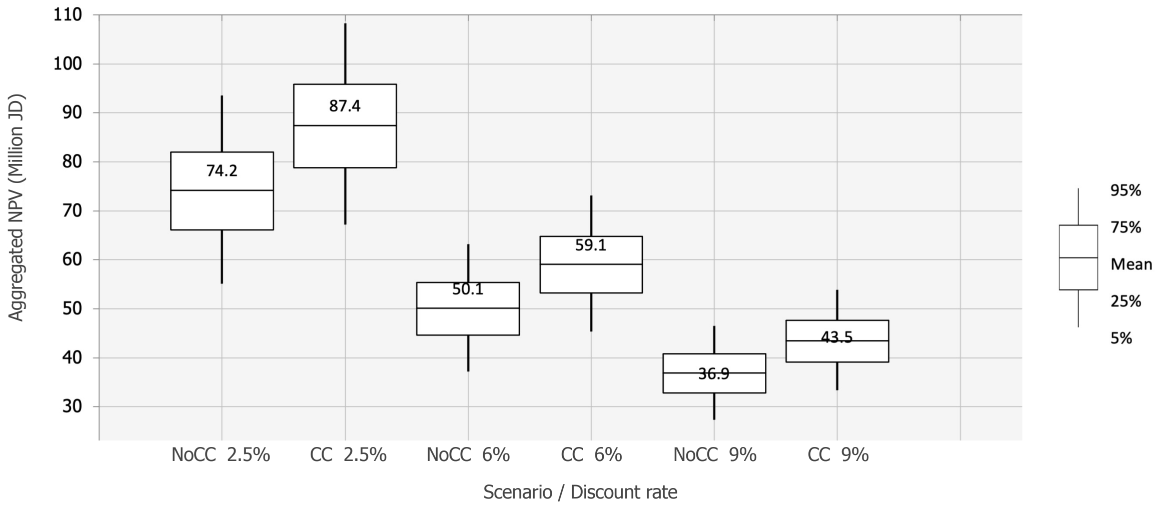


Figure 7.6 Sensitivity analysis of the NPV of vegetables package (b) (low tunnel to greenhouse) at the farm level

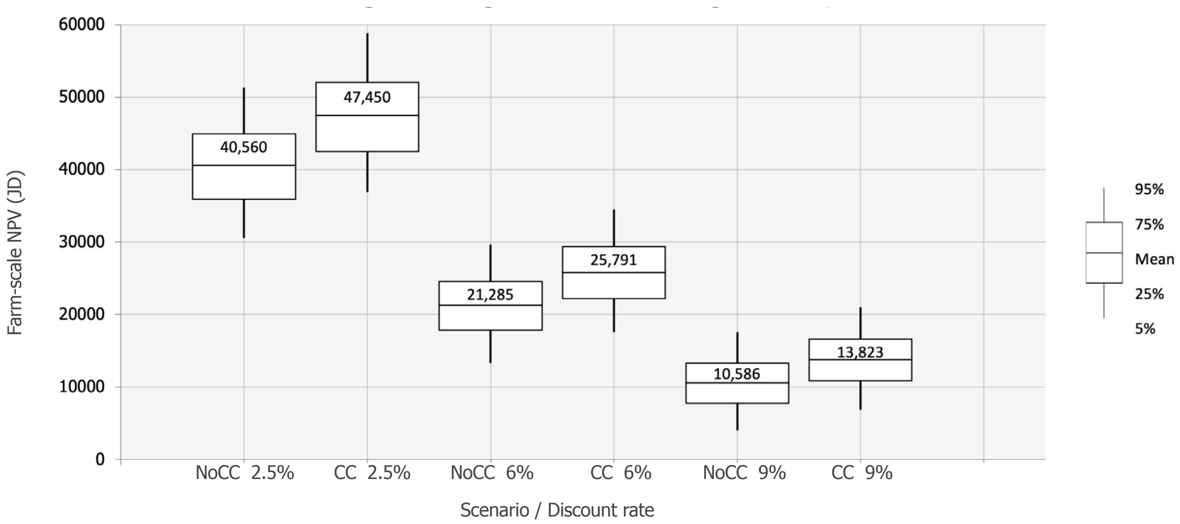


Figure 7.7 Sensitivity analysis of the NPV of vegetables package (b) (low tunnel to greenhouse) at the aggregated level

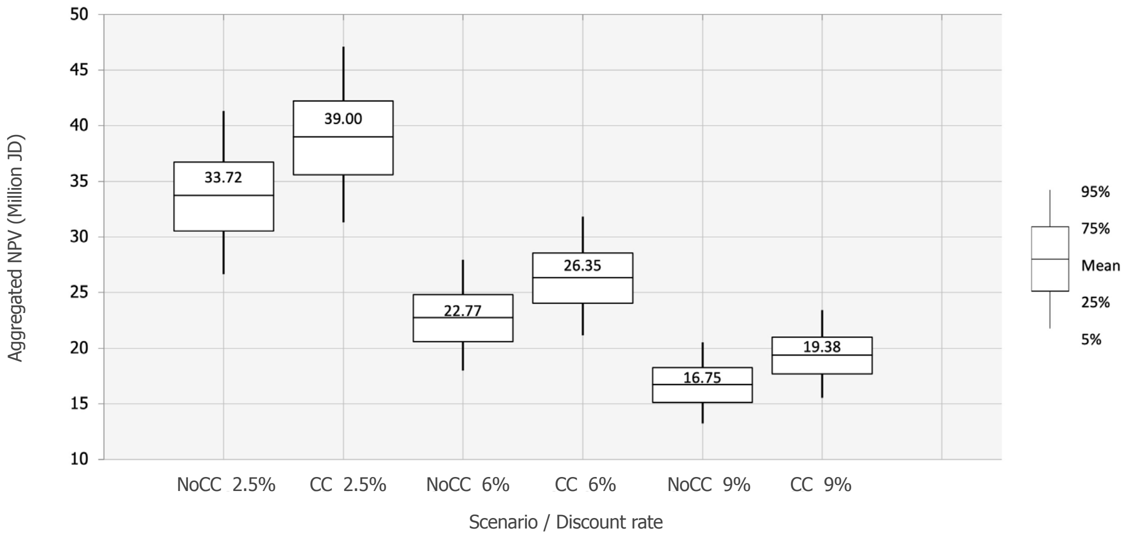


Figure 7.8 Sensitivity analysis of the NPV of vegetables package (c) (open-field to hydroponic) at the farm level

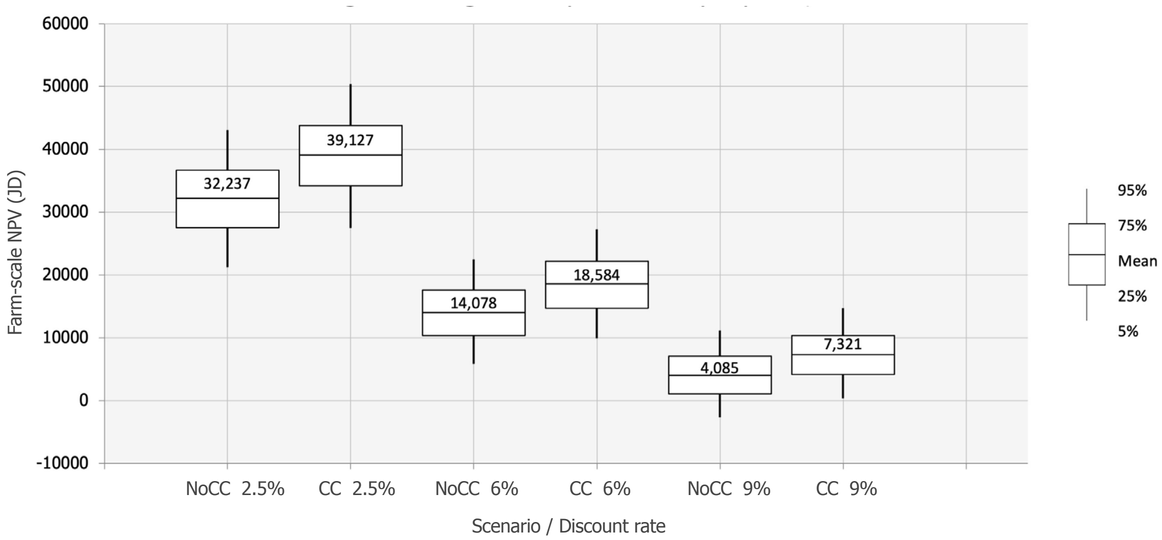
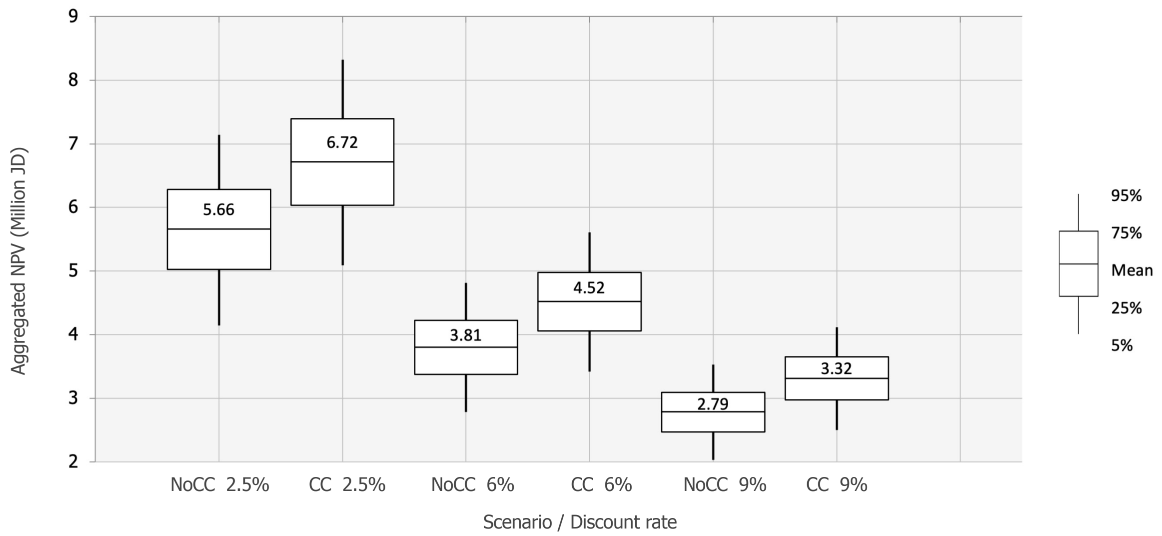


Figure 7.9 Sensitivity analysis of the NPV of vegetables package (c) (open-field to hydroponic) at the aggregated level



Olives

The profitability of the olive package depends on the discount rate, but not on CC scenarios or the output price (Figures 7.10 and 7.11). In general, the farm-scale and aggregated NPV of olives under NoCC are higher than under CC. This result differs from date palms and vegetables, where we observe a higher NPV under CC, because the olive yield is anticipated to decrease in a changing climate, while date and vegetable yields are expected to increase. Even though the olive yield produced under conventional farming (CF) is more impacted by CC than climate-smart olive production, the difference in the impact of climate change on CF and CSA is not enough to result in a higher incremental benefit under CC. Nevertheless, the difference in the NPV for the olive package between NoCC and CC scenarios is marginal at less than 1%.

The choice of discount rates affects the profitability of the olive package at both the farm and aggregated scales. The NPV at the farm and aggregated scales at a 2.5% discount rate is about double the NPV at the 9% discount rate.

Price variability does not significantly influence the incremental profitability of the olive package because olive oil and olive pickle prices do not fluctuate widely. The gap between the minimum and maximum prices of olive oil is only about 22%. The standard deviation of the NPV of the olive package at both the farm and aggregate scales is therefore smaller, as observed in shorter box plots, than for date palms and vegetables. Overall, no risk of negative profits is anticipated for this package across all scales and scenarios.

Figure 7.10 **Sensitivity analysis of the NPV of the olive package at the farm level**

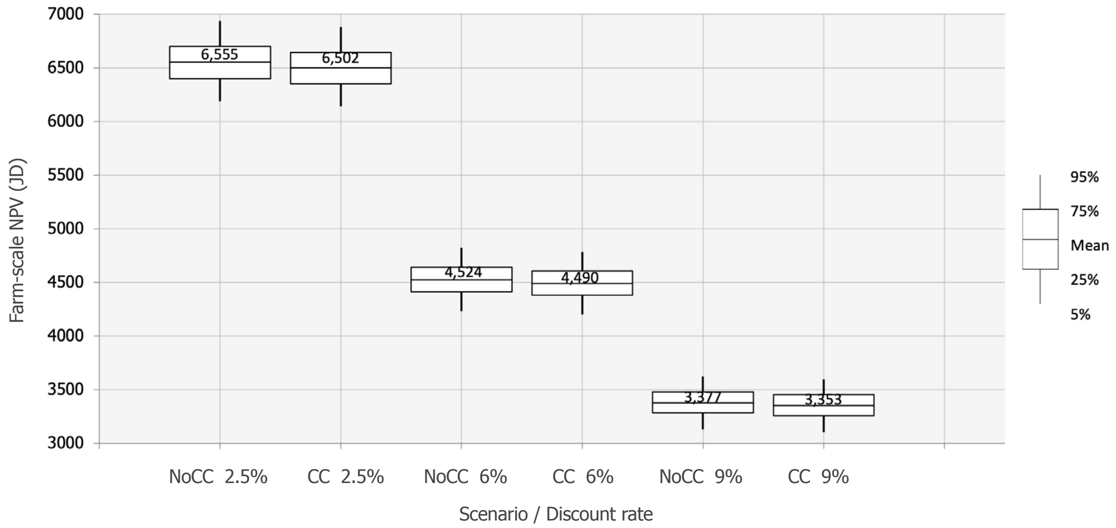
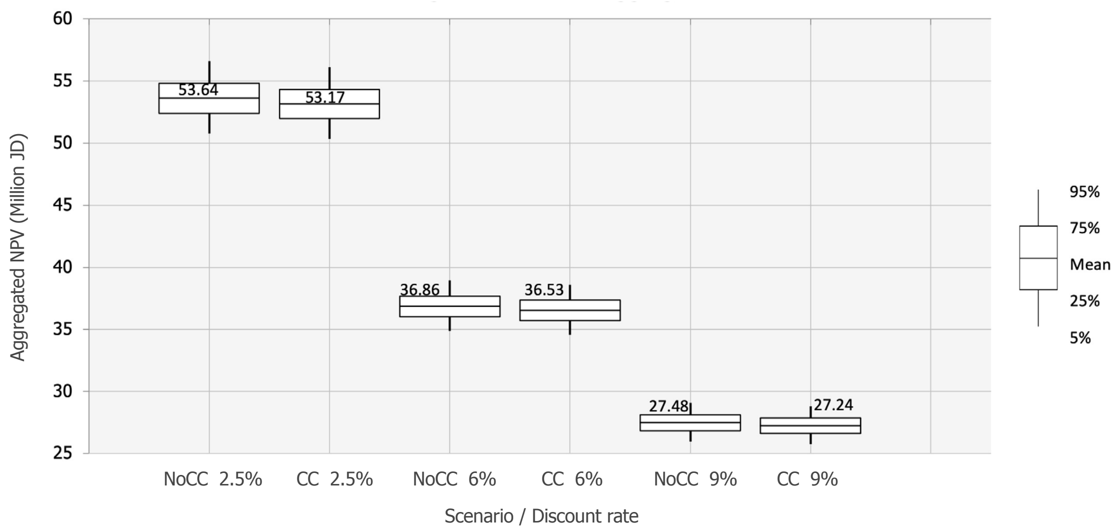


Figure 7.11 **Sensitivity analysis of the NPV of the olive package at the aggregated level**



Barley

Barley is sensitive to the selection of discount rates and to CC scenarios, but not to output prices. The CSA package for barley shows higher profitability under CC than NoCC at both the farm scale and aggregate scales (Figure7.12 and Figure 7.13). The difference between minimum and maximum barley prices, at 14% to 28%, is not large, resulting in a narrow range of NPV amounts as seen in the short box plots. The gap between the farm-scale and aggregated profitability of the package and between low and high discount rates is up to more than 50%. Overall, the package shows a positive NPV across all scales and scenarios.

Figure 7.12 Sensitivity analysis of the NPV of the barley package at the farm level

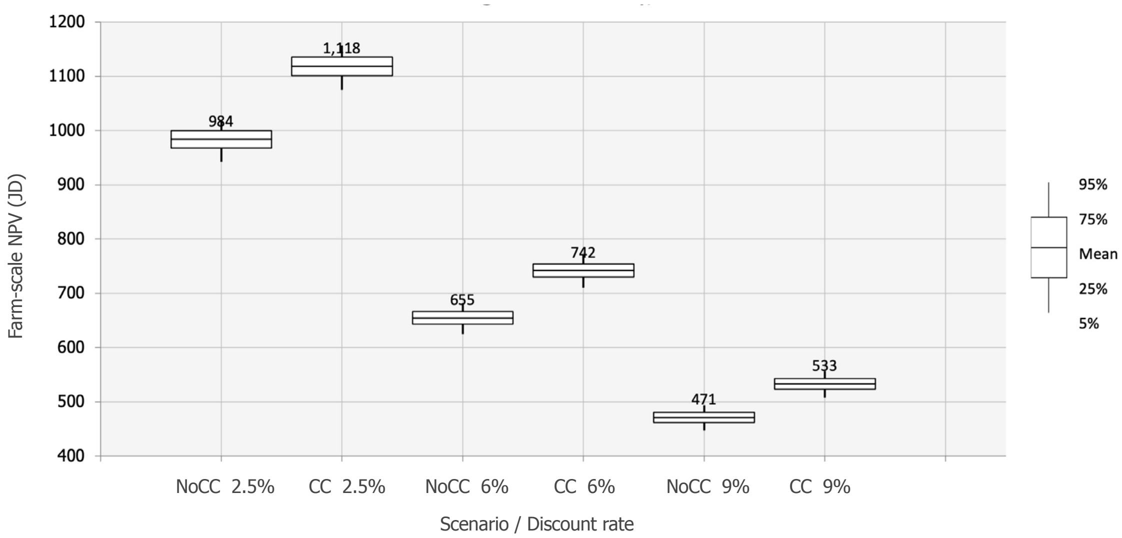
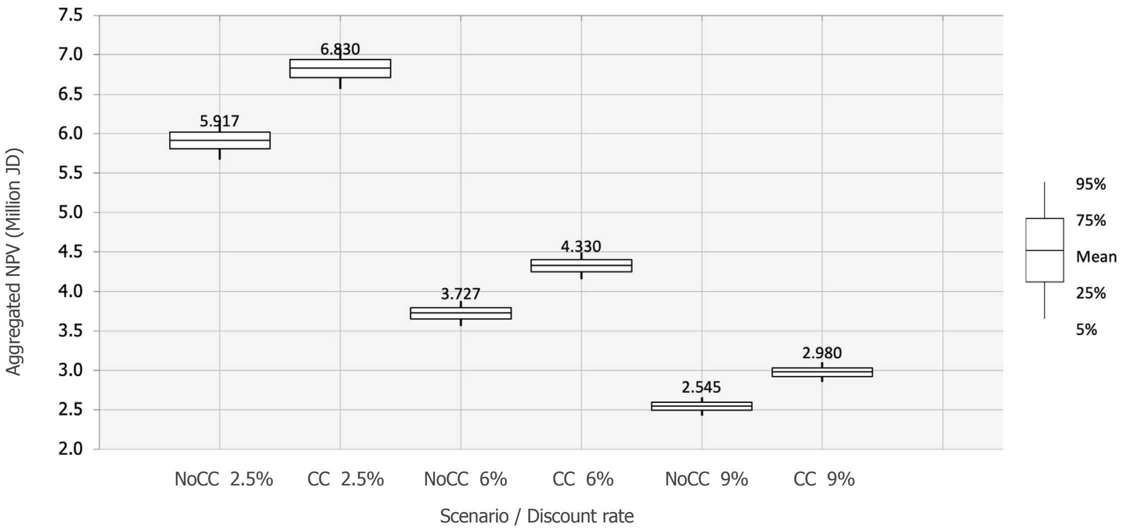


Figure 7.13 Sensitivity analysis of the NPV of the barley package at the aggregated level



Small ruminants

The profitability of the small ruminant package, like the olive package, is not highly impacted by climate change. Figures 7.14 and 7.15 show a slightly higher NPV under CC, unlike for the olive package because of the higher profitability – 137% at the farm scale – of small ruminants produced under CSA compared to CF. In addition, conventional small ruminant farming is expected to yield 30% less revenue than small ruminants produced under CSA. The combination of these two factors results in a higher incremental benefit under CC, even though the difference is minor.

The CSA investment is about 50% more profitable at low discount rates than at high discount rates at both the farm and aggregated levels. Price distribution also affects the range of NPV amounts as shown in the longer box plots and large standard deviation. However, in general this package is always profitable because a positive NPV is observed across all scales and sensitivity scenarios.

Figure 7.14 Sensitivity analysis of the NPV of the small ruminant package at the farm level

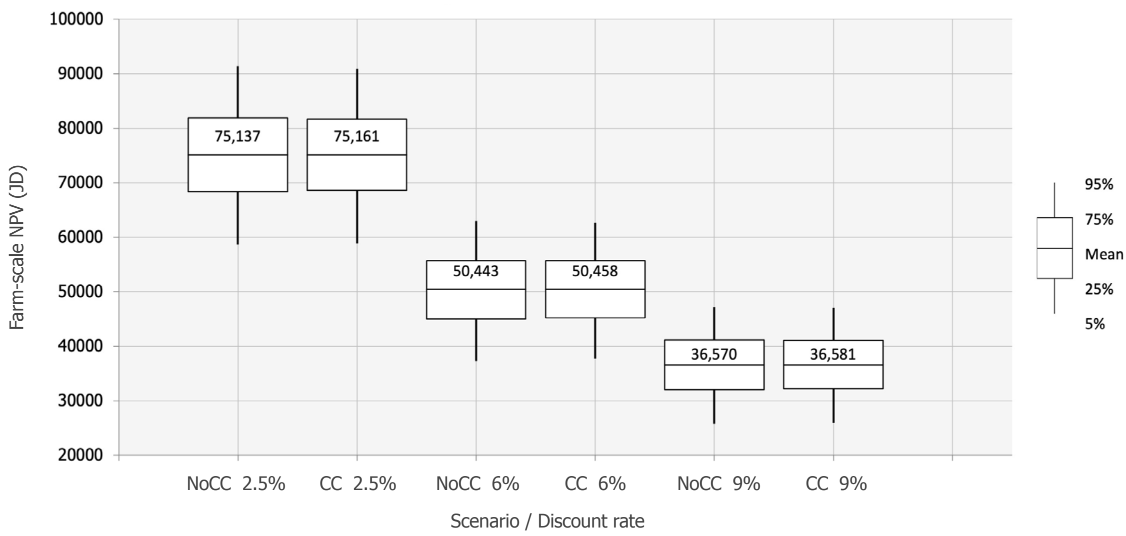
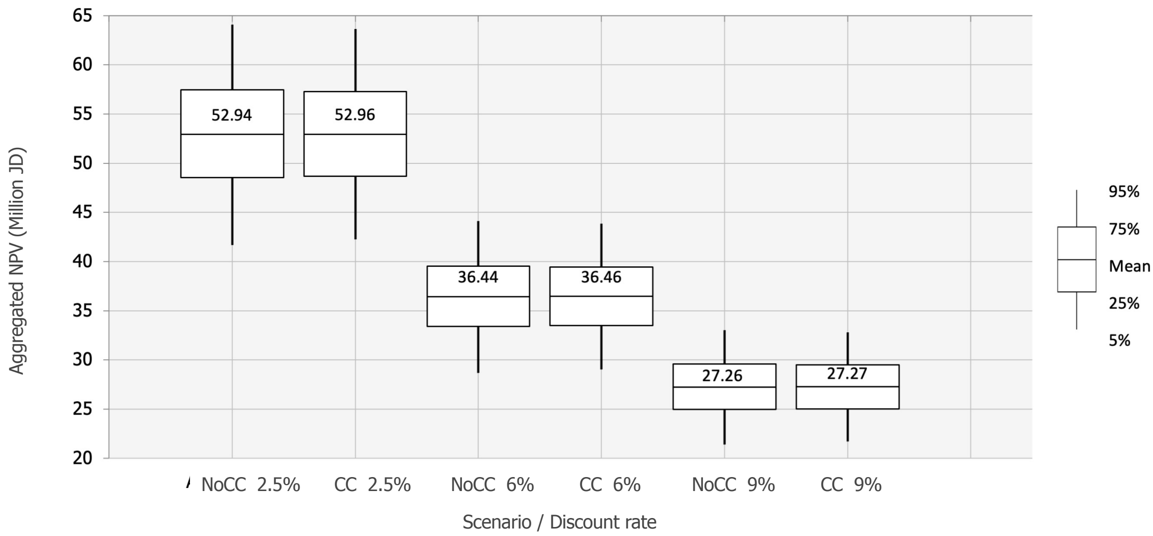


Figure 7.15 Sensitivity analysis of the NPV of the small ruminant package at the aggregated level



Badia restoration

We conducted a sensitivity analysis of the NPV of the Badia restoration package at the farm and aggregate scales under three different discount rates (see Table 7.4 and 7.5, which provide an overview for all investment packages). We assume that Badia is highly resilient to climate change, and so climate change has no impact on the package.

