TECHNICAL REPORT

Towards the Sustainable and Low-Carbon Development of Oasis Landscapes in Tunisia

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About this report

This report was prepared to inform green recovery, growth, resilience, and job creation in the oasis landscapes of southern Tunisia, based on the commitments and actions defined in the country's updated Nationally Determined Contribution (NDC).

It provides strategic guidance to support the Government of Tunisia in furthering the sustainable development of oasis landscapes in southern Tunisia by providing a broad overview of the oasis landscapes in southern Tunisia; estimating the greenhouse gas (GHG) emissions from current management practices in oasis landscapes; and identifying opportunities for GHG mitigation and job creation from more sustainable development of oases in southern Tunisia. Various development pathways and their implications for sustainable oasis landscape management are explored through scenario analyses. The report makes practical recommendations and includes a preliminary action plan with a list of likely investments to pursue.

This report is a key deliverable of a World Bank Advisory Services and Analytics program called "Nature-based Solutions for Recovery and Sustainable Development of the Oasis and Ecotourism Sectors in the Maghreb". It is also intended to inform discussions between the World Bank and the Government of Tunisia on the shape of future World Bank activities, including investment and analytical work.

Various sources were consulted in drafting this report, including academic research, government reports, and industry data. These were complemented by interviews with experts in the field and consultations with various stakeholders including government agencies, academia, NGOs, and farmers' associations, namely Groupements de Développement Agricole (GDAs, agricultural development groups), Sociétés Mutuelles des Services Agricoles (SMSAs, mutual agricultural service organizations), and Groupements d'Interet Economique (GIE, economic interest groups). In addition, a series of stakeholder consultations and regional workshops was held to gather different perspectives, views, and information in January and February 2023. To validate and promote the results of this report's deep dive analyses, a national stakeholder validation workshop was held on July 12, 2023, and a dissemination event was held on July 13, 2023 in the presence of the Minister of Environment at the time.

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Abbreviations and acronyms

AFOLU	Agriculture, forestry, and other land uses
APIA	*Agence de Promotion des Investissements Agricoles* (Agricultural Investment Promotion Agency)
AVFA	*Agence de la Vulgarisation et Des Formations Agricoles* (Agricultural Training and Extension Agency)
CRDA	*Commissariat Régional de Développement Agricole* (Regional Agricultural Development Commission)
DGACTA	*Direction Générale de l'Aménagement et de la Conservation des Terres Agricoles* (General Directorate for Agricultural Land Planning and Conservation)
DGBGTH	*Direction Générale des Barrages et Des Grands Travaux Hydrauliques* (General Directorate for Dams and Major Water Works)
DGEDA	*Direction Générale des Etudes et du Développement Agricole* (General Directorate of Agricultural Studies and Development)
DGF	*Direction Générale des Forêts* (General Directorate of Forests)
DGFIOP	*Direction Générale du Financement des Investissements et des Organismes Professionnels* (General Directorate for Financing Investments and Professional Organizations)
DGPCQPA	*Direction Générale de la Protection et du Contrôle de la Qualité des Produits Agricoles* (General Directorate for Protection and Quality Control of agricultural products)
DGRE	*Direction Générale des Ressources en Eau* (General Directorate of Water Resources)
DGPA	*Direction Générale de la Production Agricole* (General Directorate for Agricultural Production)
DGPGTH	*Direction Générale des Barrages et des Grands Travaux Hydrauliques* (General Directorate of Dams and Major Hydro Works)
FTE	Full-time equivalent
GDA	*Groupement de Développement Agricole* (Agricultural development group)
GID	*Groupement Interprofessionnel des dattes* (Interprofessional Date Producers Group)
GHG	Greenhouse gases
GIE	*Groupement d'Intérêt Economique* (Economic interest group)
Ha	Hectare
IRA	*Institut des Régions Arides* (Arid Regions Institute)

IRESA	*Institution de la recherche et de l'enseignement supérieur agricoles* (Agricultural Research and Higher Education Institute)
IRR	Internal rate of return
ktCO$_2$e	Kilotons of carbon dioxide equivalent
MtCO$_2$e	Million tons of carbon dioxide equivalent
MARHP	*Ministère de l'Agriculture, des Ressources Hydrauliques et de la Pêche* (Ministry of Agriculture, Water Resources, and Fisheries)
ME	*Ministère de l'Environnement* (Ministry of Environment)
MW	Megawatt
NDC	Nationally Determined Contribution
ODESYPANO	*Office de Développement Sylvo- Pastoral du Nord-Ouest* (North West Forestry and Pastoral Development Office)
ODRM	*Office de Développement de Rjim Maâtoug* (Rijm Maâtoug Development Office)
OEP	*Office de l'Elevage et des Pâturages* (Livestock and Pasture Office)
PDAI	*Projet de Développement Agricole Intégré* (Integrated Agricultural Development Project)
PPI	*Périmètres publics irrigués* (Public irrigation area)
SDG	Sustainable Development Goal
SMSA	*Société Mutuelle de Services Agricoles* (Mutual agricultural service organization)
SNCC	*Stratégie Nationale sur le Changement Climatique* (National Climate Change Strategy)
SPANB	*Stratégies et Plans d'Actions Nationaux pour la Biodiversité* (National Plan and Strategy for Biodiversity)
SPAN-LCD	*Stratégies et Plans d'Actions Nationaux pour la Lutte contre la Désertification* (National Plan and Strategy to Combat Desertification)
SOC	Soil organic carbon
TD	Tunisian dinar
tCO$_2$e	Tons of carbon dioxide equivalent
UNFCCC	United Nations Framework Convention on Climate Change

Executive Summary

Taking clear, decisive action to protect the health and productivity of oasis ecosystems in southern Tunisia would both improve resilience against climate threats—especially drought, excessive heat, and water scarcity—and create jobs in the agriculture, energy, waste, tourism, and culture sectors.

The four oasis governorates of southern Tunisia are home to more than a million people and have become increasingly vulnerable to the effects of climate change, with long, dry, and extremely hot seasons affecting the yield and quality of dates and other crops. The effects of climate change and poor land and water management, particularly in the Kébili region, have led to the overexploitation of groundwater. These oasis landscapes or ecosystems include 267 oases, consisting of 126 traditional oases[1] and 141 modern oases[2] or date palm plantations, with a continuously increasing surface area based on groundwater exploitation. The total area has increased from 17,500 hectares (ha) in 1992 to 33,000 ha in 2008, and 51,600 ha of productive palm grove in 2024 (MARHP, 2025).

In total, the oasis economy employs about 60,000 direct and indirect farmers in Tunisia.

Date production plays an important role in the economy of oasis communities. Dates are Tunisia's second-most important agricultural export commodity, contributing TD 717.7 million (US$232.3 million) to the economy in the 2023/24 season. Oasis agriculture is at the heart of southern Tunisia's development. At the same time, much of this development has relied on agricultural and water-management policies and practices that, while effective in the short term, may not support long-term sustainability. Representing 12 percent of agricultural land irrigated, oasis agriculture accounts for 19.4 percent of the value of production in irrigated areas and 6.8 percent of the total value of agricultural production.

1 Ancient oases characterized by a multilayered intercropping system comprising date palms, fruit trees, a shrub layer, and a herbaceous crop plantation (vegetables, legumes, fodder, medicinal and aromatic plants).

2 Modern oases are created to produce a monoculture of date palms (Deglet Nour variety). These are palm plantations.

Nowadays, oasis agriculture depends heavily on groundwater. Uncontrolled drillings have increased from 4,686 in 2016 to 21,279 in 2021, with an average drawdown of three to five meters of deep groundwater per year. This overexploitation is contributing to increased water stress, soil salinization, loss of biodiversity, and abandonment of agricultural activity in some sectors (especially in the traditional oases) while threatening oasis ecosystems and the economy at large. Without a robust intervention approach combined with voluntary action to conserve oasis ecosystems and landscapes these unique environments could face serious challenges, with potentially significant economic impacts.

A lack of adequate action to address land degradation, enable sustainable land and groundwater governance, and provide economic opportunities is contributing to the accelerated degradation and increased climate vulnerability of oasis landscapes and surrounding rangelands. This has already been observed in the oasis of El Hamma in the governorate of Gabès, as well as in Gabès itself, the only coastal oasis in the Mediterranean. Climate change is expected to exacerbate land degradation and water scarcity. According to various climate change models, Tunisia will experience an increase in average annual temperature of between 1.6°C and 1.9°C by 2050, with inland areas warming faster than coastal areas. Precipitation is expected to decrease by between 6 percent and 9 percent across the country, with significant spatial variations. This trend towards aridification will drive an increase in extreme events such as droughts, heat waves, and floods.

Oases play a significant role in Tunisia's updated Nationally Determined Contribution (NDC) under the Paris Agreement. Their sustainable development and rehabilitation would create significant opportunities for livelihoods, economic development, climate resilience, environmental preservation, and the conservation of cultural heritage. Stakeholders at all levels are aware of the urgent need to secure these ecosystems, with many initiatives—especially youth-driven ones—emerging to protect, rehabilitate, and promote the sustainable economic development of oasis landscapes. Previous projects focusing on oases have highlighted that participatory and inclusive governance is essential for the sustainability of these landscapes.

Departing from the updated Nationally Determined Contribution (NDC) Tunisia defined in 2021, different adaptation and mitigation options relevant for traditional and modern oases were identified. These options would reduce greenhouse gas (GHG) emissions, create green jobs, and have other co-benefits for oasis landscapes through improving ecosystem services such as carbon sequestration, water retention, increased yield, fodder production, natural and cultural heritage, and local biodiversity conservation. These options were assessed in terms of their feasibility (that is, how familiar oasis communities are with proposed adaptation options), their mitigation or GHG reduction potential, and their potential for creating green jobs (Table 1).

Table 1: *Greenhouse gas mitigation and job creation potential of different adaptation options as defined in the updated Nationally Determined Contribution*

Consolidated Adaptation Options Sub-options	Potential Impact		Benefit/ cost ratio
	Mitigation (in tCO_2e*)	Jobs (Unit: FTE† or WD‡)	
1. Integrated and participatory development of collective rangelands	1.3 tCO_2e/ha/year	14 FTE/1,000 ha	1.18
2. Multilayered cultivation	87.6 tCO_2e/ha (after 20 years)	75 to 100 WD/ha	1.65
3. Adoption and dissemination of sustainable land and water management practices			
3.1. Strengthening irrigation water management			
3.1.1 Traditional oases (18,586 ha)	0.44 tCO_2e/ha		1.51
3.1.2 Modern oases (39,098 ha)	Negligible potential	67 WD/ha	1.65
3.2. Hedgerows[3]	5.86 tCO_2e/ha	3 WD/ha	1.27
3.3. Organic farming	1.6 tCO_2e/ha/year	10 WD/ha/year	2.13
3.4. Soil amendment by biochar	3.66 tCO_2e/ton used	0.25 WD/ton	2.65
4. Valorization of byproducts			
4.1. Compost production	Low/limited potential	94 FTE for 450 ha of oasis as part of the creation of a company	Additional studies
4.2. Livestock feed manufacturing	Negligible potential		
4.3. Renewal of old palm trees	Low/limited potential		1.08
4.4. Mechanized agricultural service units	Negligible potential		
4.5. Biochar production (IRR: 38%§)	2.86 tCO_2e/t		

3 One hectare (ha) corresponds to 66,667 plants of vetiver.

Table 1: *Greenhouse gas mitigation and job creation potential of different adaptation options as defined in the updated Nationally Determined Contribution* (continued)

Consolidated Adaptation Options Sub-options	**Potential Impact**		**Benefit/ cost ratio**
	Mitigation (in tCO_2e*)	**Jobs (Unit: FTE† or WD‡)**	
5. Recovery and reuse of treated wastewater			
5.1 Olive tree planting (⅔) and fruit growing (⅓)	6.26 tCO_2e/ha/year (over 20 years)	117 WD/ha	2.2
5.2 Public irrigated perimeter and oasis rehabilitation	Negligible potential	67 WD/ha	1.7
6. Recovery and reuse of drainage water	Low/limited potential	Low/limited potential	Additional studies required
7. Widespread use of solar electricity			
7.1. Pumping stations	0.99 tCO_2e/ha/year	8.5 to 17.5 FTE/MW	0.7
7.2. Cold storage for dates	0.144 tCO_2e/Tc¶	Negligible potential	1.2
8. Optimization of oasis farm management	Low/limited potential	1 FTE/600 ha	
9. Valorization of Natural and Cultural assets			
9.1. Oasis cottages, agritourism	Low/limited potential	Average potential	Additional studies required
9.2. Development of ecotourism circuits	Low/limited potential	Average potential	
* Tons of carbon dioxide equivalent † Full-time equivalent job ‡ Work day	§ Rate at which biochar is generated from wood waste ¶ Tons of cold storage capacity of dates		

Different socioeconomic and political scenarios—the Trend Scenario and the Proactive Scenario—were then considered to extrapolate the potential for mitigation and green jobs creation across oases in southern Tunisia:

- **The Trend Scenario** is a conservative scenario based on a projection of trends observed over recent decades relating to the political and socioeconomic context, which have been characterized by slow changes, limited implementation capacities, low financing, and so on.