At a low discount rate of 2.5%, the farm-scale NPV is about 47% higher than that at a 9% discount rate, while aggregated NPV is about 67% higher. It should be noted that the benefit of Badia restoration analyzed in our CBA include gaining revenue from shrubs as forages for livestock and avoiding the cost of soil erosion. However, Badia restoration could generate various environmental and social benefits: for instance, recharging groundwater aquifers, increasing biomass, reducing sand storms, improving health and social welfare, and carbon sequestration. If we had assigned a monetary value to these environmental and social benefits and included them in the analysis, the profitability of this package would have been significantly higher.

Table 7.4 Sensitivity analysis of the farm-scale NPV of CSA packages under different CC and discount rate scenarios

CSA package	CC scenario	Farm-scale NPV@2.5% (JD)		Farm-scale NPV@6% (JD)		Farm-scale NPV@9% (JD)	
		Mean (SD)*	95% CI**	Mean (SD)	95% CI	Mean (SD)	95% CI
Date palm	No change	3469 (1381)	[1190, 5736]	1090 (921)	[-491, 2635]	-105 (679)	[-1263, 1019]
	CC	5667 (1537)	[3087, 8126]	2454 (939)	[940, 4009]	825 (682)	[-312, 1873]
Vegetables (a)	No change	34188 (6651)	[23531, 45131]	15965 (5126)	[7872, 24348]	5919 (4320)	[-958, 13315]
	CC	41079 (7030)	[29745, 52718]	20470 (5353)	[11962, 29140]	9156 (4475)	[2086, 16724]
Vegetables (b)	No change	40560 (6484)	[30555, 51295]	21285 (4937)	[13304, 29646]	10586 (4127)	[3974, 17599]
	CC	47450 (6870)	[36884, 58798]	25790 (5166)	[17573, 34531]	13823 (4281)	[6869, 21023]
Vegetables (c)	No change	32237 (6625)	[21260, 43089]	14078 (5087)	[5860, 22474]	4085 (4272)	[-2636, 11201]
	CC	39127 (7007)	[27530, 50375)	18583 (5136)	[9927, 27276]	7321 (4428)	[377, 14731]
Olive	No change	6555 (225)	[6194, 6926]	4524 (172)	[4242, 4803]	3377 (144)	[3136, 3604]
	CC	6502 (222)	[6148, 6863]	4490 (170)	[4211, 4765]	3352 (142)	[3117, 3575]
Barley	No change	983 (24)	[943, 1019]	655 (17)	[625, 681]	471 (14)	[447, 494]
	CC	1118 (25)	[1075,1157]	742 (18)	[710, 770]	533 (15)	[508, 557]
Small ruminants	No change	75137 (103490)	[58663, 91382]	50443 (7944)	[37266, 62988]	36570 (6659)	[25780, 47202]
	CC	75161 (9997)	[58869, 90849]	50458 (7730)	[37717, 62643]	36581 (6512)	[25948, 47028]
Badia restoration	NA	87.21		60.67		45.76	

Vegetables: (a) open field to greenhouses; (b) low tunnels to greenhouses; (c) open field to hydroponics
*Value in bracket is standard deviation; ** [lower limit, upper limit] ***Potential negative values are in red.

Table 7.5 Sensitivity analysis of the aggregated NPV of CSA packages under different CC and discount rate scenarios

CSA package	CC scenario	Farm-scale NPV@2.5% (JD)		Farm-scale NPV@6% (JD)		Farm-scale NPV@9% (JD)	
		Mean (SD)*	95% CI**	Mean (SD)	95% CI	Mean (SD)	95% CI
Date palm	No change	27.13 (8.66)	[12.93, 41.54]	18.17 (5.91)	[8.47, 28.01]	13.22 (4.39)	[6.01, 20.53]
	CC	41.45 (9.65)	[25.13, 57.31]	27.95 (6.59)	[16.80, 38.78]	20.49 (4.89)	[12.21, 28.54]
Vegetables (a)	No change	74.21 (11.62)	[55.34, 93.33]	50.13 (7.87)	[37.36, 63.08]	38.88 (5.80)	[27.46, 47.42]
	CC	87.42 (12.40)	[67.19, 107.82]	59.08 (8.39)	[45.38, 72.89]	43.47 (6.19)	[33.73, 53.65]
Vegetables (b)	No change	33.72 (4.57)	[26.65, 41.34]	22.77 (3.09)	[17.98, 27.93]	16.75 (2.28)	[13.22, 20.55]
	CC	39.00 (4.89)	[31.33, 47.10]	26.35 (3.31)	[21.16, 31.83]	19.38 (2.44)	[15.55, 23.43]
Vegetables (c)	No change	5.66 (0.93)	[4.15, 7.14]	3.81 (0.63)	[2.78, 4.81]	2.79 (0.46)	[2.03, 3.53]
	CC	6.72 (0.99)	[5.09, 8.32]	4.52 (0.67)	[3.42, 5.61]	3.32 (0.49)	[2.50, 4.12]
Olive	No change	53.64 (1.83)	[50.66, 56.62]	36.86 (1.27)	[34.78, 38.94]	27.48 (0.96)	[25.91, 29.06]
	CC	53.17 (1.79)	[50.24, 56.11]	36.53 (1.25)	[34.49, 38.58]	27.24 (0.95)	[25.69, 28.79]
Barley	No change	5.92 (0.15)	[5.67, 6.15]	3.73 (0.09)	[3.56, 3.88]	2.54 (0.07)	[2.43, 2.66]
	CC	6.83 (0.16)	[6.57, 7.08]	4.33 (0.11)	[4.16, 4.50]	2.97 (0.08)	[2.85, 3.10]
Small ruminants	No change	52.94 (6.89)	[41.69, 64.07)	36.44 (4.76)	[28.67, 44.14]	27.26 (3.58)	[21.42, 33.04]
	CC	52.96 (6.62)	[42.25, 63,65]	36.46 (4.57)	[29.05, 43.85]	27.27 (3.43)	[21.71, 32.82]
Badia restoration	NA	2.82		1.59		0.92	

*Vegetables: (a) open field to greenhouses; (b) low tunnels to greenhouses; (c) open field to hydroponics
*Value in bracket is standard deviation; ** [lower limit, upper limit]

7.5 Greenhouse gas mitigation assessment of CSA investment packages

Besides a CBA, a greenhouse gas (GHG) mitigation assessment was employed to gain a better understanding on the environmental impact of the CSA investment packages and their financial implications. The emissions presented were estimated using the Ex-Ante Carbon-balance Tool (EX-ACT) developed by the Food and Agriculture Organization of the United Nations (FAO)[218] which allows for the comparison of GHG emissions between 'business-as-usual' scenario with the improved CSA scenario. For the analysis, EX-ACT was calibrated with the following settings: a) Climate: Warm Temperate; b) Moisture Regime: Dry; c) Dominant Regional Soil Type: HAC Soils; d) Project duration: 20 years (implementation phase: 5 years; capitalisation phase: 15 years). The results are first presented per investment package and then for all packages combined. The analysis focuses mainly at the farm level (input/production), although (energy) emissions along the value chains related to storage and processing were included. For further information about the methodology, see Annex H.

Date palms

The investment package on Date Palm aims to convert 800 ha of open field vegetables farmland into new date palm plantations. Date palm is more climate resilient, specifically to drought, compared to vegetables. Date palm requires less water which makes it more viable in a water-scarce country like Jordan. The package targets 500 farmers for date palm conversion, assuming an average farm size of 1.6 ha per farmer. Squash is being used as representative crop for a larger set of open field vegetables. See Table 7.6 for an estimation of emissions.

Table 7.6 Greenhouse Gas emission assessment for Date Palms package

Date palms (800 ha)*	Total Emissions (tCO2-eq) (20 years)		
	Conventional	CSA	Balance
Land use change (sequestration)	0	-11,000	-11,000
Annual crops (vegetables)	1,218	152	-1,066
Perennial crops (date palm)	0	-109,240	-109,240
Inputs	20,066	43,315	23,249
Infrastructure	27	174	146
Total	**21,311**	**-76,700**	**-98,010**

The majority of the estimated GHG emission reduction comes from carbon sequestration which is captured by both soil carbon sequestration and above- and below-ground biomass. In this case, the main contribution to reduced emission is due to the change from annual crops (vegetables) to a perennial crop (date palms); moreover, perennial crops have the potential to increase soil carbon levels compared to conventionally utilized agricultural land. The conversion of the 800ha of vegetable land to date palm plantations was estimated to sequester around -120,088 tCO2-eq, mainly due to biomass but also due to land use change.

GHG emissions from inputs are a main source of emissions in date palm production. Conventional vegetable production is highly labor and input intensive, with farmers requiring various chemical fertilizers and pesticides in order to achieve optimal growth. Date palm, on the other hand, would be fertilized mostly through compost, cutting down on the majority of chemical fertilizers. However, due to the use of compost and slight increase in pesticide use due to the constant threat of pests, the project is expected to increase GHG emissions from inputs compared to conventional open field vegetable production by 23,249 tCO2-eq.

Overall, the net carbon balance of the investment package on date palm is -98,010 tCO2-eq. Without project interventions, conventional vegetable farming on 800 ha of land leads to the production of roughly 21,311 tCO2-eq. However, by converting these lands to data palm there is the potential to sequester about 76,700 tCO2-eq, turning it from an emission source to a carbon sink.

Vegetables

The investment package for vegetables targets in total 370 ha for the conversion of vegetables grown in open field and low tunnels to greenhouses and some to hydroponics. The introduction of greenhouses and/or hydroponics for vegetable production does no longer require (intensive) soil management, and brings with it a host of other climate-smart practices such as modern irrigation methods and precision farming for better nutrient management. To estimate the potential for emission reduction, we need to take into account the different type of conversions. Squash and tomato were used as representative crops for vegetables. GHG emissions for the various options are summarized in Table 7.7 below.

Table 7.7 Greenhouse Gas emission assessment for Vegetables package

Vegetables (squash & tomatoes) (370 ha)	Total emissions (tCO2-eq) (20 years)		
	Conventional	CSA	Balance
Option (a): open field to greenhouse (250 ha)			
Annual crops (vegetables)	1,452	-6,404	-7,856
Inputs	33,657	21,222	-12,435
Energy (post-harvest process)	18,327	12,957	-5,370
Total	**53,436**	**27,774**	**-25,662**
Option (b): low tunnel to greenhouse (100 ha)			
Annuals crops (vegetables)	664	-2,479	-3,143
Inputs	13,503	8,489	-5,015
Energy (post-harvest process)	7,305	5,175	-2,130
Total	**21,472**	**11,185**	**-10,287**
Option (c): open field to hydroponics (20 ha)			
Annuals (vegetables)	133	-97	-230
Inputs	2,701	1,698	-1,003
Energy (post-harvest process)	1,461	1,035	-426
Total	**4,295**	**2,636**	**-1,659**

Option (a) refers to the conversion of 250 ha of open field vegetables to greenhouse production, and has the largest contribution in emission reduction of the three options considered; this is mainly due to the number of hectares and is caused by a reduction in input emissions. This option targets 500 farmers, who are already growing vegetables such as tomato and squash, with an average of 0.5 ha per farmer. Open field vegetable farming is relatively labor-intensive, requiring regular manual management including weeding and pest control. Greenhouses help to mitigate climate impacts and environmental risks. Vegetables are protected from extreme temperatures, low moisture, as well as strong winds, and pests and diseases. Although improved practices may increase soil carbon storage (-6404 tCO2-eq), the main gain is achieved through an emission reduction from inputs from 33,657 tCO2-eq to 21,222 tCO2-eq by switching from multiple fertilizers and herbicides to largely compost/organic fertilizers and minimal chemical use; also energy is saved by decreasing dependency on fuel-powered refrigeration by switching to solar energy. The total amount of emissions is expected to be reduced with 50%.

Option (b) aims to convert 100 ha of low tunnel vegetable production to greenhouse production. While emission reductions are still reasonable, the amount is less compared to option (a) given the number of hectares. Option (b) targets 200 farmers growing vegetables using low tunnels, with an average land size of 0.5 ha. Tunneling provides vegetable cover and, more importantly, helps trap air and moisture during high temperature months as well as moderate temperatures during the colder months of the year. As indicated above, greenhouses help to further mitigate the impact of climate and environmental risks on vegetable production. With improved agronomic practices, nutrient and water management, change to largely compost/organic fertilizers, and energy gains (through change to solar energy for storage), GHG emissions are estimated to be reduced from 21,472 tCO2-eq to 11,185 tCO2-eq, a reduction of 50%.

Option (c) includes the conversion of 20 ha of open field vegetables to hydroponics; while reduction in emissions is minimal due to the small scale, it shows the potential for mitigation and could be a viable business opportunity for more entrepreneurial farmers. Hydroponics is targeted to 40 farmers, with 0.5 ha per farmer. The conversion includes transition from relatively labor-intensive open field production to the relatively new technology of hydroponics. It allows farmers to produce crops without the need for soil, but instead suspending crops in a water and nutrient solution, likely inside a greenhouse. This practice requires less space and allows for soil and water conservation. This practice has the potential for large GHG emissions reductions through lower input and land area needs to reach same production levels. The amount of GHG mitigation from 4,295 tCO2-eq to 2,636 tCO2-eq is however small due to the small scale.

Overall, the vegetable investment package has the potential to reduce emission with 37,608 tCO2-eq. For all options, vegetable production will remain a source, despite the reduction in emissions.

Olives

The olives investment package aims to integrate climate smart practices on 1000 ha with existing olive production activities. The package targets 1000 farmers with about 1 ha per farm. See Table 7.8 for an overview of GHG emissions for conventional and CSA practices.

Table 7.8 Greenhouse Gas emission assessment for Olives package

Olives (1000 ha)	Total emissions (tCO2-eq) (20 years)		
	Conventional	CSA	Balance
Perennial crops (Olives)	-6,600	-6,600	0
Inputs	77,723	60,595	-17,127
Infrastructure	93	10	-83
Energy (olive processing)	28,983	18,540	-10,442
Total	**100,199**	**72,546**	**-27,653**

Since there is no substantial change in land use, there is no direct gain in emission reduction through land use alone. The olive plantations are already able to sequester 6,600 tCO2-eq under conventional practice. This value is assumed to remain the same for the CSA practice, giving a net balance of 0. Reduced tillage could potentially improve carbon storage capacity but this was not included in the assessment.

Emissions can be substantially reduced through the amount of inputs used. Expert consultation indicated that animal manure was the only source of fertilizer currently being used for olive production. Animal manure is organic and cheaper compared to commercial chemical fertilizers, but farmers are using copious amounts of it in their plantations. The N_2O emissions from animal manure, combined with emissions from chemicals and pesticides, result in 77,723 tCO2-eq annually. With the upgraded practices, farmers use a mixture of animal manure and other N-fertilizers to improve olive production. This significantly reduces the amount of overall fertilizer being used in the farm, cutting down emissions to 60,595 tCO2-eq.

Another way to reduce GHG emissions is through the transition to renewable sources of energy for olive processing. In the case of olives, an estimated 28,983 tCO2-eq is produced by olive mills from processing the olives into olive oil. This can be mitigated to 18,540 tCO2-eq by switching to the use of solar panels.

Implementing the package interventions has the potential of reducing the current 100,199 tCO2-eq under conventional practices to 72,546 tCO2-eq. While still being a source of emissions, there is a difference of -27,653 tCO2-eq. Generally, olive production produces a high amount of GHG emissions both from the inputs used and the processing of the olive fruit, even under CSA. However, with the package interventions, significant reductions can be made through improved input management and energy efficient processing.

Barley

Barley is of critical importance as a livestock feed. This package intents using better agronomic practices and varieties and water harvesting through micro-catchment structures on 1000 ha. The target group is 1000 farmers, with an average land size of 1 ha. Results are shown in Table 7.9.

Table 7.9 Greenhouse Gas emission assessment for Barley package

Barley (1000 ha)	Total emissions (tCO2-eq) (20 years)		
	Conventional	CSA	Balance
Annual crops (barley)	2,538	-25,956	-28.314
Inputs	2,291	2,393	102
Total	**4,649**	**-23,563**	**-28,212**

There is potential for large reduction of emissions due to improved agronomic practices and varieties. While there is no land use change, an extra 25,959 tCO2-eq can be sequestered through improved input usage and nutrient and water management; additional emission due to input use will be minimal.

In total, the investment would lead to a -28,212 tCO2-eq net carbon balance. Current conventional barely practices are estimated to produce 4,649 tCO2-eq. By introducing improved cultivation practices and input management and use, a significant amount of GHG emissions is expected to be sequestered of about 23,563 tCO2-eq, changing it into a carbon sink.

Small ruminants

This package aims at switching livestock from open grazing to concentrated (collective) farming systems to improve nutritional management and livestock production, as well as by-product processing and marketing. By doing so, it also reduces the risk of over-grazing on pastoral lands that are degraded due to the large number of livestock in the area. CSA investments include nutrition management and breeding practices for improved productivity of the livestock for meat and milk, as well as the development of (communal) processing facilities for product differentiation and marketing. Targeting 900 farmers with 150 herd size (100 sheep and 50 goats) on average, the total number of animals is 135,000. See Table 7.10 for an assessment of GHG emissions.

Table 7.10 Greenhouse Gas emission assessment for Small Ruminant package

Small ruminants (135,000 animals)	Total emissions (tCO2-eq) (20 years)		
	Conventional	CSA	Balance
Livestock*	760,687	755,903	-4,784
Energy (product processing)	374,269	271,557	-102,713
Infrastructure	0	110	110
Total	1,134,956	1,027,569	-107,387

*Sheep used as proxy due to similarities in emissions between sheep and goats per product produced (goat emission data was not readily available in the EX-ACT tool)

Livestock farming produces high amounts GHG emissions, mainly due to enteric fermentation by the animals. The small ruminant population produces 760,687 tCO2-eq in total. Even with better feeding and management practices this value does not decrease significantly, with a balance of just -4,784 tCO2-eq.

Another large proportion of GHG emissions is the result of storing processed meat and milk. Energy use for product processing under conventional practice is estimated to produce 374,269 tCO2-eq. This is based on the assumption that the processing of meat and milk under conventional practices takes place at the household level and by larger processers far removed from the original communities. However, much like the previous CSA packages, a significant part of GHG emissions can be mitigated by establishing community level storing (cooling) and processing units, that allow for switching to renewable energy (e.g., solar panels), which could reduce emissions by 102,713 tCO2-eq.

Overall, the investment package can provide a net carbon balance of -107,387 tCO2-eq. Conventional practices lead to an estimated total of GHG emissions of 1,134,956 tCO2-eq. Improving livestock diets and management practices is expected to do little to reduce GHG emissions, but a substantial reduction can be attained with improved processing activities through energy efficiency and adopting renewable energy. This can lower GHG emissions from small ruminant production to 1,027,569 tCO2-eq, although it remains an important source of emissions. It is important to realize that the total carbon balance depends heavily on the energy saving for storage and processing and hence the assumptions made; this will require further validation.

Badia restoration

The Badia restoration package refers to a large-scale effort to rehabilitate 5,000 ha of degraded land into vibrant shrub- and grasslands. It also targets 250 land owners, who can use the land after several years of restoration to feed their herds (150 animals per farmer; 37,500 animals in total) under controlled grazing schemes. Table 7.11 gives an overview of GHG emissions under conventional and CSA practice.

Table 7.11 Greenhouse Gas emission assessment for Badia restoration package

Badia restoration (5000 ha; 37,500 animals)	Total emissions (tCO2-eq) (20 years)		
	Conventional	CSA	Balance
Land use change (sequestration)	0	-442,649	-442,649
Grassland	0	-268,217	-268,217
Livestock*	0	184,889	184,889
Energy (for tractor)	0	1,182	1,182
Total	**0**	**-524,795**	**-524,795**

*Sheep used as proxy due to similarities in emissions between sheep and goats per product produced (goat emission data was not readily available in the EX-ACT tool)

Badia restoration has large potential as a carbon sink. This is largely due to the carbon sequestration potential of being able to rehabilitate such a large area through micro-catchment water harvesting (442,649 tCO2-eq) and the restoration with shrubs and grasses that improve carbon sequestration through the soil and both above- and below-ground biomass (268,217 tCO2-eq).

The emissions from the development and construction of the micro-water harvesting development are very limited. The use of Vallerani machines on tractors to create small catchment ditches in large areas to collect water runoff from rainfall only involves fuel consumption from the tractors themselves.

Emission from animals is an important factor to consider. When including 250 beneficiaries of small farmer communities that will be able to re-use this land for controlled-grazing for 37,500 animals, roughly 184,889 tCO2-eq will be produced by the animal population.

Despite the additional GHG emissions from the livestock, the CSA package still manages to reduce the total amount of carbon emissions to -524,795 tCO2-eq. This highlights the importance of being able to restore degraded lands due to their strong ability to sequester carbon emissions sustainably. Aside from carbon sequestration, the additional ecosystem services of erosion control, water retention capacity, and nutrient fixing, among others, provides much added value to restoration efforts of degraded land.

Greenhouse gas emissions at program level

All CSA investment packages proposed by the CSA Action Plan have a negative net carbon balance, with a total reduction of GHG emissions of 823,665 tCO2-eq combined (Table 7.12). The implementation of various CSA practices shows potential for emission reduction through carbon sequestration as result of land use change, above- and below-ground biomass and soil-carbon sequestration, and improvements in type or amount of inputs used and energy savings.

The largest net carbon gain is achieved through restoration of the Badia with 524,795 tCO2-eq (64%); followed at a distance by small ruminants and date palm with around 100,000 tCO2-eq (12-13% each), then vegetables with 38,000 tCO2-eq (4.6%) and finally olives and barley with 28,000 tCO2-eq (3.4% each). There are quite some differences between investment packages. While carbon gains for date palms and barley can be explained through increased biomass and reduced emissions

Table 7.12 Greenhouse Gas emission assessment for CSA investment packages

CSA package	Area (ha)	Emission reduction for aggregated CSA investment packages (tCO2-eq))* (20 years)							US$ M Carbon price Eq**
		Land use change	Annuals	Perennials	Grassland	Livestock	Inputs & invest.	Total	
Date palms	800	-11,000	-1,066	-109,340	0	0	23,395	**-98,010**	3.00
Vegetables (a)	250	0	-7,856	0	0	0	-17,806	**-25,662**	0.79
Vegetables (b)	100	0	-3,143	0	0	0	-7,145	**-10,287**	0.32
Vegetables (c)	20	0	-230	0	0	0	-1,429	**-1,659**	0.05
Olives	1000	0	0	0	0	0	-27,653	**-27,653**	0.85
Barley	1000	0	-28,314	0	0	0	102	**-28,212**	0.86
Small ruminants	n/a	0	0	0	0	-4,784	-102,603	**-107,387**	3.29
Badia restoration	5000	-442,649	0	0	-268,217	184,889	1,182	**-524,795**	16.08
Total	n/a	-453,649	-40,609	-109,340	-268,217	180,064	-131,957	**-823,665**	25.25

*Mainly on-farm (input/production), although emission from storage/processing are included when relevant; **Based on carbon price of US$30.65/tCO2-eq.

from production, reduced emissions for vegetables, olives and small ruminants are mainly explained by changes in inputs and investments. Furthermore, it is important to realize that small ruminants will remain an important source of emissions, despite the reduction due to CSA practices.

Land use change is the largest contributor of emissions reduction accounting for 55%; production of grassland, perennials and annual contribute respectively 33%, 13% and 5%. Saving through inputs and investments (energy) accounts for 16%. Projects such as the Badia restoration account for a large amount of the total carbon sequestration as result of land use change with a carbon balance although above and below ground biomass can also contribute substantially. Inputs such as fertilizers and chemicals are inherently net producers of GHG emissions and the amount used and the type of chemicals (or organic fertilizer) can make a large difference in GHG emissions. Furthermore, being able to cut down on energy consumption along the value chain can lead to significant additional emission reductions. It is further interesting to note that only the livestock component maintained a positive net carbon balance due to the difficulty in lowering carbon emissions from livestock such as small ruminants without actively reducing the number animals in production.

Lastly, we looked at the price equivalence of the carbon emissions mitigated or sequestered with and without the project. Multiplying this with the overall carbon balance, a total value of more than US$ 25 million worth of GHG emissions could potentially be saved by implementing the investment packages. The carbon price is based on the current carbon price from the European Union Emissions Trading System (EU-ETS) (World Bank, 2020) which is pegged at US$30.65/tCO2-eq. This price allows us to capture the mitigated external cost of the pollution, ranging from emission's impacts on the environment all the way to the health and well-being of people affected by the emissions. Comparing carbon price savings per project, the highest carbon price estimation is exhibited by the Badia Restoration which accounts for US$16 million, followed by investment packages on small ruminants and date palm (US$3 million each), and then vegetables (US$1.2 million), barley and olives (US$0.9 million each).

7.6 Conclusion

The results of the cost-benefit analysis for the six selected CSA packages show that all CSA packages are profitable at both the farm and aggregate levels as a positive NPV and IRR are observed. At the farm level, the date palm and vegetables packages have the lowest IRR and the longest payback period due to high initial investment and, in the case of dates, harvesting costs at the farm level. At the aggregate scale, the date palm and vegetable packages generate a high aggregated incremental net benefit, resulting in a high IRR and shorter time to reach the break-even point. This result suggests that it might be reasonable to consider further, large-scale investment support to ease the high initial investment costs at the farm level for the date palm and vegetable packages and facilitate their adoption. Among all the packages, barley and Badia restoration generate the lowest incremental net benefit, and have a relatively high IRR and shorter payback period as the result of their low investment cost at the farm scale. However, at a larger scale, these two packages have the lowest IRR. This is due to the low incremental net benefit of these packages; it also takes a longer time to pay back the large-scale investments required. The olive and small ruminant packages show stable performance at both farm-scale and large scale. The NPV and IRR of these two packages are relatively high at the farm scale and increase further at the aggregate scale.

Our sensitivity and risks analysis shows that the variability of three factors – discount rate, climate change, and output prices – have different impacts on the profitability of each CSA package. Date palms and vegetables are influenced strongly both by CC scenarios and output prices, while barley is more sensitive to CC, and the small ruminant package is sensitive to the distribution of output price. Most of the packages are profitable across all scales and sensitivity scenarios, except for vegetables and date palms. There is a risk that the vegetable and date palm packages might not be profitable at the farm scale under NoCC when the discount rate is high and output prices are comparatively low.

All CSA investment packages proposed by the CSA Action Plan have a negative net carbon balance, with a total reduction of GHG emissions of 823,665 tCO2-eq combined. Badia restoration contributes most to GHG emission reduction (64%), followed by small ruminants and date palm value chain (12-13% each), and then vegetables value chains (4.6%%); investment packages on olives and barley contribute least (3.4% each). The total estimated GHG reduction represents a value of more than US$ 25 million and needs to be taken into account when considering investment in the CSA packages.

Chapter 8

Monitoring and evaluation (M&E)

Highlights

- Hallmarks of successful monitoring and evaluation (M&E) include a cross-cutting approach and potential to inform capacity building, continuous improvement, and the provision of comprehensive data sets for policy- and decision-making,
- Developing a strong, comprehensive, and cohesive M&E system requires indicators, an M&E system, capacity development, and finance. A results framework, with indicators based on the theory of change and impact pathways, can help gauge project performance.
- Foundational M&E elements include the *theory of change*, which defines the objectives of a project, and the *impact pathways* that specify how improvements can be realized.
- This CSA Action Plan aims to strengthen the entire agricultural sector through productive, sustainable, and climate-resilient farming systems and value chains; its impact pathways include increased production and income, increased adaptive capacity, reduced climate exposure and sensitivity, and improved marketability of commodities.

8.1 M&E and its components

Monitoring and evaluation (M&E) is a vital aspect of the CSA Action Plan; it establishes assumptions about how change will occur and provides evidence and information to implement results-based management. M&E activities are conducted throughout the project's lifecycle and beyond to document and analyze project processes and results. They provide up-to-date quantitative and qualitative information that allows the government of Jordan, development partners, and implementing agencies to track the progress of projects and their impacts.[220]

Monitoring is the systematic collection of data, analysis, and comparison of the results to a project's objectives, budget, and work plans. Monitoring entails assessing whether what has been achieved aligns with what was initially planned. Monitoring also provides information about the roles and responsibilities of individuals working on the project for accountability and transparency. Its implementation should begin with the commencement of the project and can continue past the project's life cycle.

Likewise, evaluation aims to analyze the impact of a certain project and how effective its implementation and outputs have been in providing necessary interventions for the intended beneficiaries. This analysis is paired with carefully selected indicators to gauge the performance of the project. These are often categorized as *outcome indicators*, which are usually assessed by comparing baseline data with the expected target after project implementation, or as *output indicators*, which often do not require a baseline as they introduce a new factor.[221]

The overall M&E framework consist of the theory of change, the impact pathways, the results framework, and indicators. These components are defined below.

Definitions

- Outputs: Tangible products of project activities; these may include trainings, services, publications, partnerships, technology, and policies.
- Outcomes: Changes in behavior across stakeholders with regard to their knowledge, attitudes, and practices, as a result of project activities and outputs.
- Impact: The overarching objective; all activities, outputs, and outcomes aim at and contribute toward impact.
- Indicators: Measurable data that can be used to indicate the performance of a certain activity, output, outcome, or impact.

8.2 The importance of M&E for project development, decision making, and policy

M&E allows project managers to get up-to-date information about whether projects are on track in terms of their work plans, budget, and objectives. It builds a robust base of data, the analysis of which can provide evidence of a project's impact or lack thereof. A strong M&E system allows project managers to assess project progress as whole and pinpoint areas that are doing well, portions that can be improved, and aspects of the project that need to be redirected or put back on track to meet specific objectives.

One of the key hallmarks of M&E is its cross-cutting nature. It brings together multiple institutions, government agencies, implementing partners, and stakeholders to generate a management system that is wholly unique from one project to the next. Because the overall objective of the CSA Action Plan is to benefit agriculture and the environment in a sustainable way, it requires the cooperation and collaboration of these numerous stakeholders to create a cohesive plan that can enable the government to fulfill targets for national development.

The M&E system will serve a purpose beyond just CSA. When aligned with the Jordanian government's goals and ministry objectives, investment in M&E will result in institutional capacity building as well as comprehensive data sets that can be used for policy- and decision-making. M&E often intends to collect a comprehensive data set on the basis of which multiple forms of analyses can be conducted. M&E extends beyond the CSA action plan; it tracks the entire food system and is designed to inform key policy makers. The flexible data sets and analyses can then be applied to different situations depending on what policy makers want to consider.

One important aspect of M&E is storage and accessibility. The creation of a secure data bank is necessary to ensure that the data is protected, backups are made, and the data cannot easily be tampered with. Furthermore, the data should be readily accessible to relevant actors who may want to view or use it. Storage and accessibility could be enabled through a dedicated application or website created specifically for the project and should be consumer-forward in terms of the design of its interface, its ease of use, and shareability.

Projects with a strong M&E program can reveal essential information for future interventions. M&E provides an understanding of good practices that a project has implemented and of activities that constitute obstacles to progress. It provides a powerful guide as to what can be expected should future interventions be implemented.

8.3 The theory of change and impact pathways

The theory of change serves to simplify and visualize the main objectives of a project and how these changes will occur; building on the theory of change, the impact pathways describe the different ways such changes and improvements can be realized. This Action Plan aims to address several key climate-related issues, ranging from food security to livelihood improvements in the agricultural sector. It expects to achieve this objective through a variety of interventions such as by enhancing farm productivity, strengthening climate resiliency while reducing climate exposure, and increasing the marketability and profitability of commodities across product value chains.

The investments included in its packages are designed to enhance the agricultural system as a whole, from the farm gate through marketing and export performance. These investments include the introduction or expansion of on-farm and post-harvest processing technologies and best practices to improve the yield and quality of products across value chains; capacity building for farmers through trainings and educational discussions of CSA; and extension services, information systems, and crop or livestock suitability mapping to provide a knowledge base for farmers and policy makers alike.

To achieve productive, sustainable, and climate-resilient farming systems and value chains, four pathways have been identified: increased production and income, improving adaptive capacity, decreasing climate exposure and sensitivity, and improving the marketability of commodities.

1. Increased production and income. A major focus of the identified investments involves improving on-farm management practices and techniques, and the introduction and expansion of climate-smart technology in order to attain maximum production under various climate stresses. Maximizing production may also lead to improved incomes for farmers and actors along each value chain. This focus is relevant to all CSA investments, although to a lesser extent for Badia restoration.
2. Increased adaptive capacity. Identified investments seek to strengthen farmers' ability to adjust to climate shocks through stronger institutions that provide a platform and knowledge base to allow them to respond to climate disturbances. Enhancing farmers' ability to adjust will be critical for all CSA investments, but the way this will be done will be different for each.
3. Reduced climate exposure and sensitivity. The selection of commodity value chains and areas is aimed at reducing exposure and sensitivity to climate shocks and stresses. These goals are supported by CSA interventions and by providing avenues for farmers to grow their knowledge about climate impacts and CSA through trainings, advisory services, and information. This pathway is a guiding a principle for all CSA investments, but will remain particularly relevant for hydroponic vegetable production, expansion of rainfed barley, and Badia restoration. Also, through more productive and efficient use of water and energy and through carbon storage, reduced emissions will diminish exposure to climate risks at a global scale.
4. Improved marketability of commodities. Jordan relies heavily on its domestic market to reduce dependence on imports, as well as on strong international and export linkages for some high-value commodities. Ensuring that these products are standardized, quality-controlled, and in some cases, certified, will provide better incomes for farmers and post-harvest processors, and will establish Jordan as a major agricultural actor in the region. This pathway will be important for CSA investment in date palms, vegetables, and olives, and to a lesser extent for barley and small ruminants.

The expected overall impacts of these pathways include a more resilient and productive agricultural sector and thriving commodity value chains. Moreover, these pathways are also interlinked and are likely to affect each other. Increased productivity leads to improved income, which in turn provides farmers with the capital and resources to heighten their adaptive capacity and mitigate or rebound from climate shocks and stressors. To know when these impacts have been realized across the value chains, information can be collected about the adoption rates of technologies, the use of different practices and strategies to mitigate climate risks, improvements in institutional policies and activities both by the government and private sector, and strengthened information systems and advisory services.

The theory of change and impact pathways designed for the Jordan CSA Action Plan revolve around a stronger, more climate-resilient and sustainable agricultural sector across the various commodities and regions of Jordan (Figure 8.1). The success of the investments will be monitored through their various outputs and outcomes as they feed into the four pathways and will be measured through indicators developed for this purpose.

8.4. Results framework and indicators

M&E aims to strengthen and build upon work that is already being done by the Jordanian government. The various ministries involved in this endeavor already routinely collect much of the data that is needed for a strong M&E program. One of this CSA Action Plan's main goals is to provide a framework to guide current and future projects through the establishment of impact pathways and relevant indicators.

The success of the investments will be measured through the various activities that need to be implemented to establish the necessary outputs as shown in the theory of change. The investments are expected to affect the agricultural system in several ways, for example through the adoption of technologies and practices across the value chains, through changes in farmer behavior towards climate shocks and stressors, and through the development and establishment of advisory services. These investments are also expected to create linkages with private-sector institutions that can provide agricultural financing, additional investments in small- to medium-scale enterprises, and inclusive business models that encompass whole commodity value chains. Together, these institutions will provide the enabling conditions necessary to develop a more climate-resilient agricultural sector in Jordan.

It is necessary to monitor and establish relevant indicators at the portfolio and individual investment levels. Portfolio-level investment results will be monitored against a limited number of primary indicators including the number of beneficiaries and changes in productivity, adaptive capacity, resilience, and GHG emissions. Likewise, at the project level, primary indicators will be selected for each individual investment during the development phase, tracking progress on all aspects of the theory of change and impact pathways, including impacts, outcomes, outputs, and activities.

The results framework, with a sampling of potential indicators at the program level and for each investment component (Table 8.1), can be used to measure project performance. While there are many well-established indicators for components that have been extensively researched such as productivity and yield, other components such as "resilience" may be more difficult to monitor due to the lack of an established measurement, so these indicators will be determined during the development of the full investment proposal. Table 8.1 below only shows a few possible indicators that may be used for the project but is no means exhaustive or comprehensive. The final list of indicators depends very much on how each investment proposal will be developed, so we have restricted ourselves here to suggesting some general indicators at the program, impact, outcome, and output levels. Depending upon how individual investment proposals are elaborated, specific output indicators at the investment level could be derived from the proposed activities in the concept notes in Annex E.

Figure 8.1 The theory of change and impact pathways for the Jordan CSA Action Plan

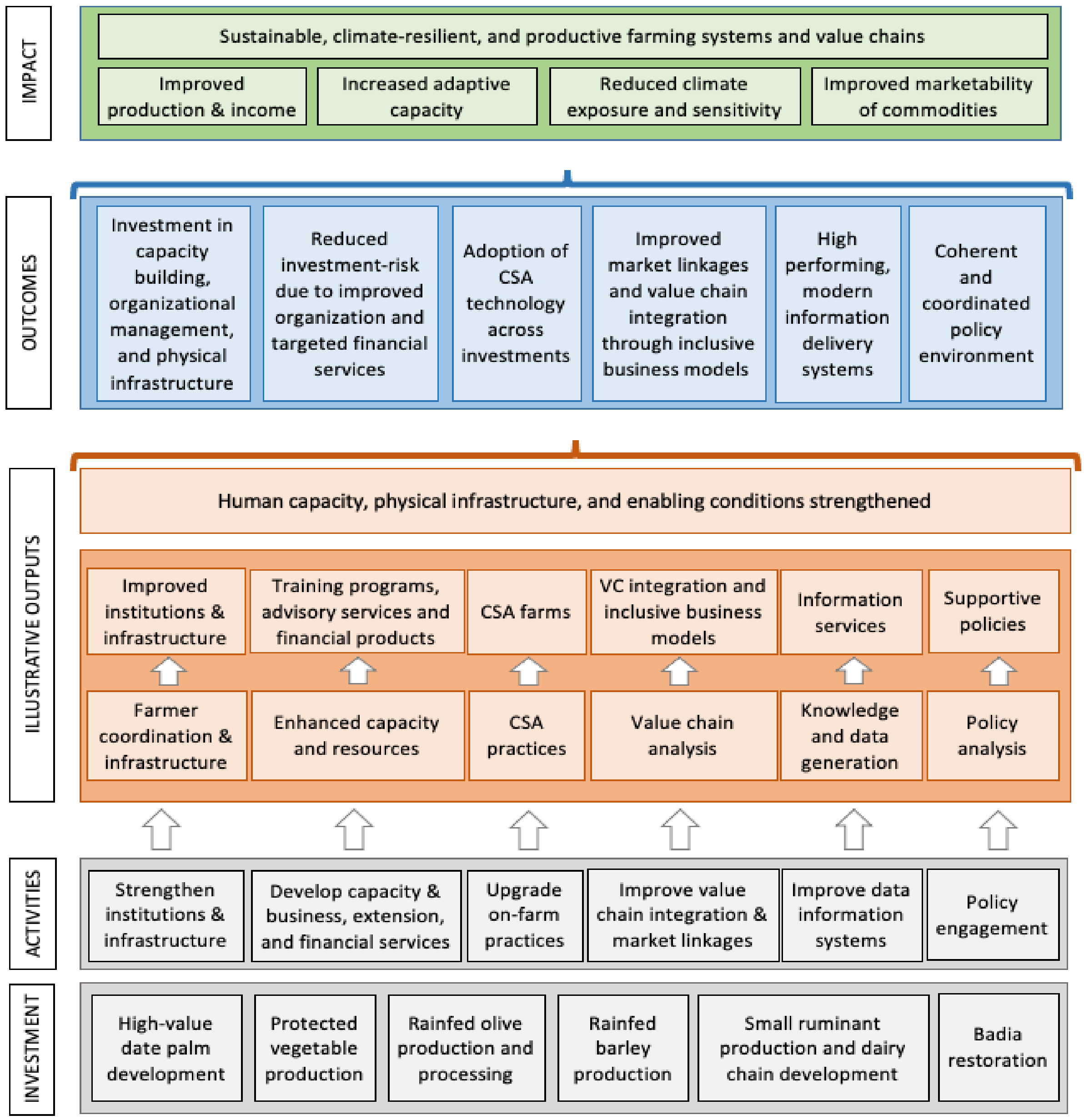


Table 8.1: Results framework with examples of indicators and measurements for CSA investments

Component	Indicator	Measure	CSA Investment
Cross-investment (program) indicators			
Beneficiaries	P1 Number of beneficiaries	Number of farmers (disaggregated by gender)	Across investments
Increased productivity	P2 Change in productivity of agricultural commodities supported by the program	Annual revenue (in JOD/year)	Across investments
Increased adaptation and resilience	P3 Farm resilience to shocks and stresses	Resilience capacity index[222]	Across investments
GHG emission reduction	P4 GHG emission intensity of production (per investment)	Kg of emissions per unit of product	Across investments (although mitigation was a co-benefit)

Component	Indicator	Measure	CSA Investment
Impact indicators (examples)			
Increased production and income	IM1.1 Change in average farm income	JOD/year	All, but Badia restoration to a lesser extent
	IM1.2 Change in production (per commodity or investment)	Kg/ha/year (depends on the commodity)	All, but Badia restoration to a lesser extent
	IM1.3 Change in post-harvest and processing losses (by target commodity)	Kg/unit (depends on the commodity or process being measured)	Date palms, vegetables, olives, small ruminants
Improved adaptive capacity	IM2.1 Improved adaptive capacity index	Weighted score	All investments
Reduced climate exposure and sensitivity	IM3.1 Exposure to climate change shocks or stresses compared to non-participants (per investment)	Frequency of climate change shocks or stresses	All investments
	IM3.2 Improved coping strategies index	Weighted score	All investments
	IM3.3 Reduced energy and water use or increased carbon storage (per investment)	Quantity/year (adapted to specific indicator)	All investments
Marketability of commodities	IM4.1 Quantity of commodity being traded in domestic markets	Kg/year	All investments, except Badia restoration
	IM4.2 Quantity of commodity being traded at export markets	Kg/year	Especially date palms, vegetables, olives
Outcome indicators (examples by action area)			
Investment in capacity building, organizational management, and physical infrastructure	OC1.1 Investment in capacity building and service development	Amount (in JOD/year)	All investments
	OC1.2 Improved physical infrastructure for production, post-harvest storage, and processing	Number of units of physical infrastructure built, amount spent on infrastructure (in JOD/ year)	All investments
Reduced investment risk	OC2.1 Number of beneficiaries with access to credit or insurance services	Number	All investments, except Badia restoration
	OC2.2 Number of credit or insurance packages or programs with direct CSA benefits	Number	All investments, except Badia restoration
	OC2.3 Ease of access of financial services	Qualitative (perception)	All investments, except Badia restoration
Increased adoption of CSA technologies	OC3.1 Increased number of beneficiaries adopting CSA practices and technologies (per CSA practice or technology and by gender)	% total of beneficiaries (per farm commodity)	All investments
	OC3.2 Increased land area under CSA practices (per CSA practice or technology and by gender)	% of total land area (per farm commodity)	All investments
Improved market linkages and value chain integration	OC4.1 Improved efficiency of the value chain	Time from farm gate to final product, productivity (yield of produce per process)	Date palms, vegetables, olives, small ruminants
	OC4.2 Improved value chain profitability	Value: subtract JOD per stage of the conventional process from JOD per stage of the upgraded process	Date palms, vegetables, olives, small ruminants
Information delivery systems	OC5.1 Access to CSA information (not through trainings or workshops)	Qualitative (perception)	Especially date palms, vegetables, olives

Component	Indicator	Measure	CSA Investment
Coherent and coordinated policy environment	OC6.1 Number of policy coordination mechanisms in place	Number	Across investments
	OC6.2 Effectiveness of coordination mechanisms	Qualitative (perception)	Across investments
Outcome indicators (examples by action area)			
Improved institutions and infrastructure	OP1.1 Coherent and coordinated institutional arrangements between farmers	Qualitative scale	All investments
	OP1.2 Strengthened capacity of producer groups and organizations to ensure farmers' access to resources and markets (by commodity or value chain)	Qualitative scale	All, except barley and Badia restoration
	OP1.3 Number of beneficiaries participating in producer groups and organizations (per commodity or value chain)	Number of farmers (disaggregated by gender)	All, except barley and Badia restoration
	OP1.4 Improved physical infrastructure for CSA production, post-harvest storage, and processing	Number of units of physical infrastructure built	All investments
Training programs, advisory services, and financial products	OP3.1 Number, types, and form of advisory, extension, and financial services provided (per institution)	Number, type, form	All investments
	OP3.2 Frequency of access to trainings by beneficiaries	Number/annum, number/month, number/season	All investments
	OP3.2 Access to financial services by beneficiaries	Number of beneficiaries (disaggregated by gender and investment)	All, except Badia restoration
CSA farms	OP4.1 Number of farmers using CSA practices and technologies	Number of beneficiaries (disaggregated by gender and investment)	All investments
	OP4.2 Number of farmers being trained in CSA practices and technologies	Number of beneficiaries (disaggregated by gender and investment)	All investments
	OP4.3 Number of farmers aware of CSA practice and technologies and their benefits	Number of beneficiaries (disaggregated by gender and investment)	All investments
Value chain integration and inclusive business models	OP4.1 Number of value chain analyses conducted	Number	Especially date palms, vegetables, olives, small ruminants
	OP4.2 Coherent and coordinated institutional arrangements between value chain actors	Qualitative scale	Especially date palms, vegetables, olives, small ruminants
	OP4.3 Improved standardization of product quality and certification processes	% being produced or sold based on certain certification standards	Especially date palms, vegetables, olives, small ruminants
	OP4.4. Proportion of smallholder farmers, women, and youths engaged in climate-smart value chains (per commodity or investment)	Number of beneficiaries (disaggregated by type, gender, age, and investment)	Especially date palms, vegetables, olives, small ruminants

Component	Indicator	Measure	CSA Investment
Information services	OP5.2 Number of commodity-focused data monitoring and database systems developed	Number	All investments
	OP5.2 Number of commodity-focused data portals and information services developed	Number	All investments
Supportive policies	OP6.1 Number of CSA-supportive policies developed or revised	Number	All investments, especially barley
	OP6.2 Number of targeted policy incentives developed (per investment)	Number	All investments, especially barley

8.5. Towards an M&E framework

The selection of indicators based on the theory of change and impact pathways is an important step toward a strong framework for monitoring the implementation and results of CSA investments, but there are still several additional steps needed to build an M&E system and ensure the sustainability of current and future projects that maybe undertaken beyond the scope of the CSA Action Plan itself. CCAFS has outlined 11 steps, categorized under indicators, M&E system, capacity development, and finance, that need to be in place in order to create a comprehensive and cohesive M&E system.[223]

Indicators

1. List of indicators – compile a comprehensive list from stakeholders and existing M&E systems.
2. Participatory alignment – work with diverse groups to select indicators that meet priority information needs.
3. Data system analysis – assess existing data collection and analysis systems for opportunities.

M&E system

4. Protocol development – create clear data collection protocols.
5. Integrated data systems – develop integrated systems for the flow of information.
6. Content and roles – assign roles and responsibilities for data collection and reporting.

Capacity development

7. Capacity needs assessment – conduct a thorough evaluation of human and institutional capacities.
8. Recruitment of staff – hire or repurpose staff to participate in integrated M&E.
9. Strengthening capacity – conduct training courses at multiple levels for M&E staff.

Finance

10. Cost-benefit analysis – conduct a detailed economic analysis of the value for stakeholders.
11. National finance – insert M&E across sectoral budgets to access national finance; integrate M&E budgets of donor-supported sector-wide approaches.

These eleven steps highlight the need for institutions to pivot toward M&E development that emphasizes the importance of assessing projects from start to finish. Introducing dedicated M&E protocols such as staff, logistics, and budgets, as well as trainings and integrated systems, will ensure that projects and project staff will have the capacity to carry out M&E activities. Furthermore, baseline data collection and assessment to characterize the initial state of farmers, farmer-households, value chain actors, and institutions can enable comparisons after project implementation.

These M&E activities need be formalized and institutionalized in an "M&E manual" that describes the specific actions, responsibilities, and steps that must be taken to conduct a comprehensive M&E assessment. These requirements may include initial staff capacity assessments to track and monitor project progress. Enabling a comprehensive M&E assessment will ensure a results-based reporting approach that can be measured against project objectives and goals.

8.6 Conclusion

While this chapter has provided an overview of the overall M&E system mechanism that may be put in place under this CSA Action Plan, it is still up to policy and decision makers to decide which investments will be implemented, when they will be introduced, and how they are to be executed. These decisions will play a major role in the formulation of the indicators needed, in the determination of which capacities require strengthening, and in the assessment of financial limitations. It is important to ensure clarity and understanding in the design of certain projects and investments so that a more comprehensive and rigorous M&E system can be constructed. M&E systems provide the backdrop for a project's long-term sustainability, implementation efficiency, and the effectiveness of its interventions.

The M&E system of this CSA Action Plan entails an opportunity to lay the foundation for future M&E activities by ensuring that its framework is aligned with government policies and national goals. As mentioned earlier, M&E systems have applications beyond a particular project and its lifespan. While Jordan currently does not have an overall integrated M&E framework encompassing relevant ministries, there have been many calls across the various government ministries to design and implement one. Building upon institutional objectives is necessary to help these ministries achieve not only their departmental goals, but overall government-wide sustainable agricultural objectives as well.