- **The Proactive Scenario** is based on the favorable evolution of the political and socioeconomic context in terms of policy reforms and the decentralization of processes, as well as the intensive adoption of sustainable farming practices such as multilayer cultivation, organic farming and mulching, and the recovery and reuse of drainage water and treated wastewater.The study estimates that under a Proactive Scenario, these adaptation options could **generate up to TD 6.95 billion** (US$2.25 billion)[4] in additional income, **creating approximately 33,500 additional jobs** and **reducing emissions by 22.5 million tons of CO_2 equivalent (tCO_2e) by 2050** (Table 2).

4 Based on the exchange rate of March 10, 2025.

Table 2: *Impacts of the Trend and Proactive scenarios*

Scenarios	Impacts						Investment (TD million)	Additional income (TD million)
	2030		2040		2045 or 2050			
	Mitigation ($ktCO_2e$*)	Jobs (FTE†)	Mitigation ($ktCO_2e$)	Jobs (FTE)	Mitigation ($ktCO_2e$)	Jobs (FTE)		
1. Trend Scenario	2,758	5,373	9,129	7,398	13,108	15,013	3,194	4,400
2. Proactive Scenario	5,700	9,453	15,379	16,081	22,481	33,489	5,056	6,949

* Kilotons of carbon dioxide equivalent
† Full-time equivalent job

In this context, decision-makers need to redefine governance and development for oasis landscapes in line with the updated NDC, the Sustainable Development Goals (SDG), and Tunisia's socioeconomic development priorities. This requires all stakeholders to be unified under a vision that regards oasis landscapes as the anchor of any development policy in southern Tunisia. Such a vision should, while keeping with the National Strategy and Action Plan for the Sustainable Development of Oases in Tunisia adopted in 2015 and other national and sectoral development priorities, advocate for and support the implementation of an inclusive local development approach that integrates the heritage dimension with the multifunctionality of oasis ecosystems. Oasis development in southern Tunisia should aim for inclusive, community-driven development that strengthens the green economy and creates jobs. It should focus primarily on:

- Better governance with rationalizing and optimizing the use of natural resources, especially groundwater
- Restoring and preserving oasis landscapes and ecosystems
- Valorizing goods and services provided by ecosystems for the well-being of populations and actors in the various related sectors.

Lessons learned from earlier projects that sought to support Tunisia's oasis landscapes point to the need to support producer organizations and local authorities in formulating and implementing site-specific **Integrated Development Plans for Oasis Landscapes Governance** that include actions for the sustainable management of natural resources in specific oasis landscapes. The development of these plans will require the convergence of sectoral strategies and a synergy between the interventions and investments of the actors concerned (including the public sector, the private sector, associations, local organizations, local authorities, and technical and financial partners). This study recommends establishing an operational framework to support oasis communities in preparing and implementing their Integrated Development Plan for Oasis Landscapes Governance. This landscape governance plan will guide stakeholders in preparing and implementing future initiatives.

In addition to establishing this operational framework, this study also proposes several policy recommendations to facilitate the transition of oasis landscapes towards sustainable, low-carbon development that maximizes opportunities for green jobs creation:

Strengthen the institutional framework for oasis development to facilitate coordination of the various interventions.

Strengthen the practices and policies enabling the sustainable management of oasis landscapes, notably with regard to optimizing the sustainable use of (ground) water resources. This includes a sound understanding of the benefits and costs of groundwater, and a decision-making framework that enables sustainable management and governance of groundwater.

Review and enhance the regulatory framework for oasis landscapes and adapt the investment code and the urban planning and regional development code to the oasis context of southern Tunisia.

Update strategies that promote the sustainable management of oasis landscapes, capitalizing upon the National Strategy and Action Plan for the Sustainable Development of Oases in Tunisia and other related strategies, and consider creating a UNESCO biosphere reserve that includes traditional oasis landscapes.

Capitalize existing initiatives with successful governance models that can promote and enable the sustainable development of oases and foster innovation for oasis agriculture.

Strengthen professional organizations of oasis producers and local governance structures and involve youth and women in exploring green job creation potential.

Without bold, voluntary action, oasis ecosystems will be at risk of eventually degrading in the medium to long term.

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Résumé exécutif

Prendre des mesures claires et décisives pour protéger la santé et la productivité des écosystèmes oasiens du sud de la Tunisie permettrait à la fois d'améliorer la résilience face aux menaces climatiques—notamment la sécheresse, les chaleurs excessives et la pénurie d'eau—et de créer des emplois verts dans les secteurs de l'agriculture, de l'énergie, des déchets, du tourisme et de la culture.

Les quatre gouvernorats oasiens du sud de la Tunisie abritent plus d'un million d'habitants et sont devenus de plus en plus vulnérables aux effets du changement climatique, les saisons longues, sèches et extrêmement chaudes affectant le rendement et la qualité des dattes et d'autres cultures.

Les effets du changement climatique et de la gestion peu durable des terres et de l'eau, en particulier dans la région de Kébili, ont conduit à la surexploitation des eaux souterraines. Ces paysages ou écosystèmes oasiens comprennent 267 oasis, dont 126 oasis traditionnelles[1] et 141 oasis[2] modernes ou plantations de palmiers dattiers, avec une superficie en constante augmentation basée sur l'exploitation des eaux souterraines. La superficie totale est passée de 17 500 hectares (ha) en 1992 à 33 000 ha en 2008 et 51 600 ha de palmeraies productifs en 2024 (MARHP, 2025). Au total, l'économie des oasis emploie directement et indirectement environ 60 000 agriculteurs en Tunisie.

La production de dattes joue un rôle important dans l'économie des communautés oasiennes. Les dattes sont le deuxième produit d'exportation agricole de la Tunisie; 717,7 million DT (US$232.3 million) durant la saison 2023/2024. L'agriculture des oasis est au cœur du développement du sud de la Tunisie. Toutefois, dans de nombreux cas, ce développement a été motivé par des politiques et des pratiques non durables en matière d'agriculture et surtout de gestion de l'eau. Représentant 12 % des terres agricoles irriguées, l'agriculture oasienne représente 19,4 % de la valeur de la production dans les zones irriguées et 6,8 % de la valeur totale de la production agricole.

De nos jours, l'agriculture oasienne dépend fortement des eaux souterraines. Les forages non contrôlés sont passés de 4 686 en 2016 à 21 279 en 2021, avec un prélèvement moyen de trois à cinq mètres de profondeur par an. Cette surexploitation contribue à l'augmentation du stress hydrique, à la salinisation des sols, à l'appauvrissement de la biodiversité et à l'abandon de l'activité agricole dans certains secteurs (en particulier dans les oasis traditionnelles) tout en menaçant les écosystèmes des oasis et l'économie en général. En l'absence d'une approche d'intervention robuste combinée à une action volontaire pour conserver les écosystèmes et les paysages des oasis, ces environnements uniques pourraient être confrontés à de sérieux défis, avec des conséquences économiques potentiellement importantes.

L'absence de mesures adéquates permettant de lutter contre la dégradation des sols, d'assurer la gouvernance durable des terres et des eaux souterraines fossiles et d'offrir des opportunités économiques et d'emplois, autres qu'agricoles, risque d'accélérer la dégradation et d'accroître la vulnérabilité climatique des paysages oasiens et des parcours environnants. Cela a déjà été observé dans l'oasis d'El Hamma dans le gouvernorat de Gabès ainsi qu'à Gabès même, unique oasis littorale de la Méditerranée. Le changement climatique devrait accentuer la dégradation des sols et la pénurie d'eau. Selon divers modèles de changement climatique, la Tunisie connaîtra une augmentation de la température annuelle moyenne comprise entre 1,6 et 1,9 °C d'ici 2050, les zones intérieures se réchauffant plus rapidement que les zones côtières. Les précipitations devraient diminuer de 6 à 9 % dans l'ensemble du pays, avec d'importantes variations spatiales. Cette tendance à l'aridification entraînera une augmentation des événements extrêmes tels que les sécheresses, les vagues de chaleur et les inondations.

1 Oasis anciennes caractérisées par un système de cultures intercalaires, dites à trois étages, à plusieurs niveaux comprenant des palmiers dattiers, des arbres fruitiers, une strate arbustive et une plantation de cultures herbacées (légumes, légumineuses, fourrage, plantes médicinales et aromatiques).

2 Les oasis modernes sont des monocultures de palmiers dattiers (variété Deglet Nour) créées. Il s'agit de palmeraies ou de plantations de palmiers.

Les oasis jouent un rôle important dans la mise à jour de la contribution déterminée au niveau national (CDN) de la Tunisie au titre de l'Accord de Paris. Leur développement et leur réhabilitation durables créeraient d'importantes opportunités pour les moyens de subsistance, le développement économique, la résilience climatique, la préservation de l'environnement et la conservation du patrimoine naturel et culturel. Les parties prenantes à tous les niveaux sont conscientes de la nécessité urgente de protéger ces écosystèmes, et de nombreuses initiatives, en particulier celles menées par les jeunes, voient le jour pour protéger, réhabiliter et promouvoir le développement économique durable des paysages oasiens. Des projets antérieurs consacrés aux oasis ont mis en évidence l'importance d'une gouvernance participative et inclusive pour la viabilité de ces paysages.

S'appuyant sur les contributions déterminées au niveau national (CDN) de la Tunisie définies en 2021, différentes options d'adaptation et d'atténuation pertinentes pour les oasis traditionnelles et modernes ont été identifiées. Ces options permettraient de réduire les émissions de gaz à effet de serre (GES), de créer des emplois verts et d'avoir d'autres avantages connexes pour les paysages des oasis grâce à l'amélioration des services écosystémiques tels que la séquestration de carbone, la rétention de l'eau, l'augmentation des rendements, la production de fourrage, la protection du patrimoine culturel et la conservation de la biodiversité locale. Ces options ont été évaluées du point de vue de leur faisabilité (c'est-à-dire la mesure dans laquelle les communautés oasiennes connaissent bien les options d'adaptation proposées), de leur potentiel d'atténuation ou de réduction des émissions de GES, et de leur potentiel de création d'emplois verts (tableau 1).