Annex A: Agricultural context

Table A.1 Regional distribution of key commodities in Jordan[224]

Commodity	Irrigated	Rainfed	Agropastoral
Barley	1%	99%	-
Wheat	9%	91%	-
Olives	1%	99%	-
Citrus	7%	93%	-
Dates	77%	23%	-
Grapes	84%	16%	-
Pomegranates	90%	10%	-
Other (Peaches, Plums, Prunes, etc.)	-	100%	-
Tomatoes	60%	40%	-
Potatoes	61%	39%	-
Squash	77%	23%	-
Cucumbers	79%	21%	-
Eggplants	88%	12%	-
Sweet peppers	81%	19%	-
Livestock	-	Minimal	Primary location
Fish	Primary location	Minimal, where groundwater is available	Minimal, where groundwater is available

Table A.2 Jordanian field crop detail for 2017[225]

Crop	Cultivated Area (Ha)	Harvested Area (Ha)	Production (MT)	Exports (MT)	Export (,000 US$)	Imports (MT)	Import (,000 US$)	Feed (MT)	Seeds (MT)	Waste (MT)	Processed (MT)	Food (MT)
Barley	56,458	39,197	48,954	-	-	960,360	177,170	954,704	1,535	50,466	2,609	-
Wheat	12,191	8,162	12,110	-	-	1,103,029	232,654	-	899	55,757	1,058,260	-
Clover	2,309	2,309	100,935	-	-	-	-	-	-	-	-	-
Maize	1,262	1,262	37,179	62,497	-	941,172	-	876,720	-	39,134	-	-
Vetch	491	307	191	-	-	-	-	-	-	-	-	-
Chickpeas	46	360	1,509	19	31	37,712	43,383	-	-	1,961	28,994	5,847
Garlic	135	135	2,589	-	-	-	-	-	-	-	-	-
Lentils	124	77	440	22	15	19,354	16,518	-	2	990	-	17,838
Other	96	87	591	-	-	-	-	-	-	-	-	-
Vetch	85	54	320	-	-	-	-		-	-	-	-
Sorghum	51	51	1,024	-	-	-	-	-	-	-	-	-
Sesame	9	6	6	-	-	-	-	-	-	725	16,600	6,041

Table A.3 Agricultural data for fruit trees in Jordan in 2017[226]

Name	Area (Ha)	Total Trees	Total Bearing Trees	Production (MT)	Exports (MT)	Value (,000 US$)	Imports (MT)	Value (,000 US$)	Waste (MT)	Processed (MT)	Food (MT)
Olives	56,214	1,053,436	970,772	145,332	1,125	-	-	-	-	-	2,907
Citrus Fruits	6,421	211,172	190,833	108,385	-	-	-	-	-	-	-
Other Citrus Fruits	-	-	-	26,067	439	-	6,421	-	-	-	-
Grapefruits and Pummelos	-	-	-	6,186	558	-	481	-	-	-	-
Lemons	-	-	-	34,577	787	1,185	16,836	19,582	-	-	5,141
Oranges	-	-	-	40,895	435	480	27,361	19,158	-	-	6,826
Dates	3,223	47,106	22,826	25,419	-	-	-	-	-	-	-
Grapes	2,894	321,756	258,595	53,509	494	1,099	1,854	3,377	-	-	5,536
Peaches	2,750	144,191	136,938	69,473	-	-	-	-	-	-	-
Apricots	1,529	75,532	72,926	18,791	8,368	-	12	-	-	-	1,880
Nectarines	860	48,520	45,781	22,137	-	-	-	-	-	-	-
Pomegranates	789	37,540	22,972	16,768	-	-	-	-	-	-	-
Apples	755	66,622	60,969	24,496	120	223	50,813	62,135	-	-	7,531
Bananas	716	79,185	55,790	33,935	25	25	32,236	25,520	-	-	6,617
Other	534	17,012	15,631	3,412	-	-	-	-	-	-	-
Almonds	333	8,873	6,516	1,801	17	-	4,734	-	-	-	-
Guavas	310	11,454	9,936	2,246	-	-	-	-	-	-	-
Plums, Prunes	280	11,401	10,078	3,070	-	-	-	-	-	-	-
Pears	220	7,921	7,840	2,398	46	132	7,355	10,072	-	-	-
Figs	120	2,520	1,966	556	-	-	-	-	-	-	-
Cherries	118	5,261	4,885	968	-	-	-	-	-	-	-

Table A.4 Agricultural data for vegetables in Jordan in 2017[227]

Crop	Winter Area (Ha)	Winter Production (MT)	Summer Area (Ha)	Summer Production (MT)	Total Area (Ha)	Total Production (MT)	Exports (MT)	Value (,000 US$)	Imports (MT)	Value (,000 US$)	Seeds (MT)	Waste (MT)	Processed (MT)	Food (MT)
Tomatoes	8,492	483,421	3,702	207,056	12,195	690,477	282,271	223,054	27	108	-	-	96,671	110,621
Potatoes	2,174	93,517	1,835	62,122	4,008	155,639	693	563	9,902	4,162	-	6,725	17,249	10,040
Squash	1,899	48,156	859	23,935	2,757	72,091	27,693	23,372	-	-	-	-	7,209	-
Eggplants	1,219	38,282	746	27,037	1,964	65,319	5,654	4,021	-	-	-	-	6,532	-
Hot peppers	217	6,499	264	7,937	481	14,435	47,970	56,068	11	14	-	-	-	-
Sweet peppers	1,043	31,345	697	22,787	1,739	54,131	-	-	-	-	-	-	-	-
Cucumber	785	91,028	869	99,819	1,654	190,847	19,024	11,545	-	-	-	-	-	-
Watermelon	1,328	85,213	161	10,314	1,488	95,527	19,095	10,424	-	-	-	-	9,553	-
Onions, dry	473	20,249	971	36,105	1,445	56,354	337	231	8,186	3,263	-	-	6,454	-
Cauliflower	930	30,978	455	15,470	1,384	46,449	14,414	9,717	9	-	-	-	4,645	-
Lettuce	776	35,137	589	22,797	1,365	57,934	-	-	-	-	-	-	-	-
Sweet mellow	1,067	53,969	127	6,251	1,194	60,220	35,417	15,034	-	-	-	-	6,022	-
Jew's mallow	869	28,373	47	1,576	916	29,949	-	-	-	-	-	-		-
Cabbages	547	33,803	285	16,632	833	50,436	4,961	1,338	-	-	-	-	5,044	-
Others	351	7,170	459	10,044	811	17,214	-	-	-	-	-	-	-	-
Okra	731	5,058	36	282	767	5,340	-	-	-	-	-	-	-	-
Broad beans	86	1,330	480	7,397	566	8,727	575	-	800	-	-	-	953	-
String beans	269	6,095	277	5,995	546	12,090	764	1,301	-	-	-	-	-	-
Onions, green	109	2,974	252	7,224	361	10,198	-	-	-	-	-	-	1,020	-
Carrots	66	2,935	206	9,778	272	12,712	53	-	10,432	-	-	-	2,314	-
Snake cucumbers	236	4,709	4	64	239	4,773	-	-	-	-	-	-	-	-
Parsley	86	3,859	116	5,615	202	9,474	-	-	-	-	-	-	-	-
Peas	46	1	78	716	124	1,280	-	-	-	-	-	-	-	-
Radishes	41	1,797	77	3,537	119	5,334	-	-	-	-	-	-	-	-
Turnips	35	1,674	71	3,332	106	5,006	-	-	-	-	-	-	-	-
Spinach	43	1,897	49	2,162	92	4,060	-	-	-	-	-	-	-	-

Table A.5 Major livestock exports and imports[228]

Type	Exports		Imports	
	Value (US$)	Quantity (kg, unless otherwise stated)	Value (US$)	Quantity (kg, unless otherwise stated)
Live horses other than for purebred breeding (number)	23,868	14 head	783,776	118 head
Live bovine animals other than for purebred breeding (number)	0	0	75,947,720	78,209 head
Live sheep (number)	161,826,756	497,091 head	54,905,615	374,529 head
Live goats (number)	7,264	13 head	38,721,058	328,994 head
Live poultry	1,571,877	95,412	6,353,870	82,178
Other live animals including zoo animals and pets	0	0	31,031	2,286
Bovine meat, fresh or frozen	2,731,944	974,177	133,118,382	33,089,635
Meat of sheep and goats, fresh or frozen	0	0	144,992,191	24,528,045
Edible offal	429,871	238,412	2,432,435	1,134,704
Slaughtered poultry, fresh or frozen	9,998,343	5,034,259	92,072,088	59,635,848
Fresh, frozen, or chilled fish	0	0	43,424,379	13,686,313
Smoked fish	0	0	83,833	817,676
Milk concentrate and cream	90,753	62,699	16,770,122	18,970,047
Powdered milk	368,988	123,279	100,544,080	31,202,857
Dried sour milk (jameed)	2,041,653	572,418	12,009,096	3,137,701
Fresh cheese (including whey cheese), not fermented, and curd	14,229,021	2,444,721	290,758	71,048
Other cheese	13,804,974	3,991,004	106,179,061	23,909,705
Bird eggs in shell for hatching, fresh or preserved (number)	4,841,665	13,005,400 eggs	1,925,632	3,296,850 eggs
Bird eggs in shell for food, fresh, preserved, or cooked (number)	2,345,420	21,050,000 eggs	0	0
Natural honey	1,542,089	31,735	6,156,344	1,079,498
Cereal straw and husks, unprepared	0	0	7,208,886	41,912,434
Bran	56,971	39,850	12,380,430	120,534,380
Oil cake	115,381	25,983	164,726,000	437,772,708
Forage	33,581,345	26,523,345	23,157,333	12,423,981
Forage concentrates	2,813,982	4,333,448	8,656,487	8,647,860
Wool	328,340	1,057,838	7,933,148	446,327

Annex B: Climate projections and risk methodology

The methodology used to assess climate hazards was adapted from the standard protocol developed by the International Center for Tropical Agriculture (CIAT) for the preparation of county risk profiles, whereby hazards are assessed using climate data and then mapped onto the geographic space. The analysis focuses on calculating specific climate indices that relate to potential hazards for commodity value chains in the district of interest (Table B.1).

Table B.1 Climate hazards and respective quantitative indices

Indicator	Description	Hazard	Season
CDD	Drought spell. Maximum number of consecutive dry days (precipitation < 1 mm day^{-1}).	Drought: long drought spells reduce productivity or cause crop failure.	W
NDWS	Moisture stress. Number of days with ratio of actual to potential evapotranspiration ratio below 0.5.	Drought: crops experience wilting due to constantly dry soils.	W
P5D	Flooding. Maximum 5-day running average precipitation.	Flooding: too much rainfall within the timeframe of a week causes flooding and wilting.	W
NT37	Heat stress for the summer season. Number of days with temperatures above 37°C.	Heat stress: many hot days affect crop growth and lead to low productivity.	S
NTWheat	Heat stress for wheat. Number of days with temperatures above 21°C. Also relevant for barley.	Heat stress as in NT37.	W
NTPotato	Heat stress for potatoes. Number of days with temperatures above 17.8°C.	Heat stress as in NT37.	W
NTTomato	Heat stress for tomatoes. Number of days with temperatures above 27°C.	Heat stress as in NT37.	W
NTDates	Heat stress for date palms. Number of days with temperatures above 45°C.	Heat stress as in NT37.	W
CDT37	Hot spell during the summer. Maximum number of consecutive days with temperatures above 37°C.	Heat stress: a long hot spell affects crops, livestock, and humans.	S
CDTWheat	Hot spell for wheat. Number of consecutive days with temperatures above 21°C. Also relevant for barley.	Heat stress as in CDT37.	W
CDTPotato	Hot spell for potatoes. Consecutive days with temperatures above 17.8°C.	Heat stress as in CDT37.	W
CDTTomato	Hot spell for tomatoes. Consecutive days with temperatures above 27°C.	Heat stress as in CDT37.	W
CDTDates	Hot spell for date palms. Consecutive days with temperatures above 45°C.	Heat stress as in CDT37.	W

To calculate these indices for each district, we used daily bias-corrected and statistically downscaled climate data from an ensemble of Regional Climate Models for historical conditions (1980–2005) and for RCP 4.5 and RCP 8.5 (2006–2050). Only results for RCP 8.5 are shown in the main text. The downscaling used an ensemble climate product developed under the Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR) project. RICCAR is an outcome of a collaborative effort between the United Nations, the League of Arab States, and respective specialized organizations to respond to the request of the Arab Ministerial Water Council and the Council of Arab Ministers Responsible for the Environment. RICCAR aims to assess the impact of climate change on freshwater resources in the Arab region through a consultative and integrated assessment that seeks to identify socioeconomic and environmental vulnerabilities.

The product used here (RICCAR) consists of the outputs of three General Circulation Models (GCMs): CNRM-CM5, SMHI-RCA4, and GFDL-ESM2M. These models were downscaled (50km) and bias-corrected for two RCPs (4.5 and 8.5). These products are available from 1950-2100. These climate products were strategically analyzed to study climate change dynamics in Jordan. We first further bias-corrected the RICCAR data using the ECMWF-ERA5 reanalysis product. Next, because the inherent resolution of the original RICCAR data is 50km, it is of limited use to understand the spatiotemporal dynamics of a small country such as Jordan, especially when the objective is to understand the impact of climate change at a local scale in order to identify climate-smart agricultural options. Thus, as the second step of the downscaling process, the bias-corrected RICCAR product that is consistent with the ERA5 dataset was spatially interpolated to a very fine resolution (5km), also considering topographic controls on micro-climate. This was done based on a superior algorithm called the Gradient plus Inverse Distance Squared method (GIDS) developed by the United States Geological Survey, which was created for interpolation in areas with sparse data, modified with the inclusion of a specified search radius limit.[229] The GIDS methodology develops a regression relationship between the climate variable and northing, easting, and elevation for every time step for every grid cell or station location to spatially interpolate to a fine scale.

The resulting data constitutes a unique set of downscaled climate products which are generated at daily time step at very high spatial resolutions. From these basic meteorological variables, we derived spatially and temporally high-resolution incoming radiation and relative humidity products to assist in the calculation of various indices. We computed all of the indices for either the hot, dry summer or cool, wet winter seasons by counting the numbers of days that meet the specific conditions. For the number of moisture stress days, we performed a simple daily water balance calculation following the method of Jones and Thornton.[230] In this method, the ratio of actual to potential evapotranspiration (ETa/ETp) is calculated using an empirical equation, and the estimated potential evapotranspiration is calculated with the Priestley-Taylor equation.[231] We computed the water balance for each day during the entire time series, and then used the results to arrive at the number of days with moisture stress (i.e. where ETa/ETp ≤ 0.5). The historical period is considered to be 1981–2010, whereas the future period is 2021–2049 (2030). All results are analyzed per AEZ.

To assess the impacts of climate change, using the EcoCrop model, we performed simulations of the suitability of wheat, potatoes, tomatoes, olives, date palms, and barley.[232] EcoCrop is a simple process-based model that uses monthly means of maximum and minimum temperatures and monthly precipitation totals to assess the degree of climate suitability for specific crops. The model uses crop-specific parameters that define the optimal and marginal seasonal temperature and precipitation conditions in which the crops can grow, and then compares these with the conditions experienced at a site, under either current or future climates. The model has been demonstrated to predict suitability accurately in a number of crop-specific assessments.[233] Parameters for running the model were mainly obtained from the FAO-EcoCrop database, although for potatoes and date palms, other sources were also used.[234] All parameter values are specified in Table 3.1. The daily climate data used to quantify the climate hazards were aggregated into monthly climatological means for all EcoCrop simulations. For irrigated areas, we used suitability based only on temperature, whereas for rainfed areas, we used suitability based on both temperature and precipitation. Model runs use a fixed growing season (as specified in Table 3.1). Model runs were performed for the historical period (1981–2010) and the 2030s (2020–2049) for RCP 8.5.

Annex C: Economic impact analysis methodology

The economic analysis presented here uses the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT), an exploratory tool for assessing linkages between agricultural policy, climate change, and technologies in agricultural systems. IMPACT was parameterized by the Shared Socio-economic Pathway 2 (SSP2), with the use of several GCM models (see Table C.1). SSP2 is a scenario that is typically considered business-as-usual, in that "The world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns. Environmental systems experience degradation, although there are some improvements and overall the intensity of resource and energy use declines. Global population growth is moderate and levels off in the second half of the century. Income inequality persists or improves only slowly and challenges to reducing vulnerability to societal and environmental changes remain."[236]

Table C.1 General circulation models used in the IMPACT analy

GCMs	Institute
MICRO-MIROC5	University of Tokyo, National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology
GFLD_ESM2G	NOAA Geophysical Fluid Dynamics
IPSL-CM5A-LR	Institute Pierre Simon Laplace
HadGEM2-ES	Met Office Hadley Centre ESM

Crops and livestock relevant to the Jordanian context and modelled in IMPACT for the purpose of this study are presented in Table C.2.

Table C.2 Crops and livestock modelled in IMPACT that are relevant to Jordanian context

Production System	Specifically modeled in IMPACT	Modeled as part of broader category
Potatoes	X	
Eggplants, cucumbers, tomatoes, squash, and peppers		Modeled under vegetables
Dates		Modeled under tropical fruits
Wheat	X	
Barley		Modeled under C3 dryland cereals
Poultry	X	
Sheep		Modeled under small ruminants
Dairy		Modeled under animal numbers and yield

For the analysis, IMPACT calculated the expected impact of climate change on chosen variables using two Representative Concentration Pathways (RCP 4.5 and 8.5). Variables available in IMPACT include yields, area, production, etc. Area is defined as the amount of land on which crops are grown, measured in hectares. Yield is the amount of production per unit area (MT/ha). Production refers to the total weight of a crop measured in megatonnes and is a product of area and yield. Yield may give some indication of changed practices, inputs, technology, etc. For example, an increase in production without an increase in area indicates that yield increased potentially with the use of improved inputs, technologies, or practices.

It should be noted that IMPACT results are not predictions, but rather scenarios that describe the future performance of crops under specific climate and policy conditions. IMPACT model results factor in several key assumptions regarding the structure of the socioeconomic system, national investment in agriculture, and climate. Thus, in interpreting the results, it is important to think of the modeled trends as plausible, not predicted, futures. As the IMPACT model is a partial equilibrium model of the agricultural sector, it is largely driven by the supply and demand of the modeled commodities. The key trends examined include changes in yields, area harvested, net trade, and animal numbers.

The impacts of climate change on a given indicator of interest are calculated as the difference in percentage differences in 2050 over the baseline year 2020 with and without climate change.[237] For example, the impact of climate change on yield ($Y_{diff(pp)}$) is assessed as follows:

$$Y_{diff(pp)} = \%\Delta y_{CC} - \%\Delta y_{NoCC} \qquad 1$$

Where

$$\%\Delta y_{CC} = \frac{y_{CC2050} - y_{CC2020}}{y_{CC2020}} \qquad 2$$

$$\%\Delta y_{NoCC} = \frac{y_{NoCC2050} - y_{NoCC2020}}{y_{NoCC2020}} \qquad 3$$

When calculated in this way, impacts are reported in terms of a percentage point difference. Impacts can also be assessed as a percentage difference of the indicator's 2050 value under CC with respect to its 2050 value under the NoCC scenario. For yield this would be:

$$Y_{diff(\%)} = \frac{y_{CC2050} - y_{NoCC2050}}{y_{NoCC2050}} \qquad 4$$

When calculated in this way, impacts are reported in terms of percentages. The same equations apply to the other characteristics examined here: area harvested, production, animal numbers, net trade, food availability, and demand.

Several outcomes are possible when looking at climate change impacts relative to a scenario of NoCC. The modeled variables show impact for each scenario (RCP4.5, RCP8.5, and NoCC), which allows for comparison between the three. It is important to note that increases and decreases in variables are relative; for example, yield may still increase under conditions of CC, but this increase may be less in comparison to a scenario where climate change had not occurred. Thus, while yield does increase under CC in this example, a diminished increase in comparison to NoCC shows the detrimental impact of climate change on yield.

Annex D: Climate-Smart Agriculture (CSA) packages

Table D.1 CSA package description

Production System	Specifically modeled in IMPACT	Modeled as part of broader category
Irrigated AEZ		
1. High-value date palm development, processing, and marketing using modern irrigation systems and improved cultural practices	• The introduction of high-quality Medjoul and Barhi date palm varieties in the Jordan valley was a successful investment by the private sector of Jordan. Farmers and industry actors managed to produce high-quality yields and process, package, and export their dates with notable profits. The use of modern irrigation systems such as sprinklers and drip irrigation, and of improved cultural practices, helped to establish a sound industry. • Planted areas have expanded only slowly due to several factors: the high initial investment required, which only wealthy farmers can afford; damage from insects and diseases; and low local consumption rates. The practice is worth expanding, though, as it addresses Jordan's water scarcity directly through its high economic water productivity. • A program to support small farmers to adopt and expand this practice and address the above issues, organize the process to reduce costs through the establishment of cooperatives, and open both internal and external markets can contribute to making agriculture in Jordan more relevant and profitable. • The package would include a program for supporting small farmers during the establishment phase, including credit and technical assistance; formulation of cooperatives that can consolidate land for larger date palm fields; plant protection programs especially against red palm weevils; and aggregate processing and marketing facilities.	• The climate-smart potential of date palms mainly stems from high adaptation and productivity levels. Date palms are very resilient to climate variability and change, as well as being water-use efficient and tolerant to lower quality water. Date palms also make an essential contribution to people's diets, especially in terms of their nutrients. • The yields and income of date palms are high, but more important in the context of Jordan is their high water productivity in economic terms. • Date palms use a moderate amount of energy for irrigation and processing fruits, and residues and date palm waste can be processed to produce environmentally friendly biofuel or biochar.
2. Expanding and upgrading protected vegetable production with drip irrigation and improved greenhouse technologies	• Vegetable production under irrigation in the Jordan Valley includes tomatoes, potatoes, cucumbers, eggplants, squash, and peppers. They are grown either in open fields or protected in greenhouses, manly relying on drip irrigation, although some furrow irrigation is still in use in open fields. The major benefit of vegetable production in the Jordan Valley is the relatively warmer temperatures in winter, which allow production without additional heating, an advantage over the highlands. Most of the production is consumed locally, but exports to neighboring countries are essential, and small amounts are exported to Europe. • Challenges facing vegetable production in the Jordan Valley include low productivity and quality in open fields, a lack of grading and quality control for export, intensive use of chemicals, production market fluctuations that cause prices to crash, and a lack of processing facilities for added-value products. • This package includes a program for converting open-field vegetable production to protected systems with drip irrigation and for improving greenhouses technologies with regard to varieties, pest and disease control, etc., in order to end up with higher quality products. This package also entails establishing grading and processing facilities for added-value production, building temporary cold storage facilities using renewable energy to avoid market flooding, and creating institutions for organizing farmers in cooperatives able to reach external markets.	• In the Jordan Valley, vegetable production in greenhouses with drip irrigation is highly water-efficient. Water productivity is potentially high; currently, though, it is often low due to marketing problems and fluctuating prices. • Production is in the warm winter of the Jordan Valley requires no heating and only a little energy for pumping water, and so will contribute to lower GHG emissions. Using renewable energy for cold storage could further minimize emissions. • Promoting vegetable consumption enhances nutritious and healthy diets and may reduce reliance on less sustainable food systems. • Developing the industry within a value chain will improve farmers' incomes and contribute to productivity and adaptation to the potential impacts of climate change.

Production System	Specifically modeled in IMPACT	Modeled as part of broader category
3. Advancing inland freshwater fish production for local nutritional food security through improved breeds and practices	• Currently, there is limited production of fish in Jordan. Freshwater ponds have recently been developed for fish production and have shown some success. Production of fish, however, is still low in Jordan, because consumption is low due to high prices. Producing fish at lower prices can enhance consumption and provide a more balanced and nutritious diet. • Investing in more advanced freshwater fish production and upscaling to other areas in Jordan would reduce prices and provide farmers with additional income. This package would introduce better ponds, improved fish varieties, and enhanced cultural practices at a larger scale.	• Fishponds use relatively small amounts of water, which can be recycled for other uses such as irrigation. The productivity of fish per cubic meter of water or land is very high, which is relevant for water-scarce Jordan. • Promoting the consumption of fish enhances nutritious and healthy diets and may reduce reliance on less sustainable food systems.
4. Upgrading irrigation water productivity through modernizing systems, changing to high-value cash crops, and applying precision agriculture	• In Jordan, extreme water scarcity makes water, not land, the most limiting resource, so strategies and water management practices need to be adjusted to ensure the highest economic return for each unit of water. Although some modern technologies such as drip irrigation have been used, still most of the irrigated agriculture is conventional with low water productivity. • This package aims at a paradigm shift in irrigation water use to achieve the highest economic return for a cubic meter of water. Transforming traditional practices requires significant policy modifications to provide incentives. Changes would involve firstly, water-productive cropping patterns that replace many current crops such as bananas, forages, and field crops with high-value economic cash crops, and secondly, converting traditional irrigation systems to modern ones with high efficiency. Precision agriculture, such as land grading and using sensors for improved management of water and nutrients, is part of this package.	• The package would significantly increase productivity and farmers' incomes because modernizing agriculture will be more productive and ensure a higher return for market-oriented cash crops. • The package will help farmers utilize scarce water resources more efficiently and more productively, so as to maintain adaptation and reduce climate risk. Using precision agriculture will direct nutrients and other inputs only where needed.
5. Strengthening the energy-water-food nexus in irrigated agriculture by replacing fossil fuel for pumps and local desalination units with renewable solar energy	• Enhancing the energy-water-food nexus is the most effective strategy for achieving higher resource efficiency. Energy is a major component in irrigation pumping and the desalination of brackish water for irrigation. In addition to higher costs for power in Jordan, energy also contributes to GHG emissions. Replacing fossil fuel for pumps and local desalination units with renewable solar energy would be more sustainable and climate-friendly. • By replacing fossil fuel and electrical pumps and desalination units with solar units, this package aims at lowering energy costs for water resources and irrigation pumping, and at maintaining sustainable energy and water for food production in irrigated areas. Farmers would need support through credit provision and arrangements to link solar energy generation with the power network.	• This package would unlock additional or alternative water potentials for agricultural production through CO2-friendly or neutral energy inputs. Solar energy systems are most feasible for Jordan, which receives plenty of sunshine. • The use of solar power systems could generate business and employment and lead to good market options. Although brine residues from brackish water desalination are minimal, they are potentially harmful for the environment and require an effort to recycle into useful byproducts.
6. Treatment and use of sewage water in agriculture through decentralized treatment at the community level, support for greywater treatment at the household level, and managing treated sewage with rainwater in supplemental irrigation systems	• Jordan uses most of its treated sewage in agriculture, but the crops that receive this water are restricted. The inclusion of more crops requires better treatment, monitoring, and safety measures. Experiments showed that much of the sewage especially in rural areas can be treated at a lower cost to people and the environment at the household or community level by separating, treating, and using greywater in the garden. • Treatment plants in the highlands dispose of their water to neighboring areas to irrigate fodder and landscapes. The use of this water is still inefficient and has little value. If treated sewage is targeted towards supplemental irrigation in winter and towards fodder and landscapes in summer, then more value can be derived. • This package aims at improving the treatment and use of sewage water in agriculture by investing in decentralized treatment at the community level, supporting greywater treatment at the household level, and managing treated sewage in the highlands conjunctively with rainwater in supplemental irrigation systems.	• This package enables the treatment and re-use of marginal-quality water instead of wasting it. • The use of treated marginal water at the household level, e.g., for rural household back garden agriculture, limits the need to exploit other resources, such as by relying on groundwater or delivering water by truck. • At the large scale of centralized treatment, water can be used without taking a long time for transfer or transportation and storage, thereby avoiding evaporation losses.

Production System	Specifically modeled in IMPACT	Modeled as part of broader category
Rainfed AEZ		
7. Upgrading olive production and processing by introducing low-cost, modern technologies for collection, cold pressing, and pickling, and by alternative use of waste	• Olive growing is a major and important production system in rainfed areas, with some olives also cultivated under irrigation. The production of olive fruits and oil exceeds local consumption, but farmers face difficulties in exporting the surplus due to various constraints. Issues include low and alternating tree productivity; the high cost of handpicking fruits; the low quality of fruits due to insect and collection damage; oil extraction methods that use hot water for pressing, which reduces oil quality; and the difficulty of marketing products and disposing of biosolids. • Upgrading production and processing systems could make olive growing more economical for farmers and more competitive in the international market. This package would focus on improving cultural practices by supporting farmers with extension and introducing new low-cost collection technologies, protection against insects and diseases, and modern technologies for cold pressing and pickling, such as using renewable energy to upgrade olive oil to higher qualities with attractive packaging and effective marketing. • Olive oil extraction mills produce considerable amounts of biosolids and liquid waste, which have potential economic value but currently are not only wasted but also pollute the environment. This package would introduce alternative, environmentally friendly ways of pressing and processing biosolids to generate useful fertilizers, heating materials, and other products that can help farmers and the environment.	• This package can help the value chain become more productive and bring farmers higher incomes. • More green water storage through soil-water efficiency will be reflected in higher returns. • Many studies mention the capacity of olive trees to increase soil carbon storage. • This package supports mitigation and reduced emissions in several ways: by improved handling of the power requirements of pressing mills, by supporting the use of solar energy and cold pressing, and by recycling biosolids and liquid wastes into economic products.
8. Soil improvement through increased infiltration and soil-health storage capacity through contouring, terracing, appropriate plows, polymers, and the use of organic matter	• Rainfed areas in Jordan are mostly undulating landscapes featuring fruit trees and field crops, and entailing the likelihood of runoff and erosion. Most precipitation is lost in evaporation and runoff. So generally, soil health is poor both in terms of chemistry and biology. Due to poor systems, carbon sequestration is also slow. Soil conservation practices are common in Jordan. However, most lands with steep slopes require measures to allow water infiltration and reduce erosion. • This package would implement soil-water practices to improve infiltration and soil storage capacity, including contouring, terracing, and the use of appropriate plows, polymers, and organic matter. These practices would increase soil-water storage, but other interventions can retain water for plant use, including soil mulching, the use of early-vigor field crop varieties, and improved schedules of supplemental irrigation for rainfed fruit trees. • The package will support the low-cost application of zero or minimum tillage and the use of manure and plant residues, which, after processing, can support healthier soils with better structure.	• Healthy soils have good physical structure, e.g., aggregates, pore systems, and infiltration and water holding characteristics. They also contain adequate carbon and nutrients for supporting plant growth and general carbon storage. • Healthy soils can better respond to extreme climate-soil hydrological conditions, for example, through quicker infiltration and an advanced capability to hold water against gravity and evaporation, or through better organic materials and residues, which, in the extreme case of mulching, significantly reduce evaporation from the surface. • Enhanced soil structure and aggregate stability build resilient soils less vulnerable to degradation. • This is a win-win case of increased land productivity in addition to environmental improvement.

Production System	Specifically modeled in IMPACT	Modeled as part of broader category
9. Agroforestry packages to reforest most of the suitable marginal lands in 10 years by planting trees and shrubs and creating development programs for follow-up	• Very little area is covered with forests in Jordan, less than 1% of the country. Historically the situation was much better, but human intervention has degraded many forests. Due to reforestation efforts late last century, mainly by the government, many new forests were successfully established. Recently, the interest in reforestation has been renewed, and plans are being made to initiate the planting of 10 million trees a year. There is plenty of marginal land, both public and private, for which forestry is the best land use. Major issues include a lack of follow-up after planting with a very low survival rate; little investment allocated to this activity, which is considered low-priority; and the preference of people who own private lands for economic cropping. • This package aims at developing a program for reforesting most of the suitable marginal lands in 10 years, not only by planting appropriate trees and shrubs but also by creating programs to follow up and ensure that development is successful. To reforest private marginal lands, incentives for landowners may be included in the package. Many tree and shrub species are suitable for different zones in Jordan, but most land awaiting reforestation is rainfed, with slopes. Large trees like pine, oak, and eucalyptus are common, but shrubs that provide feed for animals also have potential.	• Besides their contribution to storing carbon, agroforestry packages can provide shade through strategic positioning, for example in agropastoral systems, substituting CO2-intense structures. • Agroforestry packages can also help regulate microclimate through cooling; strengthen the soil by preventing erosion, for instance, through contour intercropping; reduce wind speeds through shelterbelts; and host beneficial biological predators so that less chemical pesticide may be needed. • Various trees can provide direct agricultural benefits through, e.g., medical or livestock feed value, even if no fruit trees are suitable.
10. Enhancing field crop water management and value addition, upgrading the durum wheat value chain for higher income, and expanding barley production with rainwater harvesting for animal feed	• Field crop lands in Jordan have been declining in recent decades, with fruit trees and other cash crops taking over. Wheat and barley, however, are important crops for dietary and social reasons. Importing grains is cheaper than growing them, especially because the government heavily subsidizes the prices. There is an opportunity to maintain durum wheat production through an added-value process for locally popular "freekeh" and pasta-associated products. This effort will require growing special varieties and improved processing technologies. • Jordan imports a large number of barley grains for animal feed. There are vast areas suitable for barley production with lower rainfall than is required for wheat, but some form of rainwater harvesting is needed, and lands must be well-selected. Rainfall zones receiving below 300 mm annually and areas like the "Marab" can be utilized for barley production. Recently, plots in the Marabs managed by ICARDA with appropriate water harvesting produced 6 t/h of grains, similar to irrigated areas. • This package aims to upgrade the durum wheat value chain for higher incomes and to expand barley production with rainwater harvesting for animal feed. It seeks to attain these objectives through investment in high-value processes like those for "freekeh" and pasta, and by applying integrated input packages with rainwater harvesting.	• Improved water management through runoff strips or 'Marab' flood-irrigation practices retains excess rainfall and enhances localized deep infiltration into the soil, bridging intra-seasonal dry spells and thus fostering adaptation to climate change. Overall, crop production increases, and variation in productivity due to rainfall variance decreases. • This package would also contribute to increased value addition for local products like pasta, greater economic gains, and reduced transport-related CO2 emissions. However, the processing industry also generates CO2 emissions, which need to be considered.

Production System	Specifically modeled in IMPACT	Modeled as part of broader category
Rangeland AEZ		
11. Enhancing small ruminants' production and quality with concentrated farming including by-product processing, fattening, and advanced breeding	• Currently, small ruminants, sheep, and goats mainly use open grazing with supplemental feed. Open grazing usually results in overgrazing, causing degradation of the rangelands of Jordan. Changing this practice to on-farm fattening would increase efficiency and reduce overgrazing and degradation of the rangelands. • The resilient local Awasi sheep is desired for quality and taste and enjoys international demand, although it lacks some traits of high productivity. Advancing the Awasi breed by selection and crossings would create a significant market and large industry. This will require an advanced breeding center specialized for this ruminant. • Small ruminants are used mainly for meat and milk. Other parts of the animal like wool and skin are underused due to a lack of appropriate processing facilities. Utilizing these parts, in addition to milk byproduct processing, can increase the economic return per animal substantially, decrease the amount of waste and its disposal into environment, and increase reuse and production. This package includes investment in modern sheep farm fattening and balanced feed processing and production, creates a breeding center to improve Awasi sheep, and develops facilities for whole-animal production and its value chain at local and community levels.	• Reducing overgrazing would help to revegetate the rangelands with increased carbon sequestration. • This package would also increase productivity. • The selection of breeds with high export value increases the economic benefits per head, taking into account water and feed consumption. • A local feed supplement system can partially build on food waste, such as vegetable waste.
12. Strengthening the dairy production value chain at the industry and community levels through collective cold storage using renewable energy and through training with a proper institutional setup	• The dairy processing industry in Jordan is important and relatively well-developed, but requires expansion and organization to support more farmers and provide sustainability. • Much of the milk production from the Badia goes to cities for processing. There are issues with cooling facilities and health, and herders do not always receive a fair share of the value added along the chain. Decentralizing dairy production at the community level would increase incomes and reduce the costs associated with cold storage and transportation. It would also lessen migration to urban areas and provide stability. • This package would support the dairy industry and local communities to improve the efficiency of the production chain through collective cold storage using renewable energy and through training with a proper institutional setup of the milk-producing communities in the Badia. It would also enhance the incomes of local communities through processing units. • Finally, the program would contribute to higher energy and water efficiency through advanced processing.	• Using renewable energy for cooling and storing milk products helps mitigate climate change. • Productivity improves as efficiency increases. • Local communities benefit from additional employment and income. • In addition, decentralization might help reduce the transportation of dairy products.

Production System	Specifically modeled in IMPACT	Modeled as part of broader category
13. Badia restoration with micro-catchment water harvesting and improved grazing management	• Open grazing of the Badia agropastoral system has caused severe degradation and loss of vegetative cover. Traditional restoration through protected areas and direct seeding resulted in little success. The old Hima tribal grazing system was effective at one time, but now needs updating for modern times. The implementation of sound management would reduce overgrazing for the restoration of the vegetative cover. • Research has shown that restoration might advance much faster through a progressive and integrated program for the degraded Badia that uses micro-catchment water harvesting and improved shrubs and grasses in conjunction with grazing management. In-situ water harvesting allows runoff water to infiltrate and be stored in the soil profile instead of being lost in evaporation or salt sinks. This practice is now mechanized and can expand at low cost in the Badia; it would support shrubs and grasses and halt degradation. • This package includes providing Vallerani micro-catchment water harvesting units to construct bunds at large scale, nurseries to produce millions of seedlings of indigenous shrubs, and qualified people to implement the restoration package. It also entails changing grazing management of restored areas from open to controlled, and training local communities and restoration staff about package implementation.	• This package will contribute to additional carbon sequestration through shrubs and grasses. • It will foster higher resilience of the ecosystem and local communities. • It will also increase the productivity of the Badia ecosystem. • Local and native rangeland species are better adapted to climate variance than barley agriculture.
All AEZs		
14. Rainwater harvesting for households' domestic and agricultural use	• Given the extreme water scarcity in Jordan, households – especially in rural areas – are burdened with difficulties and costs associated with securing water for drinking and growing trees, vegetables, and other plants in backyard gardens. Households can collect rainwater from rooftops and paved areas around the house to cover 40-60% of their needs depending on the level of investment in storage facilities. • This package would invest in collecting rainwater from rooftops, including from gutters and other construction materials; storing the water in a cistern; and using it for drinking and garden agriculture. These practices can be combined with renewable energy generation for pumping and home use. These investments can save water, support the household economy, and contribute to national efforts to overcome water scarcity. • Beyond the household level, in low and medium rainfall areas, rainwater runoff from small catchments can be collected and stored in small reservoirs and cisterns at the farm or along wadis (valleys) for supplemental irrigation and livestock watering. • This package would invest in farm rainwater harvesting and reservoir construction for small-scale farmers' agriculture. Relevant technologies include runoff inducement facilities, building surfaces, and underground reservoirs and small-farm supplemental irrigation systems.	• This package can contribute to reduced water use from central supplies. • It would increase farmer incomes. • At the household level, more opportunities for growing trees and for agriculture result in additional vegetation and carbon storage. • This package helps boost the resiliency of communities. • Because less water transport would be required, e.g., using water trucks, CO2 emissions would be diminished.

Production System	Specifically modeled in IMPACT	Modeled as part of broader category
15. Expanding hydroponic and aeroponic practices for high-value vegetables using groundwater	• Jordan faces huge water shortage crises. Yet it is not able to control groundwater mining in many areas (e.g., Marfaq and southern areas, but also others). Farmers, therefore, are able to mine aquifers for unsustainable agriculture and low water-use efficiency. Converting current agricultural systems and cropping patterns into more water-productive hydroponic and aeroponic practices will reduce the energy required for pumping water and provide higher value for farmers and more sustainable systems. • Hydroponic and aeroponic technologies for vegetables are utilized in Jordan on a limited scale. They are extremely water-productive, both economically and biophysically. Facilitating investment and training will help spread and save water resources. This package aims at investing in hydroponic and aeroponic protected greenhouses and the water-nutrients supply system. Training and policy incentives would help farmers adopt hydroponic and aeroponic practices instead of the current inefficient systems. Renewable energy may support not only the pumping system but also the household and community.	• This package would help reduce groundwater mining and fossil fuel use. • It would heighten water-use efficiency and productivity. • It would lessen fertilizer and pesticide use. • Finally, this package would also contribute to higher incomes.
16 . Upgrading the poultry industry and value chain with local feed production and collective cold storage using renewable energy	• Jordan is self-sufficient in poultry and eggs with great export potential. Most of its poultry production is centralized in large production farms. Jordan imports almost all its poultry maize-based feed. Issues facing poultry production include the high cost of imported feed, energy costs, the quality of cold storage, and standards for export. • This package will support the production of suitable maize or other crop varieties by contracting farmers to produce poultry feed. It will support the decentralization of poultry farms to rural communities, the creation of processing plants for chicken feed, and the establishment of collective cold storage using renewable energy.	• Efficiency improvements in local feed systems through modernization and up-scaling of the sector will positively impact water-use efficiency and water productivity. • Costs and energy would be reduced by replacing imported feeds with local ones. • Using renewable energy for cold storage is climate-friendly. • This package would also help increase productivity and income for rural communities. • The alignment of whole production chain would increase adaptation.

Annex E: Concept notes

Concept note 1: Date Palm

Title	High-value date palm development, processing, and marketing using modern irrigation and improved cultural practices
Summary	
Overall objective	Expand current date palm area by 20% (800 ha) in small landholdings and increase present plantations' economic returns by 50% over 5 years.
Beneficiaries	About 500 new small and medium-sized farm owners in addition to existing large farm owners
Target region	Irrigated areas in the Jordan Valley
CSA Pillars (A,M,P)	This project supports mainly adaptation (A) and production (P), with a co-benefit for mitigation (M). - A: Date production supports adaptation because it is resilient to climate variability and change, has high water productivity, and is tolerant to water stress and lower-quality water. - P: This investment supports production because returns are high for crop yields and income and promise high water productivity. - M: Mitigation is achieved as a co-benefit because date production uses relatively moderate energy for irrigation and fruit processing, and residues and date palm waste can be processed to produce environmentally friendly biofuel or biochar.
Introduction and strategic context	
Background	The introduction of high-quality Medjoul and Barhi date palm varieties in the Jordan Valley has been a successful investment by Jordan's private sector. Farmers and industry actors produce, process, package, and export high-quality dates with substantial profits. Modern irrigation systems like drip irrigation and improved cultural practices have helped establish a sound industry.
Problem statement and justification	Date palm production areas have expanded, but at a slow rate due to the high initial investments required, damage from insects and diseases, and low local consumption rates. The practice is worth developing, though, because it directly addresses Jordan's water scarcity through its high economic water productivity. A program to support farmers, especially small and medium holdings, to adopt and expand date palm production, and to address production challenges, especially marketing, can maximize water productivity and make Jordan more relevant and profitable. To be successful, this program must also help reduce costs by instituting cooperatives or another mode of organization or alignment, and by establishing open markets, both internal and external. Limited water resources that create competition may favor expanding date palms over low water- and land-productivity cropping, such as field crops and forages, and over low-productivity open-field vegetables.
Strategic, institutional, and policy context	Jordan struggles to cope with increasing water scarcity and declining water available for agriculture. The water and agriculture strategies of Jordan emphasize the allocation of water to high-return options. Date palm growing is among those options because of its high economic water productivity. So far, about 4000 hectares have been planted, with good returns. The private sector initiated and runs the whole business. Support from the public sector includes water supply and extension services, as well as programs to control red palm weevils. Policies to promote date palm expansion are not explicitly indicated since they may entail additional demand for water. However, a more realistic option may involve appropriate subsidies to discourage less productive cropping and encourage date palm expansion to replace crops with lower water productivity and income. As fruit quality is highly sensitive to microclimate, policies for a controlled expansion are recommended only for suitable areas. Furthermore, policies to promote the local consumption of dates and improve the quality of products and exports are essential for this sector's development.
Climate impact	
Climate modeling	Date palms can tolerate very hot conditions, and though they are perennial and hence exposed to summer temperatures, palm cultivation is not expected to experience negative impacts from higher temperatures. Under irrigated systems, date palms either maintain their current levels of suitability or, in the southern part of the Jordan Valley, increase suitability.

Title	High-value date palm development, processing, and marketing using modern irrigation and improved cultural practices
Economic impact	The date palm was modeled using IMPACT. Within IMPACT and following a business-as-usual scenario Shared Socioeconomic Pathway (SSP) 2, areas planted with tropical fruit will expand, while yield per hectare will increase even more under climate change in 2050. Tropical fruit will experience a trend towards importation to Jordan by 2050. However, this trend will diminish under climate change scenarios.
Strategic, institutional, and policy context	Jordan struggles to cope with increasing water scarcity and declining water available for agriculture. The water and agriculture strategies of Jordan emphasize the allocation of water to high-return options. Date palm growing is among those options because of its high economic water productivity. So far, about 4000 hectares have been planted, with good returns. The private sector initiated and runs the whole business. Support from the public sector includes water supply and extension services, as well as programs to control red palm weevils. Policies to promote date palm expansion are not explicitly indicated since they may entail additional demand for water. However, a more realistic option may involve appropriate subsidies to discourage less productive cropping and encourage date palm expansion to replace crops with lower water productivity and income. As fruit quality is highly sensitive to microclimate, policies for a controlled expansion are recommended only for suitable areas. Furthermore, policies to promote the local consumption of dates and improve the quality of products and exports are essential for this sector's development.
Short description of the CSA investment package	
Outline	The investment package aims to expand the existing date palm area by 20% (800 ha) in smallholdings in the Jordan Valley and increase current plantations' economic returns by 50% over 5 years. It targets 500 owners of new small and medium-sized farms and of existing large farm the Jordan Valley irrigated areas. The package would include a program supporting small- and medium-scale farmers during the establishment phase, including credit and technical assistance, the formation of cooperatives that can consolidate land for larger date palm fields, plant protection programs especially against red palm weevils, and aggregate processing and marketing facilities. The project will also facilitate investment and public support through policies and marketing instruments for large farming.
Key actors	MoA, Ministry of Water and Irrigation, NARC, Jordan Date Palm Association (JODA), Ag. credit bank, Khalifa date palm establishment, market chains, the media, farmers, and investors
Key components	
Component 1	**Increase technical and financial support for small- and medium-scale farmers.** This component will encourage these farmers to transition from low productivity cropping to more productive date palm production. Specifically, this component will include the following: (i) technical training in soil-water-nutrients conservation, pest and disease protection, and other cultural practices, as well as business management and bookkeeping; (ii) devising innovative financial mechanisms to expand production and improve quality and pre- and post-harvest practices, for instance through profit-credit schemes.
Component 2	**Form and strengthen producer groups to boost the commercial viability of new small and medium-sized producers.** Small- and medium-scale farmers can benefit from economies of scale, risk sharing, and increased access to information achieved through producer groups or other cooperative organizations. Large farmers can also benefit from producer groups that expand local and export marketing opportunities. This component entails the following: (i) the establishment of cooperatives or alignment of small and medium-sized producers, (ii) encouraging direct producer-retail relationships, and (iii) subsidizing the costs of transitioning farmers from less productive cropping to date palm expansion, hence encouraging specialization.
Component 3	**Increase product quality and yield.** This component will bolster product quality and yield among both existing and new farmers. Subcomponents will include the following: (i) practices to enhance soil-water-nutrient conservation, (ii) the establishment of plant protection programs especially against red palm weevils, (iii) the improvement of cultural practices more generally, and (iv) product quality standardization.
Component 4	**Aggregate farming, processing, and market facilities.** This component will support small- and medium-scale farmers in reducing costs and increasing market opportunities. Specifically, it will (i) modernize farm operations through the mechanization of pruning, pollination, and harvesting, in conjunction with other practices for reducing costs; (ii) support implementation of collective post-harvest and marketing infrastructure; (iii) help establish communal storage, packing, freezing, and distribution facilities; (iv) expand domestic and export market opportunities; and (v) facilitate contract farming systems and models.
Component 5	**Improve information management.** This component will furnish timely and accurate information critical for investment, planning, and marketing, and integrate information and communications technology to attract young entrepreneurs. Specifically, this component will involve (i) establishing a national database with relevant and accurate information about production, processing, and markets; and (ii) developing e-extension and e-advisory to improve service provision.

Title	High-value date palm development, processing, and marketing using modern irrigation and improved cultural practices
Risks	
	Risks refer to developments that affect outcomes but are difficult to control within the project or program context. The main risks for this project are as follows:

Risk	Probability	Severity
COVID-19	Medium	Medium
Political, regional instability	High	High
Labor availability	Medium	Medium
Pests and diseases	Medium	Medium
Enhanced salinization	Medium	Low
Water availability	Medium	High
Production cost increases and declining prices	Low	High
Dairy		Modeled under animal numbers and yield

- COVID-19 and political instability in the region are significant risks that may impact the export of agricultural products. Both threats disrupt land transport of goods to market, reduce purchasing power, shrink distribution networks, and stifle labor supplies for actors along the value chains. The influx of refugees adds additional risk to the expansion of date palm production due to competition for land coupled with the demand for low-cost food staples, potentially leading to the prioritization of caloric needs over nutrition.

- Pests, diseases, and enhanced salinization, as indirect results of climate change, are perceived as particular risks for irrigated areas where date palms are grown.

- Given increasing water scarcity in Jordan and emerging new national priorities, water availability constitutes a risk for agriculture in general and date palms in particular. With the demand for more water, pressure to use saline water is growing, along with the risk of salinization of the soil.

- A spike in production costs or a severe decline in prices is a low risk, but if it occurs, the industry may collapse.