Table 1: *Réduction des émissions de gaz à effet de serre et potentiel de création d'emplois des différentes options d'adaptation, telles que définies dans la Contribution déterminée au niveau national actualisée*

Options d'adaptation consolidées Sous-options	**Impact potentiel**		**Rapport coût/ bénéfice**
	Atténuation (en tCO_2e*)	**Emplois (unité: ETP† ou JT‡)**	
1. Aménagement intégré et participatif des parcours collectifs	1.3 tCO_2e/ha/an	14 ETP/1 000 ha	1.18
2. Culture pluri-étagées	87.6 tCO_2e/ha (après 20 ans)	75 à 100 JT/ha	1.65
3. Adoption et diffusion de pratiques durables de gestion des terres et de l'eau			
3.1. Renforcement de la gestion de l'eau d'irrigation			
3.1.1 Oasis traditionnelles (18 586 ha)	0.44 tCO_2e/ha		1.51
3.1.2 Oasis modernes (39 098 ha)	Potentiel négligeable	67 JT/ha	1.65
3.2. Haies vives[3]	5.86 tCO_2e/ha	3 JT/ha	1.27
3.3. Agriculture biologique	1.6 tCO_2e/ha/an	10 JT/ha/an	2.13
3.4. Amendement des sols par le biochar	3.66 tCO_2e/tonne	0,25 JT/tonne	2.65
4. Valorisation des sous-produits			
4.1. Production de compost	Potentiel faible/ limité	94 ETP pour 450 ha d'oasis dans le cadre de la création d'une société	Études complémentaires requises
4.2. Fabrication d'aliments pour bétail	Potentiel négligeable		
4.3. Renouvellement des vieux palmiers	Potentiel faible/ limité		1.08
4.4. Unités mécanisées de services agricoles	Potentiel négligeable		
4.5. Production de biochar (TRI : 38%§)	2.86 tCO_2e/t		

3 Bocage des parcelles avec des haies vives ; un hectare (ha) correspondant à 66 667 plants de vétiver.

Table 1: *Réduction des émissions de gaz à effet de serre et potentiel de création d'emplois des différentes options d'adaptation, telles que définies dans la Contribution déterminée au niveau national actualisée*

Options d'adaptation consolidées Sous-options	Impact potentiel		Rapport coût/ bénéfice
	Atténuation (en tCO_2e*)	Emplois (unité: ETP† ou JT‡)	
5. Récupération et réutilisation des eaux usées traitées			
5.1 Plantation d'oliviers (2/3) et arboriculture fruitière (1/3)	6.26 tCO_2e/ha/an (sur 20 ans)	117 JT/ha	2.2
5.2 Réhabilitation des périmètres publics irrigués et des oasis	Potentiel négligeable	67 JT/ha	1.7
6. Récupération et réutilisation des eaux de drainage	Potentiel faible/ limité	Potentiel faible/ limité	Études complémentaires requises
7. Généralisation de l'électricité solaire			
7.1. Stations de pompage	0.99 tCO_2e/ha/an	8.5 à 17.5 ETP/MW	0.7
7.2. Entreposage frigorifique des dattes	0.144 tCO_2e/Tc¶	Potentiel	1.2
8. Optimisation de la gestion des exploitations oasiennes	Potentiel faible/ limité	1 ETP/600 ha	
9. Valorisation du patrimoine naturel et culturel			
9.1. Gîtes oasiens, agritourisme	Potentiel faible/ limité	Potentiel moyen	Études complémentaires requises
9.2. Développement des circuits (éco)touristiques	Potentiel faible/ limité	Potentiel moyen	
* Tonnes d'équivalent dioxyde de carbone † Emploi équivalent temps plein ‡ Journée de travail	§ Taux de production de biochar à partir de déchets de bois ¶ Tonnes de capacité de stockage frigorifique de dattes		

Différents scénarios socioéconomiques et politiques – le scénario tendanciel et le scénario proactif – ont ensuite été examinés pour extrapoler le potentiel d'atténuation et de création d'emplois verts dans les oasis du sud de la Tunisie :

- **Le scénario tendanciel** est un scénario conservateur basé sur une projection des tendances observées au cours des dernières décennies du contexte politique et socioéconomique caractérisé par des changements lents, des capacités de mise en oeuvre et des financements limités, etc.

- **Le scénario proactif** repose sur l'évolution favorable du contexte politique et socio-économique en termes de réformes politiques et de décentralisation des processus, ainsi que sur l'adoption intensive de pratiques agricoles durables telles que la culture pluri-étagée, l'agriculture biologique et le paillage, la récupération et la réutilisation des eaux de drainage et des eaux usées traitées. L'étude estime que, dans le cadre d'un scénario proactif, ces options d'adaptation pourraient **générer jusqu'à 6,95 milliards de dinars tunisiens** (2,25 milliards de dollars)[4] de revenus supplémentaires, **créant environ 33 500 emplois supplémentaires** et r**éduisant les émissions de 22,5 millions de tonnes d'équivalent CO2 (tCO_2e) d'ici à 2050** (tableau 2).

4 Sur la base du taux de change en vigueur le 10 mars 2025.

Table 2: *Impacts des scénarios tendanciel et proactif*

Scénarios	Impacts						Investissement (en millions de dinars)	Revenu additionnel (en millions de dinars)
	2030		2040		2045 ou 2050			
	Réduction des émissions ($ktCO_2e$*)	Emplois (ETP†)	Réduction des émissions ($ktCO_2e$)	Emplois (ETP)	Réduction des émissions ($ktCO_2e$)	Emplois (ETP)		
1. Scénario tendanciel	2,758	5,373	9,129	7,398	13,108	15,013	3,194	4,400
2. Scénario proactif	5,700	9,453	15,379	16,081	22,481	33,489	5,056	6,949

* Kilotonnes d'équivalent dioxyde de carbone
† Equivalent temps plein

Dans ce contexte, il conviendrait que les décideurs repensent la gouvernance et le développement des paysages oasiens conformément à la CDN actualisée, aux objectifs de développement durable (ODD) et aux priorités de développement socioéconomique de la Tunisie. Cela nécessite que toutes les parties prenantes soient unifiées autour d'une vision qui considère les paysages oasiens comme le point d'ancrage de toute politique de développement dans le sud de la Tunisie. Une telle vision devrait, tout en s'inscrivant dans Stratégie et plan d'action de développement durable des oasis en Tunisie adoptée en 2015 et les autres priorités nationales et sectorielles de développement, plaider et soutenir la mise en œuvre d'une approche de développement local inclusif intégrant la dimension patrimoniale à la multifonctionnalité des écosystèmes oasiens. Le développement des oasis dans le sud tunisien devrait viser un développement inclusif et impulsé par les communautés, renforçant ainsi l'économie verte et la création d'emplois et reposant sur :

- une meilleure gouvernance grâce à la rationalisation et à l'optimisation de l'utilisation des ressources naturelles, en particulier des eaux souterraines,
- la restauration et préservation des paysages et des écosystèmes des oasis,
- la valorisation des biens et services fournis par les écosystèmes pour le bien-être des populations et des acteurs des différents secteurs connexes.

Les enseignements tirés de projets antérieurs qui visaient à soutenir de développement des paysages oasiens de la Tunisie soulignent la nécessité d'aider les organisations de producteurs et les autorités locales à formuler et à mettre en œuvre **de plans de développement intégré et de gouvernance des paysages oasiens, spécifiques à chaque site**, qui comprennent des actions pour la gestion durable des ressources naturelles dans des paysages oasiens spécifiques. L'élaboration de ces plans nécessitera la convergence des stratégies sectorielles et une synergie entre les interventions et investissements des acteurs concernés (y compris le secteur public, le secteur privé, les associations, les organisations locales, les autorités locales et les partenaires techniques et financiers). Cette étude recommande la mise en place d'un cadre opérationnel pour aider les communautés oasiennes à préparer et mettre en œuvre leurs plans de développement intégré et de gouvernance des paysages oasiens. Ces plans guideront les parties prenantes dans la préparation et la mise en œuvre des initiatives futures.

Outre la mise en place de ce cadre opérationnel, la présente étude propose également plusieurs recommandations stratégiques visant à faciliter la transition des paysages oasiens vers un développement durable et sobre en carbone qui maximise les possibilités de création d'emplois verts :

Renforcer le cadre institutionnel de développement des oasis pour faciliter la coordination des différentes interventions.

Renforcer les pratiques et les politiques permettant la gestion durable des paysages oasiens, notamment en ce qui concerne l'optimisation de l'utilisation durable des ressources en eau (souterraine). Il s'agit notamment de bien comprendre les avantages et les coûts d'utilisation des eaux souterraines et de disposer d'un cadre décisionnel qui favorise une gestion et une gouvernance durables de celles-ci.

Revoir et améliorer le cadre réglementaire des paysages oasiens et adapter le code des investissements et le code de l'urbanisme et de l'aménagement du territoire au contexte oasien du sud de la Tunisie.

Mettre à jour les stratégies qui favorisent la gestion durable des paysages oasiens, en s'appuyant sur la Stratégie et plan d'action de développement durable des oasis en Tunisie et d'autres stratégies connexes, et envisager de créer une réserve de biosphère de l'UNESCO comprenant des paysages oasiens traditionnels.

Capitaliser les initiatives existantes avec des modèles de gouvernance efficaces qui peuvent promouvoir et permettre le développement durable des oasis et encourager l'innovation pour l'agriculture oasienne.

Renforcer les organisations professionnelles de producteurs oasiens et les structures de gouvernance locales et associer les jeunes et les femmes à l'exploration du potentiel de création d'emplois verts.

En l'absence de mesures audacieuses et volontaires, les écosystèmes oasiens risquent de s'effondrer à moyen et long terme.

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ملخّص تنفيذي

إنّ اتّخاذ إجراءات واضحة وحاسمة لحماية صحّة وإنتاجيّة النّظم البيئيّة للواحات في جنوب تونس من شأنه أن يحسّن القدرة على الصّمود في مواجهة التّهديدات المناخيّة، بما في ذلك الجفاف وموجات الحرارة المفرطة وندرة المياه، وخلق فرص عمل خضراء في قطاعات الزّراعة والطّاقة والنفايات والسياحة والثقافة

تعد الولايات الأربع التي تأوي الواحات في تونس، موطنا لأكثر من مليون نسمة. وقد أصبحت معرضة بشكل متزايد لآثار تغير المناخ، حيث تؤثر المواسم الجافة الطويلة وشديدة الحرّ على إنتاج التمور، كمّا وجودة، وعلى المحاصيل الواحيّة الأخرى. وقد أدت آثار تغير المناخ، مع سوء إدارة الأراضي والمياه، لا سيما في جهة قبلي، إلى الاستغلال المفرط للمياه الجوفية. وتشمل المشاهد الطبيعية أو النظم الإيكولوجية للواحات 267 واحة، منها 126 واحة تقليدية[1] و141 واحة[2] حديثة أو بساتين نخيل التمر، تعتمد على استغلال مفرط للمياه الجوفية، مع مساحات لهذا الصنف في تزايد مستمر. فقد ارتفعت المساحة الإجمالية من 17,500 هكتار في عام 1992 إلى 33,000 هكتار في عام 2008 و51600 هكتار في عام 2024 (وزارة الفلاحة والموارد المائية والصيد البحري 2025). ويوظف اقتصاد الواحات في تونس حوالي 60,000 مزارع وعامل.

يلعب إنتاج التمور دورا مهما في اقتصاد مجتمعات الواحات. فالتمور هي ثاني أكبر الصادرات الزراعية لتونس: 717،7 مليون دينار تونسي (232،3 مليون دولار) خلال الموسم 2023/2024. وتعتبر زراعة الواحات قطاعا تنمويا هاما في جنوب البلاد التونسية. ومع ذلك، ففي كثير من الحالات، كان هذا التطور مدفوعا بسياسات وممارسات غير مستدامة في الزراعة وفي إدارة المياه. مع 12٪ فقط من الأراضي الزراعية المروية، تمثل زراعة الواحات 4,19٪ من قيمة الإنتاج في المناطق المروية و 6,8٪ من إجمالي قيمة الإنتاج الزراعي في البلاد.

وتعتمد زراعة الواحات في الوقت الحاضر بشكل كبير على المياه الجوفية. حيث تضاعف عدد الآبار غير الخاضعة للرقابة من 4686 في عام 2016 إلى 21279 في عام 2021 ، بمتوسط سحب يتراوح بين ثلاثة إلى خمسة أمتار عمق سنويا. ويساهم هذا الاستغلال المفرط في زيادة الإجهاد المائي، وتملح التربة، وتدهور التنوع البيولوجي، وفي دفع السكان إلى التخلي عن النشاط الزراعي، خاصة في الواحات التقليدية، مع تهديد للنظم الإيكولوجية بالواحات ولديمومة الاقتصاد المحلي بشكل عام. إن غياب نهج تدخل قوي وإرادي للحفاظ على النظم الإيكولوجية للواحات قد يعرض اقتصاد البلاد لمخاطر جسيمة محتملة.

إن محدودية التدابير الناجعة لمعالجة تدهور الأراضي، وللإدارة المستدامة للأراضي والمياه الجوفية، وتوفير الفرص الاقتصادية، من شأنه أن يسرع وتيرة التدهور وزيادة الهشاشة المناخية للمشاهد الطبيعية والمراعي المحيطة بالواحات. وقد لوحظ ذلك بالفعل في واحة الحامّة بجهة قابس وكذلك في مدينة قابس نفسها، التي تعتبر الواحة الساحلية الفريدة بالبحر الأبيض المتوسط. ومن المتوقع أن يؤدي تغير المناخ إلى تفاقم تدهور الأراضي وندرة المياه. فوفقا للتقديرات المختلفة لتغير المناخ، من المتوقع أن نشهد تونس ارتفاعا في المعدل السنوي لدرجة الحرارة من 1,6 إلى 1,9 درجة مئوية عام 2050، مع ارتفاع درجات الحرارة بالمناطق الداخلية بشكل أسرع من المناطق الساحلية. ومن المتوقع أيضا أن تنخفض تساقطات الأمطار بنسب 6 إلى 9 في المائة في جميع أنحاء البلاد، مع وجود فوارق بين المناطق. ومن المتوقع أن تسبب التغيرات المناخية في تنامي الظواهر الجوية المتطرفة كالجفاف وموجات الحرّ والفيضانات.

1 واحات قديمة تتميز بنظام الزراعة البينية، يعرف بثلاث طوابق: أشجار نخيل التمر وأشجار الفاكهة، وشجيرات متوسطة وزراعات عشبية (الخضر والبقوليات والأعلاف الأعشاب الطبية والعطرية).

2 تم إنشاء الواحات الحديثة أحادية الزراعة تختص بنخيل التمر (صنف دقلة نور): بساتين النخيل.

يمكن أن تلعب الواحات دورا مهما في تنفيذ المساهمة المحددة وطنيا لتونس 2021. ومن شأن التنمية المستدامة للواحات وإعادة تأهيلها أن تخلق فرصا كبيرة لموارد العيش والتنمية الاقتصادية والقدرة على الصمود أمام تغير المناخ والحفاظ على البيئة والحفاظ على التراث الثقافي. ويدرك أصحاب المصلحة على جميع المستويات الحاجة الملحة لحماية هذه النظم الإيكولوجية. كما أن العديد من المبادرات، لا سيما تلك التي يقودها الشباب، آخذة في الظهور لحماية وإعادة تأهيل الواحات وتعزيز التنمية الاقتصادية المستدامة فيها. وقد سلطت المشاريع المنجزة والناجحة في المجال الضوء على أهمية الحوكمة التشاركية والشاملة لاستدامة هذه المشاهد الطبيعية.

ومن خلال المساهمة المحددة وطنيا 2021، تم تحديد عديد الخيارات للتكيف المناخي والصمود في علاقة بالواحات التقليدية والحديثة. ومن شأن هذه الخيارات أن تقلل من انبعاثات غازات الدفيئة، وأن تخلق فرص عمل خضراء، وأن توفر فوائد مشتركة للواحات، وذلك من خلال تحسين خدمات النظام الإيكولوجي، مثل عزل الكربون، والاقتصاد في المياه، وزيادة المردود الزراعي، وإنتاج الأعلاف، وحماية التراث الثقافي، والحفاظ على التنوع البيولوجي المحلي. وقد تم التثبت من مدى جدوى وأهمية هذه الخيارات لدى الأطراف الفاعلة من خلال الدراسة. كما تم تقييم قدرة هذه الإجراءات على تخفيض انبعاثات غازات الدفيئة، وعلى خلق وظائف خضراء، كما هو مبين بالجدول 1.

جدول 1. تقديرات خفض انبعاثات الغازات الدفيئة وخلق مواطن شغل خضراء لخيارات التكيّف المدرجة بالمساهمة المحددة وطنيًا 2021.

خيارات وتدابير التكيّف	التأثير المتوقع		نسبة التكلفة إلى الفائدة
	التخفيض في ثاني أكسيد الكربون[1]	عدد الوظائف الوحدة: معادل وحدة عمل قار أو يوم عمل [3][2]	
1. التنمية المتكاملة والتشاركية للمراعي الجماعية	1.3 طن ثاني أكسيد الكربون/هكتار/السنة	14 وحدة عمل قار لكل ألف هكتار	1.18
2. الزراعة متعددة الطوابق	87.6 طن ثاني أكسيد الكربون/هكتار (على مدى 20 عاما)	من 75 إلى 100 يوم عمل للهكتار	1.65
3. تعميم ممارسات الإدارة المستدامة للأراضي والمياه			
1.3. تحسين إدارة مياه الري			
1.1.3. في الواحات التقليدية (18586 هكتار)	0.44 طن من ثاني أكسيد الكربون/هكتار		1.51
2.1.3. في الواحات الحديثة (39098 هكتار)	إمكانات ضئيلة جدا	67 يوم عمل للهكتار	1.65
2.3. تحوّطات حية[3]	5.86 طن ثاني أكسيد الكربون/هكتار	3 يوم عمل للهكتار	1.27
3.3. الزراعة البيولوجية	1.6 طن ثاني أكسيد الكربون/هكتار/السنة	10 يوم عمل للهكتار في السنة	2.13
4.3. تغذية التربة باستخدام الفحم العضوي	3.66 طن ثاني أكسيد الكربون/طن فحم مستعمل	0.25 يوم عمل للطن الواحد	2.65
4. إعادة تدوير المنتجات الثانوية			
1.4 إنتاج السماد العضوي	إمكانات محدودة	94 وحدة عمل قارة لمساحة 450 هكتار من الواحات، في نطاق شركات ناشئة	دراسات إضافية مطلوبة
2.4. تصنيع الأعلاف	إمكانات ضئيلة جدا		
3.4. تجديد أشجار النّخيل القديمة (تشبيب)	إمكانات محدودة		1.08
4.4. استخدام الزراعية الآلية	إمكانات ضئيلة جدا		
5.4. إنتاج الفحم العضوي: نسبة المردود الذاتي 3] 38٪ IRR]	2.86 طن مكافئ كربون في الطن		

3 . الهكتار الواحد يعادل 66,667 نبتة نجيل الهند

جدول 1. تقديرات خفض انبعاثات غازات الدفيئة وخلق فرص عمل لخيارات التكيّف المدرجة بالمساهمة المحددة وطنيا 2021.

خيارات وتدابير التكيّف	التأثير المتوقع		نسبة التكلفة إلى الفائدة
	التخفيض في ثاني أكسيد الكربون[1]	عدد الوظائف الوحدة: معادل وحدة عمل قار أو يوم عمل [3][2]	
5. إعادة استخدام مياه الصرف الصحي المعالجة			
1.5. في زراعة الزّيتون (2/3) وزراعة الفواكه (1/3)	6.26 طن ثاني أكسيد الكربون/هكتار/السنة (مدى أكثر من 20 عاما)	117 يوم عمل/هكتار	2.2
2.5. في إعادة تأهيل المناطق السقويّة العامة والواحات	إمكانات ضئيلة جدا	67 يوم عمل/هكتار	1.7
6. إعادة استخدام مياه الصرف السقوية	إمكانات محدودة	إمكانات محدودة	دراسات إضافية مطلوبة
7. تعميم استخدام الطاقة الشمسية			
1.7. في محطات الضخ	0.99 طن ثاني أكسيد الكربون/هكتار/السنة	8.5 إلى 17.5 وحدة عمل في الميغا واط	0.7
2.7. في التخزين البارد للتمور	0.144 طن ثاني أكسيد الكربون/طن سعة التخزين	إمكانات ضئيلة جدا	1.2
8. تحسين إدارة مزارع الواحات	إمكانات محدودة	1 وحدة عمل لكل 600 هكتار	
9. تعزيز التراث الطبيعي والثقافي			
1.9. المنتجعات الواحية والسياحة الزراعية	إمكانات محدودة	إمكانات متوسطة	دراسات إضافية مطلوبة
2.9. تطوير الجولات السياحية البيئية	إمكانات محدودة	إمكانات متوسطة	

[1] طن مكافئ ثاني أكسيد الكربون

[2] تسييج قطع الأراضي بتحوّطات حيّة؛ الهكتار الواحد يعادل 66,667 نبتة نجيل الهند.

[3] معدل إنتاج الفحم العضوي من نفايات الخشب

في مرحلة متقدمة من الدراسة تم وضع وتقييم 2 سيناريوهات اجتماعية-اقتصادية: سيناريو أوّل سمّي "محافظ"، أي مواصلة على نفس المنحى الملاحظ، وسيناريو ثاني سمّي "استباقي" يفترض القيام بإصلاحات في حوكمة وإدارة المنظومات الواحيّة في الجنوب التونسي.

- **السيناريو المرجعي** هو سيناريو يفترض مواصلة الاتجاهات التي تم ملاحظتها خلال العقود الماضية في السياقات السياسية والاجتماعية والاقتصادية، والذي يتسم بتغيرات بطيئة، وقدرات تنفيذ وموارد مالية محدودة.

- **السيناريو الاستباقي** يعتمد على تطور إيجابي للسياق السياسي والاجتماعي والاقتصادي من حيث الإصلاحات السياسية واللامركزية، بالإضافة إلى التبنّي المكثّف للممارسات الزراعية المستدامة، مثل الزراعة متعددة الطبقات، والزراعة البيولوجية، والتغطية بالتربة، وإعادة استخدام مياه الصرف ومياه الصرف الصحي المعالجة.

وتقدر الدراسة أنه في إطار السيناريو الاستباقي، يمكن أن تولّد هذه الخيارات للتكيّف ما يصل إلى 6,95 مليار دينار تونسي (2,25 مليار دولار[4]) من الإيرادات الإضافية، مما يخلق حوالي 33,500 وظيفة إضافية ويقلل من الانبعاثات بمقدار 22,5 مليون طن مكافئ ثاني أكسيد الكربون (tCO_2e) بحلول عام 2050 ، كما هو مبيّن بالجدول 2.

4 بناء على سعر الصرف الساري في 10 مارس 2025.