Financing	
Financing opportunities	Chambers of commerce and the private sector are interested in viable proposals that include modern technologies, job creation, food security, and markets; however, there is no law on social enterprises. The current environment is not conducive to private investment due to a lack of reliable policies and a dearth of information. External investment could be enormous, especially from Gulf countries. The UAE Khalifa date palm foundation is already involved with Jordan date palm association. Conclusion: There are promising opportunities for private-sector investment finance, especially concerning scaling up for export markets and digital agriculture. Blended finance could enable public money to reduce the risks shouldered by the private sector, especially by small farmers.

Concept note 2: Vegetables

Title	Expanding and upgrading protected vegetable production with advanced technologies and processing and marketing options
Summary	
Overall objective	Expand protected vegetable cultivation by 25% and economic water productivity by 40% over 5 years.
Beneficiaries	500 small and medium-sized farmers currently cultivating in open fields and 200 existing protected agriculture farmers; an extra 40 farmers will be targeted for hydroponics
Region	The Jordan Valley irrigated areas and highlands currently using groundwater
CSA Pillars (A,M,P)	The project supports mainly adaptation (A) and production (P), with a co-benefit for mitigation (M). - A: Advanced-technology vegetable production supports adaptation because it promotes efficient use of scarce water resources and nutrients through modern irrigation systems and precision agriculture. - P: Production is another critical pillar for this investment because modernizing agriculture will achieve higher yields and incomes for farmers by capitalizing on high-value export markets. - M: Mitigation is achieved as a co-benefit because production in the warm winter of Jordan Valley requires no heating and little energy for pumping water, which will contribute to lower GHG emissions. Using renewable energy for cold storage could further minimize emissions.
Introduction and strategic context	
Background	Vegetable production under irrigation in the Jordan Valley and highlands includes tomatoes, potatoes, cucumbers, eggplants, squash, and peppers. They are grown either in open fields or protected in greenhouses, mainly relying on drip irrigation, although some furrow irrigation is still used on open farms. Vegetable production in the Jordan Valley benefits from relatively warmer winter temperatures, an advantage over highlands, which allow production without additional heating in winter season. Most of the output is consumed locally, but exports to neighboring countries are essential, and small amounts are exported to Europe.
Problem statement and justification	Vegetable production in open fields is challenged by low productivity and quality, a lack of grading and quality control for export, intensive use of chemicals, production market fluctuations that cause prices to crash, and a lack of processing facilities for added-value products. In Jordan, extreme water scarcity makes water, not land, the most limiting resource, so technologies and water management practices need to be adjusted to ensure the highest economic return for each unit of water. Although some modern technologies such as drip irrigation have been utilized, most open-field vegetable cultivation continues to rely on conventional furrow systems with low water productivity. Despite the alarming depletion of groundwater in the highlands, vegetables are grown in the summer alongside forages and fruit trees with low water productivity. In such situations, cultivation may be justified only if high water-productivity technologies are adopted, such as protected agriculture using hydroponics.
Strategic, institutional, and policy context	The vegetable sector can achieve much higher water productivity – 5-10 times greater – compared to other crops, or by changing from open fields to protected or greenhouses cultivation. This is a strategic change to cope with growing water scarcity and declining agricultural water in Jordan. The vegetable sector faces serious challenges, however, especially from COVID-19. Government policies to overcome some of these challenge can improve farmers' livelihoods and help alleviate water scarcity.
Climate impact	
Climate modeling	Tomatoes and potatoes were modeled as essential vegetables presently grown or planted under irrigated conditions. Currently and under future scenarios, very early or very late-planted tomatoes could experience significant heat stress. For potatoes, temperatures may dramatically reduce tuber formation and tuber weight without adaptation, while hot spells can cause heat damage and decrease tuber yield. For irrigated areas, results suggest that by the 2030s, potatoes will become less suitable. Moderate warming is projected to increase the suitability of tomatoes from marginal to moderately appropriate, potentially representing an opportunity for future tomato cultivation under irrigation in Jordan.

Title	Expanding and upgrading protected vegetable production with advanced technologies and processing and marketing options
Economic impact	Vegetables were modeled as a broad category in IMPACT; potatoes were modeled separately as a specific category. In IMPACT, following a business-as-usual scenario (SSP2), areas used for vegetables will expand slightly, and yield per hectare rises substantially under climate change in 2050. The area used for potatoes is expected to decrease slightly, while the yield per hectare is expected to decline significantly under climate change in 2050. Vegetables are the only category of crops that experience a trend towards exportation by 2050, which is more pronounced under moderate and severe climate change scenarios. Potatoes show a very slight trend toward importation.
Short description of the CSA investment package	
Outline	This package aims to expand protected vegetable cultivation by 25% and economic water productivity by 40% over 5 years. It targets 500 small and medium-size farmers cultivating in open fields, 200 existing protected agriculture farmers in the Jordan Valley, and highland irrigated areas now using groundwater. This package involves converting open-field vegetable production in Jordan Valley irrigated areas to protected systems with modern, highly efficient irrigation. It consists of the use of improved greenhouse technologies such as promising varieties and pest and disease control for higher quality products; precision agriculture, such as using sensors for improved management of water and nutrients; building temporary cold storage facilities to help avoid market flooding; using renewable energy; development of e-extension and e-advisory to enhance service provision; and establishing grading and processing facilities for added-value production, processing, and export. This project also supports introducing hydroponic production of high-value vegetables in irrigated highlands with groundwater resources. This technology should replace low water productivity in open vegetable fields, forages, and fruit trees, rather than expanding current planting.
Key actors	MoA, NARC, extension services, credit banks, investors, and the private sector
Key components	
Component 1	**Provide technical and financial support for small- and medium-scale farmers during the transition phase.** This component will support small- and medium-scale farmers to shift from low-value cropping systems to modern high-value vegetable production. Subcomponents will include (i) technical training in pest control, quality, certification, etc., and (ii) developing credit programs to support initial investments for converting to protected vegetable production and modern technology.
Component 2	**Strengthen farmer producer groups and value chain integration for export markets.** Export markets provide Jordan with promising vegetable production opportunities, but taking advantage of these opportunities requires high-quality criteria and well-developed linkages within the value chain. Hence, this component supports small- and medium-scale farmers and other value chain actors to reach external export markets. Specific elements are as follows: (i) strengthening small- and medium-scale farmers through the development of cooperatives, contract farming, etc., to improve and standardize quality and pool their harvests; (ii) encouraging direct producer-retail relationships and establishing linkages with companies for export; and (iii) quality certification schemes to enable access to high-value export markets.
Component 3	**Convert open-field vegetable production into protected modern production systems with higher quality products.** This component will support small- and medium-scale farmers transitioning from open-field or protected vegetable production to modern production systems. Subcomponents include the following: (i) greenhouse construction and upgraded tunnels; (ii) the introduction of improved greenhouse technologies such as varieties and pest and disease control; (iii) the adoption of modern, highly efficient irrigation systems; and (iv) the use of sensor technology, for example to guide data-driven production.
Component 4	**Improve processing, storage, and marketing for higher-value production and extended shelf-life.** This component will increase products' market value. Specifically, this component will include the following aspects: (i) building temporary cold storage facilities using renewable energy to avoid market flooding, (ii) creating cold chain transportation networks, and (iii) establishing grading and processing facilities for added market value.
Component 5	**Enhance information management.** Although the vegetable sector is more diverse and less clearly organized than the date palm sector, information is still key for data-based approaches to reduce input use, predict pest and disease outbreaks, and reduce yield loss and water evaporation. Timely and reliable information about production, processing, and marketing is critical because of the perishable nature of many vegetables. Specifically, this component will involve (i) establishing a national database for different types of high-value vegetables with relevant and accurate information about production, processing, and markets; and (ii) developing e-extension and e-advisory to improve service provision.

Title	Expanding and upgrading protected vegetable production with advanced technologies and processing and marketing options

Risks and opportunities

Risks refer to developments that affect outcomes but are difficult to control within the project or program context. The main risks for this project are as follows:

Risk	Probability	Severity
COVID-19	Medium	Medium
Political, regional instability	High	High
Labor availability	Medium	Medium
Heat stress	High	Medium
Pest and diseases	High	Medium
Water availability	Medium	High

- COVID-19 and political instability in the region are significant risks that may impact opportunities for exporting agricultural products. Both threats disrupt land transport of goods to markets, reduce purchasing power, shrink distribution networks, and stifle labor supplies for actors along the value chains.

- Increased heat stress days and spells are projected under severe climate change scenarios, with varying consequences for different vegetable crops. Periods of additional heat stress minimize the window of time during which fruiting vegetables such as tomatoes can be grown, and lengthier spells of warm temperatures can dramatically reduce tuber formation and weight, resulting in lower potato yields. Pests, diseases, and enhanced salinization, as indirect results of climate change, are perceived as particular risks for irrigated areas where vegetables are grown. Integrated pest management may alleviate the risk but requires greater effort.

- Given increasing water scarcity in Jordan and emerging new national priorities, water availability constitutes a risk for agriculture in general and vegetables in particular. With the demand for more water, pressure to use saline water is growing along with the risk of salinization of the soil.

Financing

Financing opportunities	The Jordan Valley's favorable climate for vegetable production and strong employment potential constitute a comparative advantage over other countries in the region and are expected to increase over the coming decades. Advanced technology and value chain integration provide attractive financing opportunities for the private sector, including for providers of services that help guide production decisions, marketing, and planning, and increase supply-demand synergy. **Conclusion:** Despite this potential, it is unlikely that many investors from outside the farmer community will invest in small- and medium-scale farmer development. Farmers themselves can invest but need financing from the government or credit banks. Blended finance might enable public money to be used to reduce the private sector's risk.

Concept note 3: Olives

Title	Upgrading olive production and processing by introducing low-cost, modern technologies for collection, cold pressing, and pickling, as well as through alternative waste use.
Summary	
Overall objective	10% of current conventional olive farmers adopt advanced growing, collecting, processing, and packaging technologies over 5 years.
Beneficiaries	1000 olive farmers will benefit from one or more components of this package. The environmental benefits of olive waste processing cover a large number of communities in hot spots.
Region	Rainfed areas in northern and central Jordan
CSA Pillars (A,M,P)	The project supports mainly adaptation (A) and production (P), with a co-benefit for mitigation (M). - A: Olive production supports adaptation because it encourages green water storage through soil water efficiency, reflected in higher returns. - P: This investment supports production because it utilizes a value chain approach that increases production value and farmers' incomes. - M: Mitigation is achieved as a co-benefit because alternative energies, e.g., solar power, used in pressing mills and recycling biosolids and liquid wastes will lower emissions. Olive trees also play a crucial role in soil carbon storage.
Introduction and strategic context	
Background	Olive growing is a powerful and vital production system in Jordan's rainfed areas, with some olives also grown under irrigation. The production of olive fruits and oil exceeds local consumption, but farmers face difficulties exporting the surplus. The industry remains inefficient, with low resilience to market fluctuations due to inadequate and alternating tree productivity, the high cost of hand harvesting, low quality of fruits due to insect and collection damage, quality-reducing hot-water oil extraction methods, underdeveloped marketing links, and poor disposal of biosolids.
Problem statement and justification	Upgrading olive production and processing systems could make them more economical for farmers and more competitive in the international market. This package would focus on improving olive growing practices, including supporting farmers with extension, introducing low-cost and appropriate harvesting technologies, protection against insects and diseases, and modern technologies for cold pressing and pickling, including using renewable energy to upgrade olive oil to higher qualities with attractive packaging and effective outreach marketing. Olive oil extraction mills produce considerable amounts of biosolids and liquid waste, which have potential economic value but are currently wasted and polluting the environment.
Strategic, institutional, and policy context	Olive orchards are famous in Jordan, especially in the rainfed north and middle and they are expanding to other areas. Olives are a genuinely strategic crop in a water-scarce country. Except for small areas under irrigation, olives use green water and do not compete with other blue water resources. Developing this sector contributes to alleviating water scarcity, to employment in rural areas especially during harvesting and processing, and to the livelihoods of farmers with few other resources. The olive sector is a climate-smart production system not only through its productivity and adaptation but also in mitigation. The sector is dominated by farmers and processing and marketing industries; only the pressing industry is organized in larger associations. The government provides extension and sometimes protection to stabilize prices. A national strategy could enhance and maximize benefits from this sector.
Climate impact	
Climate modeling	Soil moisture stress constitutes a significant hazard in the rainfed AEZ, where key crops such as olives can experience wilting due to low moisture content levels in the growing season. Previous studies have reported an increase in drought stress and irrigation water requirements for suitable olive areas in Jordan. For olives, heat stress during the winter season is not of concern. During the summer, olives can be exposed to relatively high temperatures, though these conditions do not seem to lead to any negative impacts. Model results indicate that the crop is moderately suitable in parts of the rainfed zone, and future projections suggest that it will likely remain ideal in 2030, though yield reductions may nonetheless be expected in certain areas. Investing in CSA practices will be necessary to adapt to changes.

Title	Upgrading olive production and processing by introducing low-cost, modern technologies for collection, cold pressing, and pickling, as well as through alternative waste use.
Economic impact	Olives are a regionally important crop but were not modeled in IMPACT -- neither as a specific category nor as a broader category.
Short description of the CSA investment package	
Outline	This package aims to support 10% of current conventional olive farmers to adopt advanced growing, collecting, processing, and packaging technologies over 5 years. It targets 1000 olive farmers in northern and central Jordan rainfed areas. This package would facilitate improved harvesting through low-cost modern technologies that will enhance quality, reduce harvesting time, strengthen farmer linkages with other value chain actors, and introduce a modern, alternative cold pressing process for high-quality oil extraction. The project will improve processing quality and marketing; for export, some treatment of acidity is needed. At the same time, it will reduce solid and liquid waste in an environmentally friendly way.
Key actors	MoA, NARC, olive farmers, and pressing associations and companies
Key components	
Component 1	Build capacity for olive farmers through training as well as extension and advisory services. This component will increase capacity among olive producers. It will involve (i) soil-water-nutrients conservation, (ii) pest and disease control and protection, and (iii) other agricultural practices.
Component 2	Reduce costs and improve product quality through cooperation among small olive producers. Successful implementation requires the strengthening of farmers and their linkages with other value chain actors. The creation of farmer groups or cooperatives can reduce production costs, mitigate risks, and create new markets. However, most small individual olive farmers and some bigger farms may not currently need cooperatives. Cooperation must happen at the local level and bring added value, e.g., through packaging and enabling certification, so that farmers join to improve quality and raise their incomes. This component will strengthen the linkages between farmers. There is an appetite among producers for cooperation, but significant support is necessary in the form of resources, capacity building, and technology dissemination. Specifically, this component will include the following: (i) establishing low-cost means for cooperation through the shared use of harvesting machines, transport boxes, and mills; (ii) defining a role for the private sector and the government to support cooperative development, which will be particularly important in rainfed areas where smallholder farming is more prominent.
Component 3	Improve picking and collection through low-cost modern technology and better tools. Labor for picking and collecting olives during harvesting is one of the major costs of olive production. While recognizing the importance of employment, there is scope for introducing low-cost technologies and better tools. This component aims to reduce production costs by reducing harvesting time while maintaining jobs and product quality. Specifically, this component will involve (i) the introduction of olive picking machines and hand-held machine shakers for mechanical harvesting, and (ii) collection and transport in reusable plastic boxes.
Component 4	Facilitate high-quality processing and marketing. At the moment, olive production is primarily based on local taste. However, high production and import are affecting local markets. The quality needs to comply with demand from export markets for cold pressed virgin oil. There is potential for leading Jordanian farmers who are exporting their products and could provide an example for others. This component will improve the quality of processing and marketing for both domestic and export markets. Specifically, subcomponents will include the following: (i) introducing modern cold pressing for high-quality oil extraction; (ii) the use of attractive packing and marketing; (iii) establishing international quality and flavor guidelines including possible treatment to control oil acidity; and (iv) reducing solid and liquid waste in an environmentally friendly way.
Component 5	Improve information management: Good information is also vital for olive production. Farmers need information about production, pest control, marketing, quality improvement, and even traceability. It is essential to control temperatures during malaxation of olive fruit paste and oil extraction and to avoid any delays in pressing the fruits once they have been collected. Information and oversight are currently lacking; it is not clear where farmers can access technologies such as cold pressing. This component involves (i) generating reliable and accurate information about olive production, processing, and markets; and (ii) developing mechanisms for easy-access platforms and awareness raising among farmers and mill owners about practical means of improving oil quality.

Title	Upgrading olive production and processing by introducing low-cost, modern technologies for collection, cold pressing, and pickling, as well as through alternative waste use.
Risks and opportunities	
	Risks refer to developments that affect outcomes but are difficult to control within the project or program context. The main risks for this project are as follows:

Risk	Probability	Severity
COVID-19	Medium	Medium
Political, regional instability	High	Medium
Labor availability	Medium	Medium
Drought	High	Medium
Prices collapse	Medium	High

- COVID-19 and political instability in the region are significant risks that may impact olive export and olive oil opportunities. Both threats disrupt land transport of goods to market, reduce purchasing power, shrink distribution networks, and stifle labor supplies for actors along the value chains. The migration of refugees into Jordan adds additional risk to expanding olive tree production due to competition for land and water resources and the demand for low-cost food staples, which can potentially lead to prioritizing caloric needs over nutrition.

- Future climate projections indicate that the numbers of days of drought and soil moisture stress will increase, causing olive trees to experience wilting that results in higher susceptibility to pests and diseases and in decreased fruit yield. Changing rainfall patterns and distribution through the growing season stands out as a risk particular to rainfed areas where olives are produced, as too much or too little rain will negatively impact fruit growth and yield.

Financing	
Financing opportunities	Jordanian virgin olive oil is of high quality but requires further treatment for export markets; increased value chain integration and potential export markets could be interesting for private-sector investment. Olive trees are traditionally grown by many households for olive oil and pickling; the practice of olive cultivation is firmly engrained in Jordanian culture, providing scope for strong public support. **Conclusion:** There are opportunities for private-sector investment finance, especially for high-quality products for export markets. Blended finance might enable public money to reduce the private sector’s risk.

Concept note 4: Barley

Title	Enhancing barley production in rainfed areas and the Badia through rainwater harvesting and improved management
Summary	
Overall objective	Doubling barley areas and yields in 5 years with improved land selection, cultural practices, and rainwater harvesting.
Beneficiaries	1000 barley farmers (about 200 families) and their communities
Region	Marginal rainfed areas and the Badia with a mean annual rainfall of 200-300 mm and 100-200 mm, respectively
CSA Pillars (A,M,P)	The project supports mainly adaptation (A) and production (P), with a co-benefit for mitigation (M), namely carbon storage. - A: This investment supports adaptation through improved water management by means of runoff strips or 'Marab' flood-irrigation practices that retain excess rainfall; and through enhancing localized deep-infiltration into the soil, ultimately bridging intra-seasonal dry spells. - P: Production is a key pillar for this investment because it aims to increase crop production and decrease productivity variation due to rainfall variance. - M: Mitigation is achieved as a co-benefit due to carbon sequestration through land-use change. Producing locally reduces transportation and associated gas emission operations.
Introduction and strategic context	
Background	Jordan imports large quantities of barley grain for animal feed that are heavily subsidized by the government. Currently, small areas are planted in the rainfed zone with an annual rainfall greater than 200 mm. However, their yields are low due to the use of old varieties and low-tech conventional practices. Vast areas of barley are grown annually in the Badia, in the agropastoral zone, mainly for animal grazing and for establishing land ownership. Grain production in this zone occurs at low yields and only once every several years. Further, barley cultivation is usually poorly managed, leading to wind erosion and further degradation of the Badia ecosystem. Some regions, however, are planted with wheat and other field crops at the southern edge of the rainfed zone that are more suitable for barley production. Appropriate and more fertile lands in the Badia can be supported by one or more types of rainwater harvesting, e.g., Marab catchments, runoff strips, and small reservoirs for supplemental irrigation.
Problem statement and justification	Jordan subsidizes imported barley for animal feed that could be produced domestically with benefits like enhanced food security, increased rural economic opportunities, and improved ecosystem management. Horizontal and vertical increases in barley production within the rainfall zone receiving 100-300 mm can be achieved along the southern edge of the rainfed AEZ and favorable Badia lands using "micro-water harvesting" and "Marab" catchment methods and other rainwater harvesting techniques.
Strategic, institutional, and policy context	Small ruminants are essential to Jordanians' food security and livelihoods. Substantial political and financial support is provided to herders through barley subsidies. Positive developments in the barley sector may, therefore, result in negative consequences such as ecosystem degradation due to overgrazing by increased numbers of livestock. Hence, it is a significant strategic priority to produce more barley locally and to organize populations of concentrated small ruminants reared in the Badia. Policies subsidizing local production and financing water harvesting are essential to implement CSA by enhancing barley production.

Title	Enhancing barley production in rainfed areas and the Badia through rainwater harvesting and improved management
Climate impact	
Climate modeling	Currently and under future scenarios, supra-optimal temperatures are a hazard throughout the rainfed area for field crops such as barley. These heat stress days are typically concentrated towards spring when grain filling and maturity occur. Results also indicate relatively lengthy heat spells that are projected to increase. Warming and/or drought stress can severely impact agricultural production. A recent study projected barley yield reductions in the range 25–50% by 2050 for Jordan, depending on the climate scenario used. Without adaptation, these projected changes and impacts are likely to reduce feed availability for livestock, leading to significant effects on Jordan's agricultural livelihoods. Despite precipitation reductions, the suitable area for barley is projected to marginally increase. These increases are, however, concentrated toward the west of the rainfed zone. In the east of the rainfed AEZ and in the rangelands, suitable areas remain either marginally or moderately appropriate given the scarcity of rainfall water and the hot temperatures.
Economic impact	Barley was modeled in IMPACT as a specific category. Within IMPACT and following a business-as-usual scenario (SSP2), the area planted with barley will slightly decrease, but yield per hectare is expected to increase under climate change in 2050 due to technological and socioeconomic developments. Barley is expected to experience a trend towards importation by 2050, higher under moderate and severe climate change scenarios.
Short description of the CSA investment package	
Outline	This package aims to double the area under barley cultivation and barley yields through improved land selection and cultural practices. It also seeks to implement rainwater harvesting in 5 years. It targets 1000 barley farmers, about 200 families, and their communities in rainfed areas of western Jordan and in the western Badia. The program consists of rainwater harvesting and the introduction of highly productive and drought-tolerant barley varieties, a risk-reducing combination, as well as integrated cultivation packages.
Key actors	MOA, NARC, CGIAR, Jordanian Hashemite Fund for Human Development
Key components	
Component 1	**Promote barley cultivation through the identification of suitable land and supporting practices including rainwater harvesting.** Horizontal and vertical increases in barley production within the rainfall zone receiving below 300 mm annually, including in favorable Badia lands like the "Marab," can be utilized and enhanced for barley production. This component involves (i) selecting suitable areas for barley production in the Badia and along the lower edge of the rainfed zone; (ii) supporting appropriate and more fertile lands in the Badia through one or more types of rainwater harvesting, such as Marabs, runoff strips, and small reservoirs for supplemental irrigation.
Component 2	**Introduce improved varieties, integrated input packages, and mechanization.** Many small- and medium-scale farmers producing barley have limited capacity to purchase inputs and to implement improved barley cultivation practices. This component intends to address these challenges through (i) improving access to drought-tolerant barley varieties, especially mixtures to reduce risk; and (ii) applying integrated input packages with appropriate mechanization.
Component 3	**Redefine subsidies through policy engagement.** Substantial political and financial support is provided to herders through barley subsidies. A positive effect on the barley sector can have negative consequences when increasing livestock numbers result in overgrazing and further degradation of the Badia. Thus, it is a significant strategic priority to produce more barley locally and to organize farmers raising small ruminants in a concentrated manner in the Badia. Supportive policies linking policies to outputs instead of inputs are essential to enhancing the climate-smart potential of barley production. This component entails the development of alternative subsidy models in consultation with the barley sector and relevant ministries.

Title	Enhancing barley production in rainfed areas and the Badia through rainwater harvesting and improved management

Risks and opportunities

Risks refer to developments that affect outcomes but are difficult to control within the project or program context. The main risks for this project are as follows:

Risk	Probability	Severity
Open grazing and trespassing	Medium	Low
Prolonged drought	Medium	High
Heat stress	Medium	Medium
Subsidies that discourage production	Medium	Medium

- Increased temperatures, coupled with a reduction in rainfall, are expected to decrease barley production and reduce the water and pastureland available for livestock. The direct physiological effects of heat stress on livestock create uncertainty in the market for feedstock supply, further exacerbating challenges to the barley sector's development. Changing rainfall patterns stand out as a risk for rainfed areas where barley is grown, as too much or too little water can negatively impact grain growth.

- In the absence of institutions that can control open grazing, barley cultivation may be subject to trespassing and heavy losses in both dry matter and yield.

- Considerable goverment subsidies for barley, if continued, would discourage farmers from investing in cultivation. If the government does not put alternative policies forward, this entails a risk for the barley sector.