جدول 2. توقعات تخفيض الكربون والوظائف والدخل الإضافي والاستثمارات حسب السيناريوهات: 2030، 2040، 2050

السيناريوهات	الأثـــــر						الدخل الإضافي (مليون دينار)	الاستثمار (مليون دنانير)
	2030		2040		2045 أو 2050			
	وظائف (معادل وحدة عمل قار)	تخفيض الانبعاثات (ألف طن مكافئ كربون)	الوظائف (معادل وحدة عمل قار)	تخفيض الانبعاثات (ألف طن مكافئ كربون)	الوظائف (معادل وحدة عمل قار)	تخفيض الانبعاثات (ألف طن مكافئ كربون)		
السيناريو المحافظ	5 373	2 758	7 398	9 129	15 013	13 108	4 400	3 194
السيناريو الاستباقي	9 453	5 700	16 081	15 379	33 489	22 481	6 949	6,949

[1] ألف طن مكافئ ثاني اكسيد الكربون
[2] معادل وحدة عمل قار

في هذا السياق، يحتاج صانعو القرار إلى إعادة النظر في حوكمة وتنمية المنظومات الواحيّة بما يتماشى مع المساهمة المحددة وطنيا وأهداف التنمية المستدامة وأولويات التنمية الاجتماعية والاقتصادية في تونس. وهذا يتطلب تجميع أصحاب المصلحة حول رؤية موحدة تضع الواحات في محور السياسات التنموية للجنوب التونسي. ويجب أن تكون هذه الرؤية في انسجام مع استراتيجية التنمية المستدامة للواحات في تونس، التي تم تبنيها في عام 2015 وغيرها من أولويات التنمية الوطنية والقطاعية، وأن ترمي إلى تحقيق تنمية محلية شاملة، تدمج البعد التراثي مع المحافظة على تعدد وظائف النظم الإيكولوجية للواحات. يجب أن يهدف تطوير الواحات في الجنوب التونسي إلى تنمية مدفوعة اجتماعيا، وبالتالي تعزز الاقتصاد الأخضر وتساهم في خلق المزيد من فرص العمل. ويقترح أن تستند هذه الرؤية التنموية إلى العناصر التالية:

- حوكمة أفضل من خلال ترشيد استخدام الموارد الطبيعية، ولا سيما المياه الجوفية.
- الحفاظ على المشاهد الطبيعية للواحات ونظمها الإيكولوجية مع استصلاحها وإعادة إحيائها.
- تثمين السلع والخدمات التي تقدمها النظم الإيكولوجية للواحات من أجل رفاهية السكان ولفائدة الجهات الفاعلة في مختلف القطاعات ذات الصلة.

لقد سلّطت الدروس المستفادة من المشاريع السابقة، التي تهدف إلى تطوير المشاهد الطبيعية للواحات في تونس، الضوء على الحاجة إلى دعم منظمات المنتجين والسلطات المحلية في صياغة وتنفيذ خطط التنمية والحوكمة المتكاملة الخاصة بالنظم الطبيعية والبيئية للواحات، والتي تشمل إجراءات للإدارة المستدامة للموارد الطبيعية. ويتطلب وضع هذه الخطط التكامل والانسجام بين مختلف الاستراتيجيات القطاعية وكذلك التنسيق التام بين تدخلات واستثمارات الجهات الفاعلة المعنية، بما فيها القطاع العام، والقطاع الخاص، والرابطات المهنية، والجمعيات المحلية، والسلطات المحلية، وشركاء التعاون الدولي التقني والمالي . كما توصي هذه الدراسة بمساعدة مجتمعات الواحات على إعداد وتنفيذ مخططات متكاملة للتنمية والحوكمة في الواحات، والتي ستوجه أصحاب المصلحة في إعداد وتنفيذ المبادرات المستقبلية.

بالإضافة إلى ذلك، تقترح هذه الدراسة أيضا عددا من التوصيات الاستراتيجية لتسهيل الانتقال بالمنظومات الواحية الطبيعية إلى منوال تنمية مستدامة ومنخفضة الكربون تزيد من فرص الشغل الخضراء. وتتلخص هذه التوصيات في ما يلي:

تعزيز الإطار المؤسساتي لتطوير الواحات ولإحكام التنسيق بين مختلف المتدخلين.

تعزيز ممارسات وسياسات الإدارة المستدامة للواحات، بما في ذلك الاستخدام الأمثل لموارد المياه الجوفية. وهذا يتطلب تطوير المعرفة والادراك لدى أصحاب المصلحة لفوائد وتكاليف استخدام المياه الجوفية وإيجاد إطار لأخذ القرار يدعم الإدارة الرشيدة والمستدامة للمياه الجوفية.

مراجعة وتحسين الإطار التنظيمي للواحات وتكييف قانون الاستثمار وقانون التخطيط العمراني والتخطيط الإقليمي مع سياق الواحات في جنوب تونس.

تحديث الاستراتيجيات التي تعزز الإدارة المستدامة للواحات، والاعتماد على مخرجات الاستراتيجية الوطنية للتنمية المستدامة للواحات وغيرها من الاستراتيجيات ذات الصلة، والنظر في إدراج الواحات التقليدية تحت نظام محمية اليونسكو للمحيط الحيوي.

الاستفادة من المبادرات الناجحة في نماذج الحوكمة الفعالة التي يمكن أن تعزز التنمية المستدامة للواحات وتشجع الابتكار في زراعة الواحات.

تعزيز المنظمات المهنية لمستغلي الواحات وهياكل الحكم المحلي وإشراك الشباب والنساء في استكشاف وبعث فرص التشغيل الخضراء.

إن اتخاذ مثل هذه التوصيات والإجراءات من طرف أصحاب القرار من شأنه إنقاذ النظم الإيكولوجية للواحات من خطر الانهيار على المدايين القصير والطويل.

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1 Introduction

The four oasis governorates of southern Tunisia are home to more than a million inhabitants (8.3 percent of the Tunisian population) and have become increasingly vulnerable to the effects of climate change due to the overexploitation of groundwater and declining economic relevance.

Over the past decade, the degradation of oasis landscapes has accelerated due to a combination of factors, including governance challenges and unsustainable use of natural resources, leading to a reduction of their production and ecosystem potential, an increased vulnerability to climate change, and decreasing economic opportunities, notably for young people.

Oasis ecosystems are a principal element of Tunisia's updated NDC under the United Nations Framework Convention on Climate Change (UNFCCC). The 2021 NDC update underscored the importance of oasis ecosystems for Tunisia's climate change mitigation and adaptation efforts. Tunisia's NDC describes national priorities to reduce greenhouse gas (GHG) emissions and combat the growing impacts of climate change in four sectors of activity: agriculture, forestry, and other land uses (AFOLU); energy; industrial processes; and waste.

Oasis landscapes have significant potential to fulfill multiple functions to strengthen the resilience of Tunisia's deserts and their inhabitants, in line with the objectives of the updated NDC.

Several initiatives have already been launched to address land degradation in Tunisia's oasis ecosystems, including the Strategy and Action Plan for Sustainable Development of Oases in Tunisia, developed in 2015 with the support of the World Bank as part of a pilot project (the Tunisia Oases Ecosystems and Livelihoods Project), which was implemented from 2015 to 2019. This work provided the point of departure for this report and further initiatives to rehabilitate, develop, and conserve oasis ecosystems.

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The Government of Tunisia's Ministry of Environment requested support from the World Bank to better understand and unlock the green recovery, growth, and job creation potential of oasis landscapes in southern Tunisia, considering Tunisia's updated NDC. This study therefore had the following objectives:

- **Provide insights to promote green recovery, growth, resilience, and green jobs creation** in oasis landscapes based on the commitments of the updated NDC and related strategies
- **Contribute to the definition of a conducive framework for implementing green recovery, growth, resilience, and green jobs creation activities** in oases landscapes, including finance opportunities.

This study focuses on the typical oasis landscapes found in the governorates of Gabès, Gafsa, Kébili, and Tozeur, but its findings are applicable to all oasis landscapes in southern Tunisia, especially in the context of future development projects. In this note, the term "oasis landscape" refers to oases in the strict sense, as well as their adjacent environments (pastures, expansions, tourist and sociocultural areas, areas of ecological interest, wetlands, national parks, and drainage areas).

The study builds on the commitments of the NDC, supports the implementation of the UNFCCC in Tunisia, and is synergistic with the implementation of other Rio Conventions, that is, the Convention on Biological Diversity and the United Nations Convention to Combat Desertification.

This synthesis report presents the findings of four stand-alone analytical reports that separately assessed (i) the opportunities and challenges of the Tunisian NDC in relation to oases, (ii) the potential for GHG mitigation and job creation potential in oasis ecosystems, (iii) the impacts and scaling opportunities for GHG mitigation and green jobs, and (iv) lessons learned and recommendations for oases landscapes.

1.1 Climate and environmental context

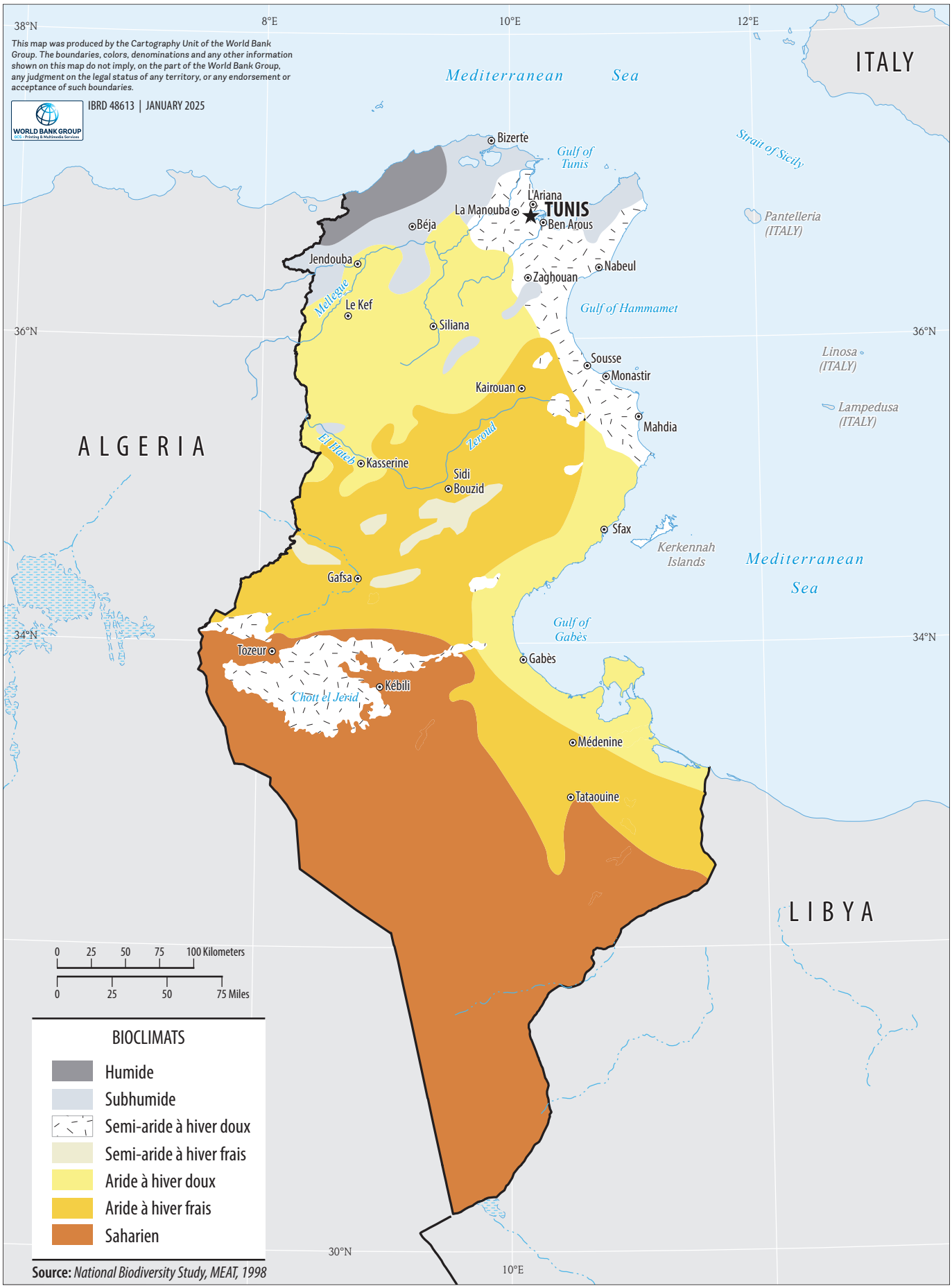
Tunisia is a country of 164,000 square kilometers in North Africa, bordered to the west by Algeria and to the southeast by Libya (Figure 1), and populated by 12.3 million inhabitants (World Bank, 2023). Administratively, Tunisia is divided into 24 governorates, each of which is named after their capital. Tunis is the national capital and the country's largest city. The northern part of the country is crossed by the Tunisian Ridge, an extension of the Atlas Mountains that runs from the southwest to the northeast. The central and southern half of Tunisia consists of semi-arid steppe or desert with chotts (shallow saline lakes), rocky plateaus, and dunes. Oases are located in the southern region of the country (Gabès, Gafsa, Kébili, Tozeur and some small oases in Médenine and Tataouine governorates).