Financing

Financing opportunities	JBarley production for livestock feed is mainly undertaken for relatively poor livestock owners to overcome feed shortages. Financing for barley is necessary if improved technologies such as new varieties, optimized fertilizer management, and water harvesting structures are introduced. Public support may be necessary because growing barley locally will reduce imports and hence also subsidies that may formerly have been directed toward growers. **Conclusion:** Barley production has potential in marginal rainfall areas, especially with the implementation of rainwater harvesting and improved land allocation, varieties, and cultural practices. Policies to support production by reducing price subsidies for imported barley may be required but could be unpopular. Still, current subsidies can be redirected toward local production.

Concept note 5: Small Ruminants

Title	Enhanced small ruminant production through concentrated (Intensive) farming systems and dairy chain development.
Summary	
Overall objective	Building and running 3 collective Awasi sheep pilot community farms in north, middle, and south Badia that adopt modern feed and fattening, milk processing, and marketing technologies.
Beneficiaries	3 major communities with 900 farmer families (total population of about 6000), with potential indirect benefits through out-scaling to other agropastoral communities
Region	Agropastoral areas, the Badia
CSA Pillars (A,M,P)	The project supports mainly adaptation (A) and production (P), with a co-benefit for mitigation (M). - A: Small ruminant development supports adaptation because local feed supplement systems can partially utilize food waste like vegetable waste, while the selection and development of higher-producing breeds together increase economic and water-efficiency benefits per head. - P: Production is a crucial pillar of this investment because local communities gain employment and higher incomes through increased productivity and market value. - M: Mitigation is achieved as a co-benefit because the reduction of overgrazing aids in the revegetation of rangelands with increased carbon sequestration. Further, decentralization and renewable energy for cooling and storing milk products will reduce energy use and transport. Finally, offsetting dairy cattle milk with sheep or goat milk would reduce the amounts of methane gases contributed by animal production.
Introduction and strategic context	
Background	Small ruminants such as Awasi sheep and Baladi goats mainly rely on open grazing with supplemental feed. Open grazing is usually practiced in agropastoral areas like the Badia, and animals rotate through other agroecosystems to graze on residues of mainly wheat, barley, and vegetable farming. This approach with many animals usually results in overgrazing, causing land degradation of the rangelands of Jordan. Besides, sheep and goats must travel long distances searching for feed, reducing their productivity output and minimizing farmers' marginal benefits. Adopting on-farm fattening practices and local milk processing would increase efficiency and incomes and reduce overgrazing and degradation of Badia rangelands.
Problem statement and justification	The resilient local Awasi sheep is desired for quality and taste and enjoys international demand, but lacks high-productivity traits. Advancing the Awasi breed by selection and crossbreeding would improve the industry, but would also require an advanced breeding center specializing in this ruminant. The management of Awasi sheep, however, mainly fed for maximum milk production and fattened by grazing, can already be substantially improved through concentrated intensive farms with careful nutrition and health care, and this option seems more feasible. Small ruminants are used mainly for meat and milk, although other parts of the animal like its wool and skin can also be utilized. Increasing by-product processing and marketing can substantially increase the economic return per animal and reduce the negative impacts of uncontrolled waste disposal. Additionally, most of the milk produced in the Badia is transported to cities for processing, cutting herders out of value-added profits. Decentralizing dairy production to the community level would increase rural incomes and reduce costs associated with cold storage and transportation.
Strategic, institutional, and policy context	Sheep products are integral to the Jordanian diet and to the country's food security. Compared to cattle, sheep meat and milk are more acceptable to the Jordanian population and are more climate-friendly with lower production of gases and higher economic water productivity. Badia communities depend primarily on sheep rearing, which therefore takes on notable political and social importance. Such a vital link between people and their ecosystem helps slow migration to urban areas. Tribal institutional power is strong among local Badia communities, which also helps solve problems associated with development and conflicts. The well-known "Hima" grazing system by which tribes organize grazing based on seasonal rainfall and land carrying capacity was successful in the past and is an excellent example of the role tribal institutions play in managing Badia resources. The dairy processing industry in Jordan is relatively well-developed. It is an important industry but depends heavily on cattle milk. The sector requires expansion of sheep milk, as well as organization to support more farmers and long-term productivity. Decentralizing dairy production and processing facilities would also reduce migration to urban areas and provide income and stability in rural zones.

Title	Enhanced small ruminant production through concentrated (Intensive) farming systems and dairy chain development.
Climate impact	
Climate modeling	Future climate projections indicate that rangelands will generally become drier, with an average of 2–10 more moisture-stress days in winter. Winters, meanwhile, are projected to become hotter in the future. Heat stress can become a problem when temperatures may exceed 40oC the summer. Such temperatures can hinder livestock productivity and also affect human labor. These stresses put the livestock sector at risk in terms of available grazing area and fodder. Currently, the livestock sector is experiencing a shortage of feeds, and climate change is likely to exacerbate this situation.
Economic impact	IMPACT does not currently include a dynamic livestock model, and model results thus serve as an indication of possible changes in the production of meat rather than demonstrating a precise response to climate change on the basis of animal models. Sheep were modeled in the IMPACT model as part of a broader category of small ruminants; dairy was modeled as part of a broader category under animal numbers and yield. The impact of climate change on livestock production appears to be relatively small. Lamb and dairy tend toward importation by 2050, under all scenarios. However, climate change increases the trend very slightly for lamb and reduces the trend slightly for dairy.
Short description of the CSA investment package	
Outline	This package will establish, with collective community management, three Awasi sheep pilot community farms in the north, middle, and south Badia. The three communities will see over 6000 people adopt modern feed and fattening, milk processing, and marketing technologies, with potential indirect benefits through out-scaling to other agropastoral communities. This package entails investment in training and advisory for the production and processing of sheep, development of small ruminant cooperative groups based on traditional community structures, and strengthened dairy processing and marketing. Value-added facilities would include by-product processing at local and community levels, including product diversification and marketing, and improved cold storage using renewable energy.
Key actors	MOA, NARC, local communities, and pioneer farmers
Key components	
Component 1	**Provide training and advisory about production, processing, and marketing for small ruminant keepers.** This component will help build capacity among farmers, including women, in various aspects relevant to concentrated intensive and semi-intensive farming systems, including (i) fattening through balanced feed and nutrition; (ii) improvement of Awasi sheep through breeding, selection, and herd management; (iii) livestock husbandry and health; (iv) processing of by-products; and (v) processing and marketing of milk products.
Component 2	**Develop appropriate local structures or cooperative groups based on traditional community structures.** Farmer households in the Badia regularly move around based on the availability of livestock feed. Hence it is essential to work with people and their leaders in that area by using participatory approaches; trust plays a key role, and traditional social and community structures need to be considered. Technical activities such as concentrated farming systems may require lifestyle changes and learning from experiences. Women's roles deserved specific attention; women play a crucial part in small ruminant husbandry and in dairy production and processing and need to be involved in the transformation process. This component will try to build on local cultural values through (i) assessing local community structures and farming systems while exploring options to build on and enhance concentrated farming systems and product processing; and (ii) partnering with external organizations to help scale local cooperatives, especially when it comes to processing by-products and milk products.
Component 3	**Improve small ruminant production.** This component supports local livestock keepers through the introduction of various technologies for whole-animal production. Specifically, subcomponents will include the following: (i) modern sheep farm fattening and balanced feed processing and production; (ii) introducing breeding and selection programs and herd management techniques to improve Awasi sheep; (iii) developing facilities for whole-animal production; and (iv) enhancing techniques and technology that increase animal comfort during milking to increase the quantity and quality of milk.
Component 4	**Improve the efficiency of the dairy production chain.** This component will strengthen dairy processing and marketing. Specifically, subcomponents will involve the following: (i) greater efficiency of the dairy production chain through collective cold storage, processing, and transport using renewable energy, as well as product diversification and marketing; (ii) improved processing technology and management to reduce losses during milk processing, including temperature testing, milk fat separators, and larger cookers; (iii) the provision of technologies for higher-quality production, product standardization, food safety, and local value capture; (iv) branding as well as geographic indications (GI), product diversification, and access to markets; and (v) quality certification and standardization schemes.

Title	Enhanced small ruminant production through concentrated (Intensive) farming systems and dairy chain development.
Risks and opportunities	
	Risks refer to developments that affect outcomes but are difficult to control within the project or program context. The main risks for this project are as follows:

Risk	Probability	Severity
COVID-19	Medium	Low
Migration	Low	Low
Conflicts	Medium	Medium
Heat stress during summer	Low	Low
Social and cultural resistance to concentrated farming	Medium	High

- COVID-19 and political instability in the region are significant risks that may impact the import of feed and the export of animals and products. Both threats disrupt the transport of goods to market, reduce purchasing power, shrink distribution networks, and stifle labor supplies for actors along the value chains. The migration of refugees into Jordan adds additional risk to converting open grazing to concentrated farming by heightening the demand for low-cost food staples.

- Future climate projections indicate higher temperatures especially in the Badia, where maximum daytime heat may affect sheep health.

- People in the Badia are attached to their traditions, and changing from open grazing to concentrated farming may be an issue especially if no incentives are provided. Furthermore, conflicts between sheep owners about grazing or about changing norms, in the absence of proper institutions to resolve them, may affect agricultural development.

Financing	
Financing opportunities	Private-sector involvement in the initial stages is expected to be limited, at least until market linkages are established. This investment will require public funding to support pastoralist households in the driest area of Jordan. Feed subsidies and other government support for the Badia communities can play a role in establishing pilot farms. **Conclusion:** Subsidies and other government support need to be considered at the initial stage, but could possibly be combined with blended finance when market linkages have been established.

Concept note 6: Badia Restoration

Title	Badia restoration with micro-catchment water harvesting and improved grazing management
Summary	
Overall objective	Restoring 5000 hectares in 5 years with shrubs and grasses using micro-catchment water harvesting.
Beneficiaries	About 250 landowners
Region	Agropastoral areas, the Badia
CSA Pillars (A,M,P)	This project supports mainly adaptation (A) and production (P), with a co-benefit for mitigation (M). - A: Badia restoration supports adaptation goals because landscapes inhabited by local and native rangeland species are better adapted to extreme climate variance, they provide micro-ecosystems with benefits for soil health and moisture, and they enable more effective use of scarce water sources. - P: Production is a vital pillar of this investment because better ecosystem management will yield more sustainable livestock feed cultivation. - M: Mitigation is a co-benefit because the Badia will achieve more carbon sequestration through new shrubs and grasses; this will also reduce energy use by current unsustainable cultivation practices in the Badia.
Introduction and strategic context	
Background	Open grazing, coupled with other anthropogenic and climate change-related implications, has caused severe degradation and loss of vegetative cover in the Badia. The traditional 'Hima' grazing system worked well under tribal institutions in the past, but nowadays may not support modern production and consumption practices. Conventional restoration through fencing and protecting relatively small areas and through direct seeding approaches has resulted in limited success. Severely degraded ecosystems may not revegetate until soil-water can support plant growth, and animal grazing is a constraint to the actual carrying capacity of the rangeland.
Problem statement and justification	Research has shown that a progressive and integrated restoration program for the degraded Badia using micro-catchment water harvesting and improved native shrubs and grasses, together with appropriate grazing management, can advance restoration faster. In-situ water harvesting allows runoff water to infiltrate and be stored in the soil profile instead of being lost in evaporation or salt sinks. This practice is now mechanized and can expand at low cost in the Badia; it would support shrubs and grasses and halt erosion and land degradation.
Strategic, institutional, and policy context	The current policies of open grazing and barley subsidies allowed sheep populations to increase beyond the rangelands' carrying capacity and have resulted in the continuing degradation of the Badia ecosystem. New, strategic thinking should be adopted to aggressively restore and maintain the ecosystem because it occupies over 75% of Jordan. New policies and institutional setup that can replace or adapt the Hima system to modern times can control grazing and allow restoration efforts to succeed; land ownership, both private and public, needs to be aligned with this objective.
Climate impact	
Climate modeling	Jordan's rangelands are the driest and hottest areas of the country. In the rangelands, rainfall is hardly enough to grow crops, and livelihoods are primarily supported by livestock production. The wet winter season yields marginal rain, on average 25 mm or less of rain per month and many moisture stress days. Conversely, the summer is dry, with no precipitation and many days with temperatures above 37°C (a threshold chosen to indicate discomfort from heat among livestock and humans). Future climate projections suggest that the rangelands will become generally drier and hotter.
Economic impact	N/A

Title	**Badia restoration with micro-catchment water harvesting and improved grazing management**
Short description of the CSA investment package	
Outline	This package involves providing micro-catchment (Vallerani) water harvesting units to construct bunds and contour ridges at a large scale, and establishing nurseries to produce millions of seedlings of native shrubs in collaboration with local communities. The project also endeavors to change grazing management of restored areas from open to controlled, to train local communities and restoration staff in producing seedlings and package implementation, and to inaugurate an M&E program to assess the impact of restoration on ecosystem services.
Key actors	MoA, Ministry of Water and Irrigation, NARC, CGIAR, local communities, and NGOs in the Badia
Key components	
Component 1	Select project land, organize communities, and contract with owners and the government for project implementation. Badia restoration is a complex, long-term process, with a strong focus on the environment and restoration of ecosystem services, including the production of livestock feed. The involvement of different actors will enable broad endorsement and support. This component will establish relations between the government, local communities, and other partners, and focuses on the critical elements of the start-up phase, including (i) a careful selection of suitable sites based on biophysical and social characteristics; (ii) establishment of a management structure with strong involvement of local communities; and (iii) contracting with landowners and the government for project implementation.
Component 2	Train local communities and workforces involved in implementing the restoration package. Communities in the Badia have a strong internal and social bond; hence, building people's capacity within local communities themselves can play a key role in sustainable management. Involvement from the private sector may be necessary. This component will increase the capacity of farmers and project staff. Specifically, it will include training in (i) micro-catchment water harvesting and the construction of bunds and contour ridges at a large scale; (ii) nurseries for seedlings of indigenous shrubs; and (iii) sustainable grazing management.
Component 3	Restore selected sites through rainwater harvesting, re-seeding, and sustainable grazing management. This component will restore sites chosen through a combination of technologies and practices for sustainable management. Subcomponents include the following: (i) providing Vallerani micro-catchment water harvesting units with laser guiding systems to construct bunds and contour ridges at a large scale; (ii) building nurseries to produce millions of seedlings of native shrubs; and (iii) developing and implementing a controlled grazing management program for restored areas with community institutions.
Component 4	Implement a M&E program, including applied research activities for the first 5 years. Badia restoration can significantly impact ecosystem services and could be scaled out to other areas when successful. While there has been previous success with Badia restoration, scaling it out would require a more robust evidence base. This component aims to do the following: (i) set up a rigorous M&E program that uses remote sensing to assess the impact of restoration on ecosystem services; and (ii) apply research on the effects of specific technologies and how these can be further improved.

Title	Badia restoration with micro-catchment water harvesting and improved grazing management
Risks and opportunities	
	Risks refer to developments that affect outcomes but are difficult to control within the project or program context. The main risks for this project are as follows:

Risk	Probability	Severity
A lack of public and govermental support	Medium	High
Social and cultural resistance	Medium	High
Conflicts about grazing	High	High
Erosion	Medium	Medium
Prolonged drought	Medium	Medium

- This investment will require different partners' involvement, including broad public and political support. Public support is essential to pay for the establishment of restored areas and for institutional setup for grazing management.

- Badia restoration will necessitate initial protection of grazing areas, which may cause conflicts due to traditionally held values such as open access to grazing.

- During the evaluation of investments, erosion caused by poor land management and exacerbated by climate change was perceived as a particular risk for agropastoral areas.

- Climate change predictions indicate intensified extreme events including drought. Prolonged droughts will affect the survival and growth of shrubs and grasses, constituting a risk for Badia restoration.

Financing	
Financing opportunities	While the project is not directly interesting from a private investment point of view and will mainly depend on public funding, there is potential for financing through the carbon-credit market. **Conclusion:** It was noted that no commercial bank or finance institution will invest in agricultural production in the Badia. For this reason – in addition to the private sector's reluctance to get involved and the significant public benefits of restoring the region – the role of multilateral and bilateral development organizations will need to be substantial.

Annex F: Projects, studies and initiatives in Jordan relevant to investment packages

CSA Package	Title (year)	Short description
Date Palm, Vegetables and Olive	2016 Export Value Chain Analysis for Fruits and Vegetables in Jordan	The Value Chain Analysis (VCA) offers an in-depth overview of Jordan's fruit and vegetable sector. It describes the structure, actors and their position in the value chain. It aims to prepare a business case (a detailed programme plan description of Netherlands Enterprise Agency (NEA) service delivery) with interventions to strengthen Jordan's fruit and vegetable sector, taking into account the entire chain with eye for exports to the EU/EFTA markets.
Date Palm	2019 Pre-Feasibility Study Medjool Palm Cultivation Project in the Balqa governorate	The study aims to determine the pre-feasibility of establishing (Medjool) palm trees project due to the increase in these dates' consumption rates and the increased opportunities for its production in the kingdom. The project is to cultivate (Medjool) palm trees in the Jordan Valley area of the Balqa governorate located along the banks of the Jordan River, which is mostly part of the Jordanian lands and extends to the Palestinian territories on the other side.
Vegetables	2014 Value chain analysis of tomato sector in Mafraq governorate	The project is implemented under the ILO framework to respond to the Syrian refugee crisis. The component named 'Enhancing access to employment opportunities and livelihoods in host communities, was in turn implemented under the framework of the UNDP project 'Mitigating the impact of the Syrian refugee crisis on Jordanian vulnerable host communities. The project has four interventions areas: 1. Value chain development in selected sectors in Irbid and Mafraq, 2. Business enabling environment improvement, including addressing labor market challenges, 3. Developing effective employment services and improving employability, 4. Local capacity building to support business start-up and expansion
Vegetables	2017 Pre-Feasibility Study to Cultivate and Produce Dried Tomatoes	The project aims to cultivate and produce dry tomatoes of varieties suitable for drying and packing in vacuumed bags for the local market and exports to the European, the Gulf, the Russian Federation and the Balkan countries.
Vegetables Tomato	2018 Fresh Fruit & Vegetables of Jordan	The project aims to improve exports in terms of quantity and quality. The aim is to contribute towards the further upgrading of the value chain by supporting the introduction of new technologies and introducing new and higher-value-added crops, and penetrating higher-end consumer markets. In addition to looking for opportunities to reduce risk and water consumption. The objectives of this project are to have 25 producers increase their efficiency in the production and 25 producers to increase their export turnover with higher-end products to new markets.
Vegetables Hydroponic	2017 Hydroponic Green Farming Initiative:	The main goal was to investigate and implement different hydroponic farming systems in Jordan to increase water efficiency, profitability, and advanced livelihoods by use of hydroponic cultivation methods.

CSA Package	Title (year)	Short description
Vegetables Hydroponic	2019 Environmental and Social Impact Assessment (ESIA Final Report) for the Hydroponics Farm in Tannur-Wadi.	The main goal was to investigate and implement different hydroponic farming systems in Jordan to increase water efficiency, profitability, and advanced livelihoods by use of hydroponic cultivation methods.
Vegetables Hydroponic	2015 Hydroponic Green Farming Initiative Program (HGFI)	The program aims to investigate and implement the different hydroponic farming systems in Jordan to increase water efficiency, increase profitability, and advance livelihood. The program explores and studies the integration of renewable energy from PV solar systems to the large, commercial and small, rural household farms for increased efficiency.
Olive	2015 USAID Jordan Local Enterprise Support Project (LENS)	The project activity aims at improving the productivity and quality of olive production in target governorates
Olive	2017 Market system assessment of the olive oil value chain in Irbid & Mafraq governorates	This rapid assessment was done using semi-structured interviews focused on understanding the olive market chain, relationships between market actors, power structures, and inequities or imbalances. It relied heavily on the value chain assessment and market strategy completed by ILO. Other sources on the econometrics of oil production were also reviewed, as their analysis utilized larger samples than it was possible to gather during this assessment. Secondary data was also influential in guiding interview questions, allowing for more profound follow-up and minimizing new data gathered.
Olive	2019 Competitiveness of olive crop in Jordan	The aim was to assess the competitiveness of the olive crop in Jordan through the identification of economic and social characteristics of the farmers and their families and to study the enterprise budget of the olive crop in six governorates (Amman, Balqa, Irbid, Jerash, Mafraq, Madaba), and to identify the strengths and weaknesses of the olive sector on the one hand, and to identify the opportunities and challenges facing this sector from the other hand.
Barley	2005 On-Farm Evaluation of Improved Barley Production Technology Packages in Jordan – part of Mashreq project	The Mashreq Project's aimed to increase barley production, in order to support the increasing livestock population and reduce the high grazing pressure on the already degraded rangelands.
Barley	2018 The Impact of Governmental Price Policy on the Economic Returns of the Barley Crop Farmers in Jordan	The objective of the study was to analyze the impact of governmental price policy on barley production in Amman governarate, Jordan.
Barley & small ruminants	2003 From Formal to Participatory Plant Breeding: Improving Barley Production in the Rainfed Areas of Jordan	The project aimed at "Improving the welfare of small resource-poor farmers by increasing and stabilizing barley and animal production in rainfed areas" and had five specific objectives: 1. Promote participatory plant breeding and assess the potential to institutionalize the approach in the barley breeding program in Jordan; 2. Improved barley varieties that fulfill the needs of poor farmers in the rainfed environments of Jordan; 3. Enhanced rate of adoption of new varieties through farmers' participation in selection and testing; 4. Identification of differences between selection criteria used by men and women farmers and by breeders, and 5. Disseminate experimental results through publications, scientific articles, visits of breeders from neighboring countries and traveling workshops.

CSA Package	Title (year)	Short description
Barley, water harvesting & small ruminants	2012 National Programme for Rangeland Rehabilitation and Development - The National Programme for Rangeland Rehabilitation and Development	The project aimed at arresting and reverting the continued decline in Jordanian rangeland resources linked in particular to sharp increase in livestock numbers. The overall goal was to reestablish the productive capacity of rangeland resources in order to realize their significant environmental, social, cultural and economic contribution for present and future generations. The project introduced sustainable community driven resource management practices and supports the establishment of a functional Directorate of Rangeland Management in the Ministry of Agriculture. It included capacity building in generating the information and knowledge needed to develop strategies and policies for the sustainable improvement and use of the rangeland resources. At the local level, participatory rangeland restoration and management activities were implemented in five pilot areas in North-East and South Badia.
Badia restoration & small ruminants	2010 Badia Ecosystem Restoration Program Community Action Plan of Badia Ecosystem Restoration Program	The main goal of BRP is to rehabilitate the ecological productivity of the Badia ecosystems for wildlife and sustainable grazing by restoring the vegetation composition, structure and sustainability to allow wildlife populations to rebuild and provide a foundation for sustainable grazing practices across the entire Badia region. Even though the program is managed by the Ministry of environment, it is an integral part of the national development efforts to promote agricultural growth, improve the Bedouin population's livelihoods, and reduce poverty with sustainable pastoral development agropastoral production systems.
Barley, water harvesting & small ruminants	2014 Increasing the resilience of poor and vulnerable communities to climate change impacts in Jordan through Implementing Innovative projects in water and agriculture in support of adaptation to climate change	The overall objective of the proposed programme is to adapt the agricultural sector in Jordan to climate change induced water shortages and stresses on food security through piloting innovative technology transfer, policy support linked to community livelihoods and resilience.
Badia restoration & small ruminants	2011 Restoring Range Lands for Improved Livelihoods in the Badia of the Zarqa River Basin	The project objective is to contribute to reversing land degradation in the traditional drylands in the country. This project was implemented with the Jordan Badia Restoration Program (BRP), and National Center for Research and Development (NCRD)
Badia restoration & small ruminants	2016 Technology Needs Assessment Project	This is to fill the technology gap and complement the integrated approach that Jordan adopt to addresses climate change impacts.
Badia restoration	2012 The Badia Ecosystem and Livelihoods Project	The project aims to restore the Badia services through a dual approach of sustainable rangeland rehabilitation on the one hand and the promotion of alternative income-generating activities, such as eco-tourism, to selected communities in three poverty pockets in the Jordan Badia, namely Ar Ruwaished (Northern Badia), and Al Jafr and Al Husseinieh (Southern Badia)

Annex G: Cost-Benefit Analysis methodology

Financial profitability at the farm level

We employed a cost-benefit analysis (CBA) to assess the financial profitability of different CSA packages at a farm-level. CBA is widely used to value and compare all the costs and benefits of CSA interventions, from which to guide decision on whether or not an investment should be implemented given a limited resource. [238, 239, 240] At a farm-level, an ex-post CBA was used because these CSA interventions have already been experimented and/or implemented by several farmers (and/or areas). We used the two most common indicators in CBA, Net Present Value (NPV) and Internal Rate of Return (IRR) to estimate the incremental net profitability of the commodity produced under CSA and under the conventional farming.