Tunisia, which is characterized by a Mediterranean climate with Saharan influence, has two strongly contrasting seasons: a hot and dry summer, and a mild, humid winter. Its territory is spread over five bioclimatic regions. The most arid (Saharan desert) is in the south, while the wettest is in the north (Figure 2). Annual precipitation is low and variable depending on the time of year or location within the country. Although the average annual rainfall is 158 mm per year, precipitation occurs mostly in the north, which receives more than 700 mm per year, while the south of the country receives less than 100 mm per year. Average annual temperatures are high, ranging between 16°C and 20°C. In the north, average temperatures can range from 10°C in winter (December to February) to 27°C in summer (June to August), while in central and southern Tunisia, average temperatures range from 11°C in winter to 32°C in summer. Droughts are frequent in the semi-arid and arid areas, while coastlines face flooding due to local weather conditions.

Figure 1: *General map of Tunisia*

Source: Original World Bank map for this report.

Figure 2: *Bioclimatic regions*



Source: Original World Bank map for this report.

The characteristics of Tunisia's natural environment create seven major ecosystem types: coastal ecosystems, island ecosystems, wetland ecosystems, mountainous ecosystems, steppe ecosystems, desert ecosystems, and oasis ecosystems. Oasis ecosystems or landscapes can be classified into traditional oases and modern oases.

Like all other oases in the world, Tunisia's historic oases have played a social, cultural, economic, and ecological role over millennia. The name "oasis" has its origins in ancient Greek and refers to an isolated area of vegetation in a desert. Oases are generally considered to be ecosystems in their own right because of the many environmental and ecosystem services they provide. These services are often collectively referred to as the "oasis effect", in which three climatic elements—namely luminosity, wind turbulence, and evaporation—are reduced relative to the Saharan climate (Toutain, 1979). The oasis effect allows different forms of plant and animal life to develop while mitigating the effects of the desert climate. This makes it possible to practice many human activities.

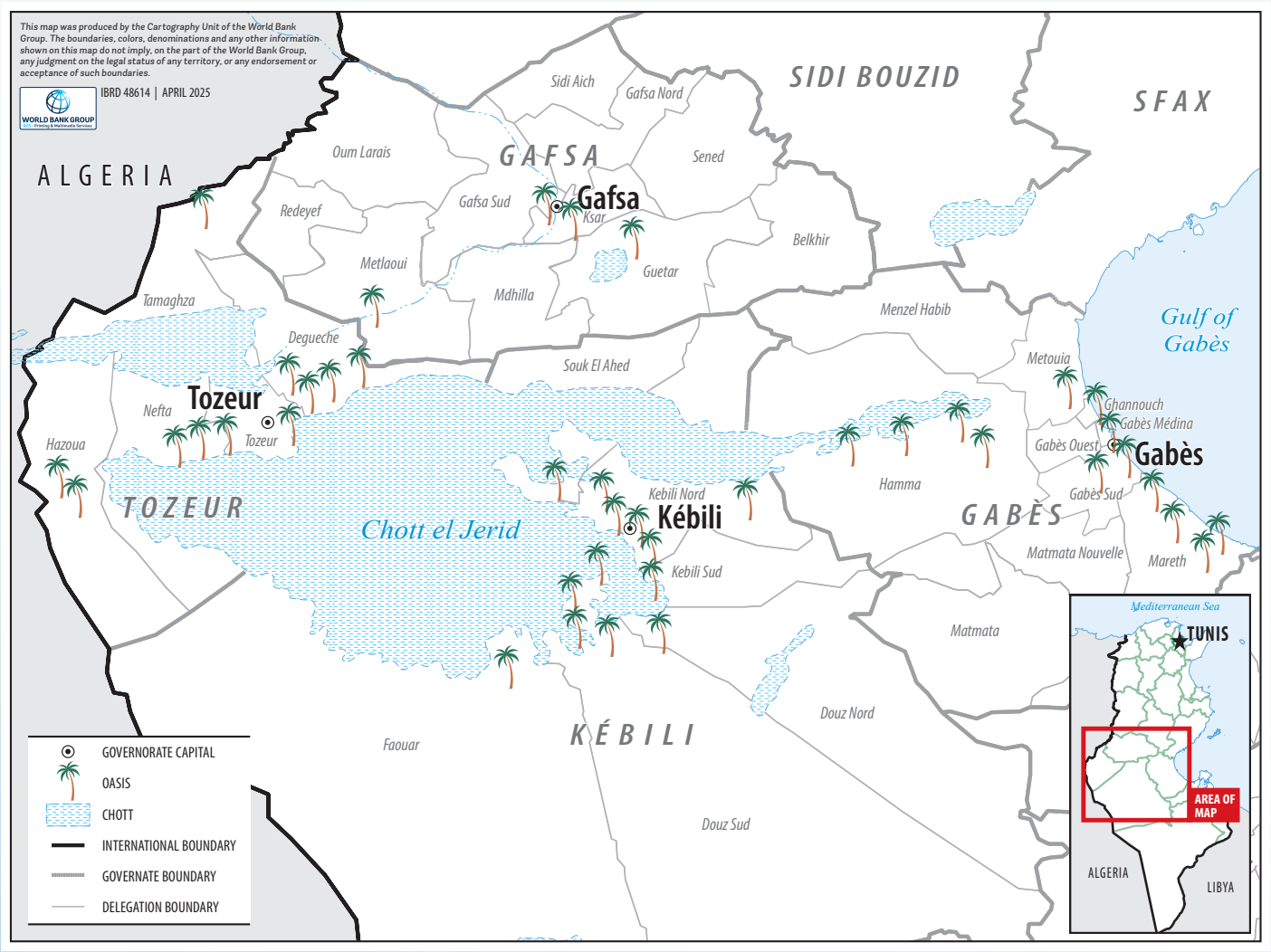
Oasis landscapes provide several critical services in arid environments:

- **They enhance the resilience of the natural environment** in terms of maintaining biological diversity, combating desertification, regulating the local climate, adapting to the impacts of climate change, and mitigating climate change through carbon sequestration.
- **They maintain a decent living space for populations** in arid and desert environments in terms of providing livelihoods, creating opportunities for people to interact with surrounding natural areas, and creating living conditions that are conducive to the development of sociocultural and historical heritage.
- **They develop arid environments** to create habitable spaces that facilitate commercial connections within vast, uninhabited territories.

There are 126 traditional oases in Tunisia. These are characterized by a multilayer cultivation system consisting of a date palm layer, followed by a tree or shrub layer (apricots, olives, citrus, figs, pomegranate), and a herbaceous cultivation layer (vegetables, fodder, medicinal and aromatic plants). The 141 "modern" oases are more recently established (early twentieth century, by the French administration) and largely consist of monoculture of the Deglet Nour date palm variety. Together, the surface area of these 267 oases has increased from 17,500 hectares (ha) in 1992 to 51,600 ha in 2024 (MARHP, 2025)—a growth of more than 320 percent in 27 years—mainly due to expansions of Deglet Nour date palm plantations. Currently, oases are mainly found in four governorates (Figure 3): Kébili (38,000 ha or 66 percent of total oases), Tozeur (9,574 ha or 17 percent), Gabès (6,660 ha or 12 percent), and Gafsa (2,950 ha or 5 percent) (ONAGRI, 2022).

The oasis landscapes of southern Tunisia are surrounded by natural pastures that cover 3,678 million ha, of which 1.6 million ha are in the oasis governorates. These rangelands are state, common, or private, depending on the area. They play an important role in livestock production (accounting for 13.2 percent of sheep, 21.8 percent of goats, and 46.3 percent of camels in Tunisia) and provide employment for pastoralists.

Figure 3: *Distribution and location of traditional oases in the four targeted governorates*[5]



Source: Original World Bank map based on MALE (2017) and CDCGE (2015).

5 The map does not include the approximately 2,000 ha of oases in the Rjim Maâtoug in Kebili.

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1.2 Role of oasis landscapes in Tunisia's economy

The agricultural sector and oasis landscapes production

The agricultural sector in Tunisia is of great socioeconomic importance because of its contribution to food security, income, employment, regional development, and the management of natural resources. Between 2019 and 2023, the agricultural sector[6] contributed an average of 10.1 percent to Tunisia's GDP (World Bank, 2025). At the same time, Tunisia spends about 4 percent of its annual budget on agriculture (FAO, 2023).

At more than 57,000 ha, Tunisia's 267 oases represent about 1.1 percent of the country's agricultural area and between 9 and 10 percent of Tunisia's irrigated area (with 30 percent of the irrigated arboriculture area, 25 percent of the irrigated forage area, and 10 percent of the irrigated vegetable area). Yet economically, oasis agriculture accounts for 6.8 percent of the total value of agricultural production, providing employment in arid areas that would otherwise have low employment potential.

Oases also play a remarkable role in the development of water resources and the conservation of local agrobiodiversity (in the form of palm trees, fruit trees, fodder, medicinal and aromatic plants, as well as fauna, livestock, and aquaculture).

They contribute to the national agricultural production system mainly through:

- **Date production,** which has undergone a notable evolution in the past decade, particularly following the unregulated expansion of Deglet Nour palm groves. With an average added value of TD 692 million (2010 to 2019), date production represents 6.8 percent of total agricultural added value and 24 percent of arboriculture's added value. Tunisia has become a leading exporter of dates, covering 20 percent of the world market. Over the past century, the Deglet Nour variety has come to dominate date production in Tunisia, where it currently accounts for nearly 75 percent of plantations, compared with 6 percent in 1906. The date ranks second in Tunisian agricultural exports after olive oil.
- **Livestock**, which at TD 3,637 million represents nearly 34.1 percent of the agriculture sector's value. Apart from dairy farming, which uses about 400,000 ha of fodder crops, the rest of livestock (small ruminants and camels) occupies only 4.8 million ha of the steppe and desert rangelands that are part of the oasis landscapes.
- **Vegetable production**, which hardly exceeds 1 percent of national production in terms of volume, remains particularly important in terms of conserving local agricultural biodiversity (see Box 1).

BOX 1: LOCAL AGROBIODIVERSITY IN SOUTHERN TUNISIA

The oasis landscapes are characterized by substantial agricultural biodiversity, driven by the presence of local species of camels, goats, sheep, date palms, fruit trees, and medicinal and aromatic plants. The four species of goats commonly bred in the governorate's oasis—namely Arbi or local, Cherki, Damasquine, and Alpine goats—are important and play an important role in breeding schemes (Nafti et al., 2009).

Traditional varieties of date palms and fruit trees once cultivated in the oases of southern Tunisia have slowly diminished. Once-plentiful fruit groves of figs, olives, and pomegranates are vanishing due to thinning of ancient date-palm groves. Olives are increasingly affected by the heat and lack of rain, while native pomegranates have been replaced by a smaller, less tasty variety due to environmental climate pressures (Bryce, 2016). Once common, apricot and peach trees have decreased. Traditionally cultivated oasis species, including legumes (broad beans), cucumber, okra, tomato, zucchini, lettuce, chilli, eggplant, peppers, and alfalfa, are still maintained in the traditional oases.

There has been a shift towards cultivating Deglet Nour date palms, which are largely produced in monoculture, with traditional varieties of dates diminishing. These monocultures are more vulnerable to heat waves than traditional farming systems that use greater biodiversity. According to Tunisia's National Biodiversity Strategy and Action Plan 2018–2030, one key objective is to conserve the biodiversity of date palm by maintaining the proportion of traditional date palm varieties at a level of at least 28 percent compared to all date palm genetic resources.

6 Tunisia's agricultural sector is composed of five subsectors: crop production; livestock; fisheries; water management; and forest and natural resource management.

The diversity of value chains in oasis landscapes

Date production plays a vital role in the oasis landscapes, with the date industry ranking second in the country's agrifood exports. In total, the date industry is supported by 60,000 farmers. Nearly one million people derive part of their income from the sector.

The date sector offers multiple diversified opportunities to create jobs (especially those that target youth) and develop short supply chains. It involves various stakeholders such as producers, collectors, packers, exporters, wholesalers, traders, retailers, wholesale and local markets, and public institutions whose relationships are organized around the production and supply chain of dates. In recent years, however, there has been an increase in out-migration from date-growing areas, especially of young people; abandonment of the land (absenteeism); changes in occupation and in land use (for example, olive groves in Gafsa, pomegranate trees in Gabès); and the transformation of some traditional oases into monoculture date palm groves, using only the Deglet Nour variety.

Date industry

Dates are Tunisia's second-most important agricultural export commodity, contributing TD 717.7 million (US$232.3 million) to the economy in the 2023/24 season.

The sector has been strengthened by creating byproducts and focusing on certified organic production. Certified Deglet Nour organic dates are exported to Germany (67 percent), the United States (11 percent), and France (7 percent). To further encourage improvement in quality and promote Tunisian dates on foreign markets, a date promotion fund, financed by a tax of 1 percent of the customs value on export, has been established. Although organic dates are in high demand on international markets, the share of organic dates produced remained stable at about 8 percent of total production (9,313 tons in 2018/19) or about 10 percent of the export value (TD 79.4 million in 2018/19).

Other agricultural and livestock sector activities in the oases

Other agricultural and livestock activities are intertwined with the production of date palms: fruit growing, market gardening, and industrial crops. These activities provide employment for farmers and contribute to improving the incomes of oasis populations. In addition, the herding of livestock—notably small ruminants—based on fodder crops from oases landscapes and surrounding rangelands are an important economic activity.

Other associated non-agricultural value chains

Other economic activities include artisanal activities relating to processing and valorizing date palm byproducts. These include basketry, carpentry, and the manufacture of art objects. In addition, dates are also transformed into products like syrups.

Tourism activities and sectors

The contrast of desert and oases landscapes found in southern Tunisia creates potential for tourism development, which has been valued in recent decades through five specific tourism products: Saharan tourism; motorized activities (in the form of excursions into the desert); camel rides or trekking; hiking; and leisure and entertainment opportunities for tourists. However, the development of tourism potential seems to have reached its limits (Carpentier, 2017).

1.3 Policy and institutional environment related to Tunisia's oasis landscapes

Oases are at the center of an array of institutional and non-institutional public and private stakeholders involved in the date value chain, from production to the distribution of finished products, nationally and globally.

The way institutions are organized reflects the vertical nature of sub-sectoral strategies and results in a certain degree of complexity. In the absence of a fully operational coordination mechanism, some overlaps in mandates can be observed, contributing to pressures on limited financial resources. This can pose challenges to coherence and efficiency when implementing programs and managing resources.

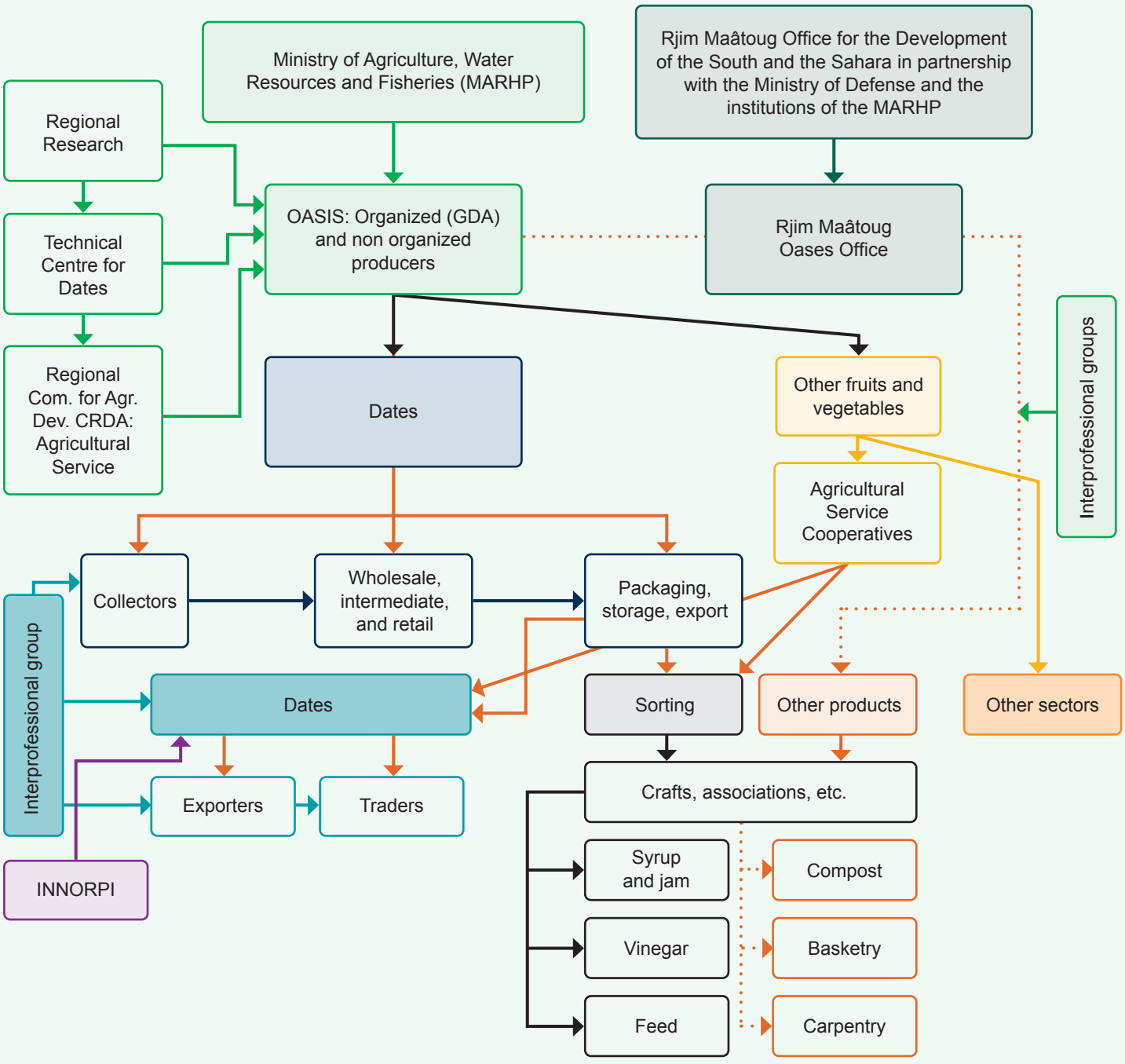
Various stakeholders, including different ministries, producer organizations, and technical centers are involved in oasis agriculture in Tunisia. Figure 4 on page 33 provides an overview of the actors and stakeholders involved in oasis agriculture, while Figure 5 on page 34 summarizes the policy and institutional context of the broader agricultural sector.

The regulatory environment[7] brings several challenges to Tunisia's oases. Environmental and agricultural production policies are not fully integrated, so that externalities (such as water use) are often not considered in agricultural practice. As a result, the growth of some agricultural sectors is achieved at the expense of natural resource degradation (in the form of groundwater depletion, soil salinization, and so on) which is further exacerbated by a changing climate. Sectoral strategies are often fragmented along sub-sectoral and branch levels, and do not provide for location-specific policies. In other words, they do not allow for an area-specific vision of the different sectoral issues, nor do they reflect the specificity of subsectors and activities.

This is the case with oasis agriculture, which takes place in unique ecosystems but is often approached only from an irrigation management perspective that is not properly implemented or sanctioned.

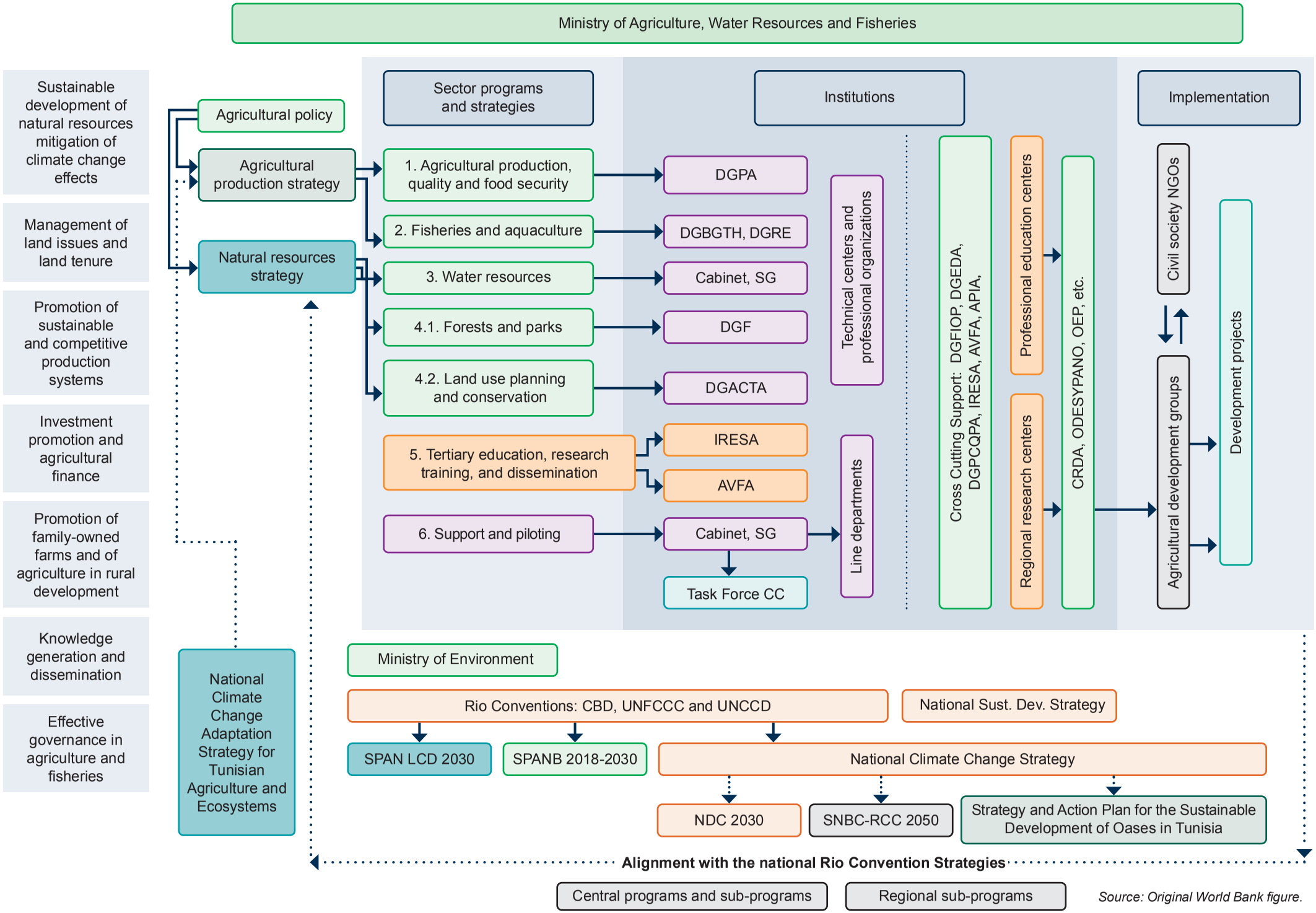
While the NDC provides a framework, opportunities remain to enhance collaboration between the Ministry of Environment and MARHP to further align environmental policies with agricultural development programs. It is therefore important to continue strengthening the mechanism for operational coordination between the ministries on issues relating to the environment and climate change.