The net benefit of commodity produced under climate smart agriculture csa and conventional farming cf discounted at present value over a period of time T and a discount rate r presented in NPV and IRR is calculated as follows:

$$NPV_j^{csa-cf} = \sum_{t=1}^{T} \frac{1}{(1+r)^t} \left[\sum_{j=1}^{J} p_{jt}.\Delta Y_{jt}^{csa-cf} - \sum_{j=1}^{J} \Delta C_{jt}^{csa-cf} \right]$$

$$IRR = NPV_j^{csa-cf} = 0,$$

where p_{jt} is the price of commodity j at time t, ΔY_{jt}^{csa-cf} is the difference in yield of commodity j produced under csa and cf at time t, and ΔY_{jt}^{csa-cf} is the difference in production costs of commodity j produced under csa and cf at time t. The *IRR* is the discount rate at which *NPV* is equal to 0. If the difference in production costs of commodity j between csa and cf at period 1 is negative or equal to 0, $\Delta C_{j1}^{csa-cf} \leq 0,$, this means that the CSA intervention does not require additional investment cost compared to conventional farming and thus the IRR is not obtainable because NPV is always positive.

A positive value of NPV and IRR indicates positive net incremental benefit hence the CSA intervention is profitable. The higher the NPV and the IRR are, the higher profitability the CSA intervention brings. Payback period (PP) is calculated to estimate the number of years the investment reaches break-even point.

Due to COVID19 pandemic, we faced some restrictions in data collection for CBA. For conventional scenario, we collected data via interviews with farmers and experts; for CSA scenario, we interviewed experts in each commodity sector for data collection. We then compared our data with different sources of literature including project reports and journal articles for validation.

Table G.1 provides a summary of conventional farming and CSA practice at farm-scale level, as well as the expected impact on revenue and production costs.

Table G.1 Summary of conventional farming scenario, CSA practice and the associated impact

CSA package	Conventional farming (CF)	CSA practice at farm-level	Expected impact of CSA compared to CF
Date palms	Open-field vegetables (squash)*	Date palm, using modern irrigation and improved cultural practices	- Increased profitability as date palm is more profitable crop - Higher initial investment cost for date palm
Vegetables	Open-field and old tunnel vegetables (tomatoes and squash)*	Greenhouse vegetables and hydroponics, combined with precision farming	- Increased profitability due to increased yield and price of outputs - Less inputs (fertilizer, water, pesticide) are required - Higher initial investment cost due to greenhouse/hydroponic establishment
Olive	Rainfed olive production	Rainfed olive with micro-water harvesting combined with modern technologies for harvesting	- Increased yield and price of outputs - Reduced labor cost for harvest - Higher initial investment cost due to harvesting technologies
Barley	Rainfed barley with old low productivity variety	Rainfed barley with micro-water harvesting and improved varieties	- Increased yield - Slightly higher investment cost for setting up water harvesting
Small ruminants	Open-grazing	Concentrated farming: on-farm fattening; production and processing by-products	- Increased revenue due to higher quantity and quality of meat and by-products - Higher feeding cost - Higher initial investment cost for fencing, processing and storage
Badia restoration	Severely degraded landscape	Restoration with shrubs and grasses and macro-water harvesting**	- Increased quantity of forages - Reduced soil erosion - High investment cost

*'Squash' and 'squash and tomatoes' were selected as representative for a larger set of vegetables

** landscape level

Adoption rate prediction and profitability at the aggregated, large-scale level

Prediction of adoption rate

We used the Adoption and Diffusion Outcome Prediction Tool (ADOPT) to predict the adoption rate for the targeted beneficiaries. ADOPT is an online Tool that has been developed to predict the probability of adoption and diffusion of an agricultural innovation for a specific target population241 . The Tool consists of twenty-two qualitative questions dividing into four different categories, including:

(i) Relative advantage of the population, referring to whether the advantage that the population could gain from the innovation is sufficient to encourage them to adopt it;
(ii) Learnability characteristics of the innovation, referring to the characteristics of the innovation (e.g. easy or complex) that determine a group's ability to learn about it;
(iii) Learnability of population, referring to the ability to learn the innovation of the targeted population;
(iv) Relative advantage of the innovation, referring to whether the innovation is better than the existing technology.

Because ADOPT tool relies on knowledge from experts to predict the adoption of innovation, we sent ADOPT questions to relevant experts for each package. The answers from experts for each package were then systematized and incorporated into the online ADOPT tool for analysis. The ADOPT tool generates results of adoption rate per year for each package until the year that the adoption rate reaches maximum. The ADOPT results were used to estimate the aggregated economic profitability of CSA packages. Details are illustrated in the following section.

Aggregated economic profitability

The aggregated economic profitability refers to the large-scale economic impact of each CSA package.

The aggregated net present value of economic profitability of a CSA package for commodity given a particular targeted beneficiaries Q_j, denoted NPV_j^{agg}, is calculated by the subtraction of the large-scale investment at time t, denoted I_{jt} for targeted beneficiaries of commodity j and the product of farm-level net incremental benefit of commodity j at time t produced under CSA and conventional farming which is described in equation (1), the adoption rate at time t, K_{jt} and the targeted beneficiaries Q_j. The aggregated NPV of a CSA package can be written as follows:

$$NPV_j^{agg} = \sum_{t=1}^{T} \frac{1}{(1+r)^t} \left[I_{jt} - \left(\sum_{j=1}^{J} p_{jt}.\Delta Y_{jt}^{csa-cf} - \sum_{j=1}^{J} \Delta C_{jt}^{csa-cf}\right).K_{jt}.Q_j \right] \quad (2)$$

The data on large-scale investment was collected via focus group discussion with experts. For each commodity, three to five relevant experts were invited to participate in the (on-line) group discussions. The invited experts come from private sectors such as companies, and public sectors such as ministry of agriculture, and farmers' association etc.

Table G.2 summarizes all components for large-scale investment and targeted beneficiaries of each CSA package.

Table G.2 Components for large-scale investments and targeted beneficiaries of CSA packages

CSA package	Conventional farming (CF)	Expected impact of CSA compared to CF
Date palms	- Total 4 weeks training (during project timeframe) for targeted beneficiaries on date palm cultivation: soil-water nutrients conservation, pest and diseases protection, proper harvesting and other cultural practices - Investing in post-harvest facilities	- 500 farmers - 800 new hectares
Vegetables	- Total 4 weeks training (during project timeframe) for targeted beneficiaries on how to set up/use greenhouse facilities effectively, precision farming, pest control - Investing on vegetables post-harvest (grading and sorting) and storage facilities (cooling units)	- 500 open-field vegetables farmers - 200 conventional low tunnel farmers - 40 open-field vegetables farmers (for hydroponics)
Olive	- Investing on 2 phase decanter olive mills with solar energy system and maintenance - Total 4 weeks training (during project timeframe) for targeted beneficiaries on soil-water nutrients conservation, pest and diseases protection, other agricultural practices - Support farmers on Global GAP certificate registration	- 1000 farmers
Barley	- Total 4 weeks training (during project timeframe) for targeted beneficiaries on water harvesting and precision farming	- 1000 farmers

CSA package	Conventional farming (CF)	Expected impact of CSA compared to CF
Small ruminants	- Total 4 weeks training (during project timeframe) for targeted beneficiaries on fattening through balanced feed/nutrition, production and processing of by-products	- 3 communities, 6000 people (900 farmers)
Badia restoration	- Establishing and maintaining the water harvesting structures - Total 4 weeks training (during project timeframe) for landowners and project staffs on establishing and maintaining the water harvesting catchment - Investing on tractor (Delfino) and contour laser device	- 250 landowners and project staffs (local community) - 5000 hectare

Risk and sensitivity analysis

Climate impact

We estimate the NPV and aggregated NPV of each CSA package under two scenarios: (i) NoCC scenario (baseline), and (ii) CC scenario.

We follow the impact of CC scenario RCP 8.5 on yield of date palm, vegetables, and barley (chapter 4, Table 4.1) to estimate the NPV and aggregated NPV of these packages under CC scenario. According to the IMPACT model under CC scenario RCP 8.5 and business as usual scenario (SSP2), an increase in yield of date palm, vegetables, barley is foreseen in 2050. This increase is explained by several factors, including additional investment, better input prices, use of improved varieties and agronomic practices. Therefore, we assume that the impact of the CC scenario RCP 8.5 on yield reported in Table 4.1 is for commodities that are produced under CSA practice.

The impact of CC on yield of commodities that are produced under conventional/current farming practice is estimated as follows:

$$CC_j^{cf} = CC_j^{csa} . \frac{Y_j^{cf}}{Y_j^{csa}} \quad (3)$$

where CC_j^{cf} and CC_j^{csa} are the impact of CC scenario RCP 8.5 on yield of commodity j produced under conventional farming and CSA; and Y_j^{cf} and Y_j^{csa} are the current yield under NoCC scenario of commodity produced under conventional farming and CSA practice respectively.

The annual impact of CC was then estimated using the following equation:

$$IP_t = \frac{t.IP_T}{T} \quad (4)$$

where IP_t is the CC impact at time t ; IP_T is the CC impact at the end of analysis period and T is analysis period.

Because we did not model the yield of olive and small ruminants under RCP 8.5 using IMPACT, the impact on CC scenario on yield of such commodities were used based on literature and expert interviews. According to Ministry of Environment (2014), the yield of rainfed olive under current farming practice is anticipated to decrease by 10% due to lower water availability when the temperature increases by 2 degree and precipitation decreases by 20%. We assume that with water harvesting and improved farming included in CSA package for olive, the impact of CC on CSA olive yield is predicted to be less than CF olive yield. The impact of CC on olive yield produced under CSA is calculated using equation (3).

For small ruminants, experts' interview indicated that extreme weather leads to 15% yield loss under open-grazing (conventional farming) and 10% loss under concentrated farming (CSA). Due to lack of data availability, we assume that this weather impact on small ruminants indicated by experts is anticipated under CC scenario in 2050.

We did not consider CC scenario for Badia restoration because this package is highly adaptable and resilient with CC.

Table G3 provides the impact of CC scenario on yield of each commodity and the information sources.

Table G.3: Yield impact for conventional farming (CF) and climate-smart agriculture (CSA) under climate change scenario compared to no-climate change scenario

CSA package	Yield change under CC scenario compared to no-CC scenario by 2050 (%)		Sources
	CF	CSA	
Date palm	14.5	20	IMPACT model
Vegetables	(open-field vegetables)	19	IMPACT model
Olive	14.5	-5	Ministry of Environment (2014)
Barley	-10	21	IMPACT model
Small ruminants	7.6	-10	Experts' interview
Badia restoration (shrubs)	-15	NA	Assumption
Badia restoration (shrubs)	NA	NA	Assumption

Discount rate

Another parameter that influences the economic profitability of an agricultural project funded by public investment is the social discount rate. In a cost benefit analysis, the choice of appropriate discount rate is crucial in determining whether or not the project should be implemented. A high social discount rate could result in excluding many socially desirable project while the low one might end up making a lot of economically inefficient investments[243] .

We estimated farm-scale NPV and aggregated NPV of all CSA packages under three different discount rates: 2.5%, 6% and 9%. This value represents the minimum, average and maximum discount rate over the last 10 years in Jordan (retrieved from https://tradingeconomics.com/jordan/interest-rate). The combination of two CC scenarios (NoCC and CC) and three discount rate scenarios results in a total of six values for farm-scale NPV and aggregated NPV for each CSA package.

Output prices

During the focus group discussions, all invited experts emphasized the variability in the price of output products as the result of the recent regional instability. Price of products also varies with seasons. For example, winter crops that are produced in off-season could reach significant higher price than in winter.

Therefore, in this study, we take into account the variability of output price. We set the minimum, most likely and maximum value for the output price of each commodity and run Monte Carlo simulation using Pert distribution (Pert distribution is a smooth version of uniform or triangular distribution that relies on minimum, maximum and most likely (most common) value of a parameter). 1,000 iterations were run to estimate the farm-scale NPV and the aggregated NPV under no-CC and CC scenario and three discount rate scenarios for each CSA package using @Risk. @Risk is an add-in to Microsoft Excel that uses Monte Carlo simulation to analyse project risks and uncertainties. The software was developed by Palisade Company. Table G.4 provides the values (minimum, most likely, maximum) of outputs price and the source of information.

Table G.4 Minimum, most likely and maximum values of outputs price and discount rate used in risks and sensitivity analysis

CSA package / commodity	Price*/Unit	Min	Most likely	Max	Sources
Date	JD/kg	1.50	3.00	4.00	Expert interviews
Tomatoes (conventional)	JD/kg	0.04	0.15	0.30	Experts' interviews
Tomatoes (CSA)	JD/kg	0.16	0.6	1.2	Most likely value (Advance Consulting, 2019); Min and max value assumed to follow price variation of conventional
Squash (conventional)	JD/kg	0.10	0.20	0.56	Experts' interviews
Squash (CSA)	JD/kg	0.20	0.40	1.12	Most likely value (Advance Consulting, 2019); Min and max value assumed to follow price variation of conventional
Olive oil (conventional)	JD/litre	3.75	5.00	5.60	Expert interviews
Olive oil (CSA)	JD/litre	4.30	5.30	5.90	Expert interviews
Table olive (conventional)	JD/kg	0.75	1.00	1.50	Expert interviews
Table olive (CSA)	JD/kg	1.00	1.25	1.75	Expert interviews
Barley grain (conventional and CSA)	JD/kg	0.25	0.30	0.35	Expert interviews
Barley straw (conventional and CSA)	JD/kg	0.10	0.12	0.14	Expert interviews
Small ruminants revenue (conventional)	JD/150 heads	16,941	21,177	25,412	Assumption (min and max =± 20% most likely)
Small ruminants revenue (CSA)	JD/150 heads	25,374	31,178	38,062	Assumption (min and max =± 20% most likely)
Badia restoration	NA	NA	NA	NA	

*1 JD = 1.41 US$ (Dec, 2020)

For Badia restoration package, sensitivity analysis is only performed for the variability of discount rate since this package is not impacted by CC and the price of output products (shrubs in this case) does not vary significantly.

Annex H: Greenhouse gas assessment methodology

In order to get a more comprehensive understanding of the costs and benefits of adopting different climate smart practices in Jordan, a greenhouse gas emissions estimation was employed to gain an understanding on the greater environmental impact adopting these CSA practices may have.

The Greenhouse Gas (GHG) emissions estimation was done using the Ex-Ante Carbon-balance Tool (EX-ACT) developed by the Food and Agriculture Organization of the United Nations (FAO). EX-ACT is an open-source, land-based appraisal system that estimates the amount of GHG emissions certain land uses, agricultural and aquaculture activities, programmes, policies, and development projects may have and expresses it in the form of equivalent tonnes of CO2 per ha (tCO2-eq). In general, the tool aims to provide net carbon balance estimations from a host of different agricultural and aquaculture scenarios across multiple different environments and soil types. The tool aims to provide an estimation of carbon balance due to the adoption of different types of land management and agricultural practices and compares it with the 'business as usual' (BAU) or traditional scenario. The impacts from different agricultural, aquaculture, and forestry developments are calculated simply through the addition of estimated GHG emissions reduction and the amount of carbon sequestered above and below ground and is expressed in tonnes of carbon dioxide emitted per ha or year (tCO2-eq/ha or /year). This methodology is taken largely from the EX-ACT technical guidelines produced by EasyPol for FAO (FAO, 2018)

The majority of data collected on carbon emissions on land-based emissions for EX-ACT are from the Guidelines for National Greenhouse Gas Inventories (IPCC 2006) along with other methodologies to create a basis for default coefficients. The tool's estimates are made using the following categories: Above ground biomass (tonnes of dry matter), below ground biomass (ration R[244] of below-ground biomass to above-ground biomass, tonnes of dry matter), Litter and dead-wood (used for forests, tree crops, and perennials), and soil carbon (Soil organic carbon stocks[245] for minerals soils up to 30 cm depth, in cases of land use change – a default time period of 20 years is used). The default values for carbon stocks for mineral soil under HAC soils in a Tropical Dry environment (used for Jordan) is set at 38 tC ha.[246]

For non-CO_2 GHG emissions such as N_2O and CH_4, an emission factor is used for a specific gas and is based on the activity which emits the gas (methane produced from livestock, emissions from specific fertilizer use). Biomass burning is also considered when specified and is given by the following equation:

$$GHG_{fire} = M_{biomass} \times CF \times C_{ef} \qquad \textbf{eq. 1}$$

Where:

GHG_{fire} = amount of GHG from fire, kg of each GHG (CH_4 or N_2O)
$M_{biomass}$ = mass of fuel available for combustion, tons
C_F = combustion factor
G_{ef} emission factor, g kg^{-1} dry matter burnt

EX-ACT also allows users to set the dynamic of change – that is, how quickly farmers adopt the changes made – moving from the current determined situation to one where the CSA practices By default, the tool is set to a 'linear' setting which is given by the following equation:

$$Total_{linear} = 0.5 \text{ x } (100 \text{ x } 5 \text{ xEF}) \qquad \textbf{eq. 2}$$

Where:

EF = emission factor of GHG, tCO2-eq/ha/year

For the GHG analysis, it was initially planned to interview farmers for each CSA package through a survey. However, due to the COVID-19 pandemic, travel restrictions, and inherent health risks, data was collected through expert interviews for each commodity/sector instead. This is coupled with literature reviews to help build assumptions and validate interview answers.

Table H.1 below summarizes each packages current situation, proposed CSA practice, as well as the expected impact on GHG emissions. Furthermore, due to travel restrictions, survey data results were limited and need to be supplemented with secondary sources and literature review. Some of the key assumptions included in the analysis are presented below:

Table H.1 Summary of conventional and CSA farming practice, associated impacts on GHG emissions, and reference data used from literature.

CSA package	Conventional farming (CF)	CSA practice at farm-level	Expected impact of CSA on GHG emissions	Reference data used from literature
Date palms	Open-field vegetables (squash)*	Date palm, using modern irrigation and improved cultural practices	- Higher carbon sequestration by switching from vegetables.	- GHG Emissions from drip irrigation for change in irrigation system
Vegetables	Open-field and old tunnel vegetables (tomatoes and squash)*	Greenhouse vegetables and hydroponics, combined with precision farming	- Lower water and energy requirements - Use of renewable energy for cold storage	- Energy consumption of vegetable cold storage and processing - Emissions from hydroponic farms in comparison with conventional practices
Olives	Rain-fed olive production	Rainfed olive with micro-water harvesting combined with modern technologies for harvesting	- Larger areas planted to olive leads to larger biomass for carbon sequestration.	- Irrigation requirements of olive plantations to estimate hectarage of irrigation - Energy consumption and efficiency of olive mills - Data on olive oil sector, number mills, and amount of olive oil produced in Jordan - Olive sector production data
Barley	Rain-fed barley with old low productivity variety	Rainfed barley with micro-water harvesting and improved variety	- Land use change leads to larger carbon sequestration from barely production	- Similarities in the GHG emissions of goat and sheep per kilogram of meat produced.
Small ruminants	Open-grazing	Concentrated farming: on-farm fattening; production and processing by-products	- Improved carbon sequestration from biomass and soil due reduction of overgrazing pastures. Offsets GHG emissions from livestock production	- The area covered and fuel consumption of Vallerani Machines used in water-catchment development
Badia restoration	Severely degraded landscape	Restoration with shrubs and grasses and macro-water harvesting**	- Carbon sequestration from revitalizing degraded land.	- GHG Emissions from drip irrigation for change in irrigation system

Annex I: Experts consulted during the study

The following experts were either involved in expert panels for the prioritization of CSA packages per agroecological zone, in group/stakeholder interviews for further elaboration of each investment package, or were consulted for their expertise during the CBA/GHG mitigation assessment. Respondent to the on-line survey are not included in the list.

#	Name	Title
1.	Abdullah Al-Musa	Director General. Islamic World Academy of Sciences. Islamic World Academy of Sciences
2.	Abeer Saqer	Extension Sector Extension programs Department. Ministry of Agriculture. Ministry of Agriculture (MoA)
3.	Abir AlBalawnah	Director of Environment and Climate Change Directorate & Expert researcher
4.	Adel Y. Alobeiaat	National Agricultural Research Center (NARC)
5.	Ahed Mohammad Alqdah	Marketing sector Head of Marketing Facilities and Post-Harvest Techniques Division. Ministry of Agriculture (MoA)
6.	Ahmed Olwan	Director of Dair Allah Research Station National Agriculture Research Center (NARC)
7.	Amer Al-Ghorbany	Environmental Specialist (Environmental safeguards). World Bank
8.	Amer Jabareen	Economist – Agribusiness
9.	Anwra Haddad	Chairman Jordan Dates Association (JODA)
10.	Awni Taimeh	Land, Water, and Environment Specialist University of Jordan
11.	Ayman Salti	Marketing sector Secretary General Assistant. Ministry of Agriculture (MoA)
12.	Bassam Snobar	University of Jordan
13.	Bilal Shagareen	Director of Climate Change Directorate Ministry of Environment (MoEnv)
14.	Blair Edward Lapres	Economist. World Bank
15.	Buthaina Batarseh	Water and Environmental Management Ministry of environment (MoEnv)
16.	Dorte Verner	Lead Agricultural Economist. World Bank
17.	Emiliano Duch	Lead Private Sector Specialist. World Bank
18.	Faisal Awawdeh	Animal production specialist Former director of the National Agricultural Research Center (NARC)
19.	Fayyad Zyoud	Private sector
20.	Feda Garadat	Head of Projects Department Ministry of Planning and International Cooperation (MOPIC)
21.	Feras Al -Momani	Ministry of Planning and International Cooperation (MoPIC)
22.	Firas Gnaidi	Jordan Dates Association (JODA)
23.	Ghassan Hamdallah	External EX FAO Sr. Land &Water Officer Soil specialist
24.	Haitham Hamdan	National Agriculture Research Center (NARC)

25.	Hani M. Alhareshah	Ministry of Water and Irrigation (MoWI)
26.	Hassan Abu Sido	Private sector
27.	Hazim Smadi	Director of Agreements and International Cooperation Directorate Ministry of Agriculture (MoA)
28.	Hisham Al-Hisa	Ministry of Water and Irrigation (MoWI)
29.	Ibrahim Alamad	Olive and olive oil Expert National Agriculture Research Center (NARC)
30.	Ibrahim Hamdan	National Agriculture Research Center (NARC)
31.	Ibrahim Mbaidin	Ministry of Planning and International Cooperation (MoPIC)
32.	Ismail Edwan	Extension Sector Training & Farmers Awareness Department. Ministry of Agriculture (MoA)
33.	Jaafar Al Widyan	Head of Ecosystems Research Department Environment and Climate Change Directorate National Agriculture Research Center (NARC)
34.	Jamal R.Qasem	Landscape specialist. University of Jordan
35.	Khaled Abulaila	Botanist, Conservation Biologist Director/Directorate of Plant Diversity National Agriculture Research Center (NARC)
36.	Khalil Y. Alabsi	Ministry of Water and Irrigation (MoWI)
37.	Luna Hadidi	Researcher. National Agriculture Research Center (NARC)
38.	Mahmoud AlRbie	Director of Studies and Development of Production Chains Directorate Ministry of Agriculture (MoA)
39.	Mahmoud Duwairi	Former Minister Ministry of Agriculture (MoA)
40.	Mahmoud Freihat	Director of the Lands and Irrigation Directorate Ministry of Agriculture (MoA)
41.	Manar Abu Haziem	Head of Mitigation Division Ministry of Environment (MoEnv)
42.	Marwan Suaifan	Badia Restoration Project Ministry of Environment (MoEnv)
43.	Maysoon Hazeem AL amro	Plant wealth. Ministry of Agriculture. Ministry of Agriculture (MoA)
44.	Meriem Ait Ali Slimane	Senior Private Sector Specialist. World Bank
45.	Mohammad al Shibli	Studies and Development of Production Chains Directorate Head of Climate change Division. Ministry of Agriculture (MoA)
46.	Mohammed m. Ershaid	Ministry of Water and Irrigation (MoWI)
47.	Muhammad Nsoor	Natural Resources Manager watershed development initiative National Agriculture Research Center (NARC)
48.	Muhammad Shahbaz	Regional Vice-Chair for West Asia, Commission on Environment, Economic and Social Policy CEESP – IUCN and Director General of the Royal Botanic Garden of Jordan
49.	Mustafa Shudiefat	Director of Programs Royal Botanic Garden of Jordan
50.	Nabeel Arrar	Jordan Dates Association (JODA)
51.	Nada AlFrihat	Head of Organizations Division Ministry of Agriculture (MoA)
52.	Naem Mazahreh	Director General Assistant for Research Irrigation Water and Environment Management National Agriculture Research Center (NARC)
53.	Narmeen Qatatsheh	Extension Sector Training & Farmers Awareness Department. Ministry of Agriculture (MoA)
54.	Nidal Samain	Private sector

55.	Nizar Haddad	Director General National Agriculture Research Center (NARC)
56.	Oqab Awamleh	National Agriculture Research Center (NARC)
57.	Osama Qattan	Plant wealth. Ministry of Agriculture (MoA)
58.	Ra'ed Daoud	Director of Eco Consult
59.	Salam Ayoub	National Agriculture Research Center (NARC)
60.	Salem Nino	Jordan Dates Association (JODA)
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PRODUCTIVITY RESILIENCE LOWER EMISSIONS

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