Figure 4: *Schematic overview of stakeholders involved in oasis agriculture*



7 See the main regulatory texts: (i) the texts establishing the organization and powers of the Ministry of Agriculture, Water Resources, and Fisheries (Decree No. 2001–420 of February 13, 2001); (ii) the texts establishing and organizing the Regional Commissions for Agricultural Development and the organizations under the supervision of the Ministry of Agriculture, Water Resources, and Fisheries; and (iii) codes such as the Forest Code, the Water Code, and the Soil Protection Code.

Figure 5: *Diagram of the policy and institutional context of the agricultural sector*



Source: Original World Bank figure.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1.4 Vulnerability of Tunisia's oasis landscapes

Several studies have highlighted the increasing vulnerability of oasis ecosystems to the effects of climate change, driven by many interrelated factors, including challenges in water resources governance, the fragmentation of oasis farms, the loss of soil fertility and increased soil salinity, urban sprawl on agricultural land, and the limited capacity of GDAs in irrigation water governance and oasis ecosystem development.

The agricultural sector and oasis landscapes production

Traditional oases have faced various challenges throughout their history, often related to the consequences of overexploitation of water resources and related poor governance. The expansion of oases, particularly the monoculture planting of the Deglet Nour date variety, has increased the use of irrigation water from deep aquifers. These aquifers are non-renewable, located between 60 meters and 500 meters deep, and include the Intercalary Complex, which is found at a depth of more than 2,000 meters, as well as artesian and geothermal (70°C) sources.

In 2015, groundwater exploitation rates ranged from 85 percent (in the Governorate of Tozeur) to 157 percent (in the Governorate of Gafsa). In the Governorate of Kébili, the rate was 6.7 percent due to the poor quality of water. Overall, there has been an increase in the use of water resources due to climate change and the uncontrolled expansion of irrigated areas for Deglet Nour monoculture. The number of unregulated wells in the four oasis regions increased from 4,686 in 2016, with an exploitation of about 214,282 million cubic meters (DGRE, 2016), to 21,279 wells in 2021 (or 60 percent of the total inventoried wells), of which 9,552 wells (49 percent) were in Kébili. This competition for water has had a serious impact on water resources, resulting in acute water stress, high soil salinization, and loss of soil fertility.

Fragmentation of oasis farms

Oases have experienced a continuous land dynamic that has led to the current fragmented mosaic of plots. This dynamic is linked to two simultaneous phenomena: the division of inheritance and the expansion of irrigated areas. Traditional oases occur on private land, while expansions are more likely to be on state land (in the case of Tozeur) or collective land (in the case of Kébili). Most of the unregulated extensions in the Kébili Governorate have been installed on collective land. With the exception of oases, which are considered regulatory, agricultural and grazing lands are legally collectively owned. Common or collective land is sometimes shared among rights holders to create boreholes and plant palm groves—all without formal permissions, thus violating the law in force.

From time to time, violent conflicts arise between groups and communities around these common lands. Overall, the oases in southern Tunisia would total about 41,000 ha spread over 54,000 plots operated by 50,000 farmers (average area of 0.82 ha per producer). Of the 50,000 producers across all oases, 34,000 producers are found in Kébili (average area of 0.7 ha per producer); 11,000 producers are in Tozeur (average area of 0.76 ha per producer); 12,000 producers are in Gabès (average area of 0.56 ha per producer); and 3,000 producers are in Gafsa (average area of 0.68 ha per producer).

Loss of soil fertility and increased soil salinity

Soils in modern oases generally have very low levels of organic matter (less or equal to 0.5 percent). A large amount of organic waste is lost annually (burned or discarded) instead of being returned to the soil in the form of compost which could contribute to carbon sequestration. These practices are compounded by a lack of manure due to the decline of livestock, once an integral part of the oasis production system.

In addition to the depletion of organic matter in the soil, there is the salinization of the topsoil due to saline irrigation (using water with an average dry residue of more than 3 grams of salt per liter), the accumulation of drainage water, and the waterlogging of the soil due to the lack of maintenance and adequate development of irrigation and drainage networks. Operators are trying to remedy this situation with sand-organic amendments, but this is expensive and government support is low.

Urban sprawl on agricultural land

Uncontrolled and rampant urbanization around and inside oases has aggravated water scarcity and soil degradation throughout oasis regions, damaging biodiversity and accelerating the abandonment of agricultural activity. Although this phenomenon affects all agricultural land in Tunisia, including the irrigated public perimeters (*périmètre public irrigué*, PPI), the socioeconomic and environmental impacts are much more noticeable in oases due to their small size and ecological characteristics. The land taken from an oasis can thus not be replaced by other similar lands, as is the case with a PPI in another region of Tunisia.

Limited capacity of agricultural development groups in irrigation water governance and oasis ecosystem development

The role and capacities of the agricultural development groups (GDAs) are hampered by their statutes and attributions, which largely limit their room to maneuver, particularly in terms of access to incentives for agricultural investment, their capacity for human and material interventions, and internal organization.

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2

Climate change and the role of Tunisia's oasis landscapes

2.1 Climate change projections and their impacts on Tunisia's oasis landscapes

According to the National Meteorological Institute, climate observations between 1978 and 2012 show a significant upward trend of about 2.1°C in annual maximum, average, and minimum temperatures, with regional variations. A slight, non-significant upward trend in cumulative precipitation was also noted.

The Representative Concentration Pathways (RCP) illustrate different future greenhouse gas (GHG) concentrations according to IPCC's 5th Assessment Report (IPCC, 2014). RCP 4.5 represents an intermediate scenario (most probable baseline scenario) and RCP 8.5 is the basis for worst case climate change scenarios. The following climate projections were therefore used for this analysis:

- **RCP 4.5 scenario:** An increase in the annual mean temperature of between 1°C and 1.8°C by 2050, and between 2°C and 3°C by the end of the century, with a 5–10 percent decrease in annual mean precipitation by 2050 and a 5–20 percent decrease in precipitation by 2100.
- **RCP 8.5 scenario:** An increase in the annual mean temperature of between 2°C and 2.3°C by 2050, and between 4.1°C and 5.2°C by the end of the century, with a 1–14 percent decrease in annual mean precipitation by 2050 and an 18–27 percent decrease in precipitation by 2100.

Given the overall dependence of oases on groundwater resources, oasis landscapes are particularly vulnerable to the effects of climate change. Climate change is expected to affect water resources by decreasing precipitation, increasing temperatures, increasing evapotranspiration, and increasing the intensity and frequency of droughts. This will likely affect agriculture and ecosystems due to a potential decline in water resources. In addition, the increase in droughts will likely reduce the foraging biomass of rangelands, increase the risk of wildfires, and increase the salinization and eutrophication of wetlands.


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2.2 Tunisia's commitments under the Paris Agreement

In accordance with its commitments under the Paris Climate Agreement, Tunisia submitted its NDC in August 2015. The NDC was updated in 2021. The NDC sets the objective of *"promoting a Tunisia resilient to climate change, having significantly reduced vulnerabilities and strengthened the adaptive capacities of its ecosystems, population, economy, territories, and made the necessary transformations capable of ensuring an inclusive and sustainable model of socioeconomic development and thereby contributing to a more resilient world"* by 2030. This goal is in line with the Tunisian Strategy for Carbon Neutral and Climate Resilient Development to 2050 (Republic of Tunisia, 2022a), which has a target horizon of 2050. The updated NDC emphasizes that achieving this goal requires adopting a global, cross-cutting framework for climate change adaptation and mitigation across all sectors. In the NDC, climate change adaptation is based on the "Star of Resilience", a framework that gives the country direction in its quest for resilience by 2050, with 2030 as the transformative deadline for strengthening capacities for adaptation and risk identification and anticipation.

Tunisia's unconditional contribution to GHG mitigation corresponds with a 27 percent reduction in its carbon intensity compared to the base year, 2010.

Its conditional contribution, which is subject to the availability of financial resources, would allow an additional reduction of 18 percent, leading to a combined total reduction in carbon intensity of 45 percent.

Tunisia's commitments would avoid cumulative GHG emissions of about 207 million tons of carbon dioxide equivalent ($MtCO_2e$) over the period 2015 to 2030, of which 52 $MtCO_2e$ would be unconditional and 155 $MteCO_2e$ conditional on the support of the international community. By 2030, the main sources of GHG mitigation in Tunisia would be its energy sector (18.9 $MtCO_2e$), followed by waste management (3.3 $MtCO_2e$) and the agriculture, forestry, and other land uses (AFOLU) sector (2.2 $MtCO_2e$). Compared to the business-as-usual scenario, the waste sector would then see the largest reduction in emissions (43 percent) in 2030, followed by the energy sector (38 percent) and AFOLU (23 percent). Table 3 provides an overview of mitigation and adaptation options relevant to traditional oases, modern oases (date palm plantations) and/or other oasis characteristics.

Table 3: *Mitigation and adaptation options for oasis ecosystems as defined in the updated Nationally Determined Contribution, by sector*

SECTOR Option Concrete measures/actions	Type of oasis
AGRICULTURE, FORESTRY, AND OTHER LAND USES	
1. Integrated and participatory development of collective rangelands Reseed and protect planted areas Integrate fodder trees and shrubs Valorize aromatic or medicinal species and so on Improve livestock management	Traditional oases
2. Multilayered cultivation Introduce suitable fruit crops Introduce annual and perennial herbaceous crops	Modern oases that can be transformed into multilayer cropping systems that resemble traditional oases (i.e. converted modern oases)
3. Adoption and dissemination of sustainable land and water management practices Hedgerows (shrub, alfalfa, vetiver, and so on) Microbial/bio/mycorrhizal fertilizers Organic mulching Soil amendment by biochar	Traditional oases and converted modern oases
4. Organic farming and integrated pest management Organic farming Push-pull pest control using appropriate species such as vetiver	Traditional oases and converted modern oases
WASTE	
5. Valorization of date palm byproducts and other agricultural products Produce compost Biochar production Regenerate old palm trees	All oases
6. Recovery and reuse of treated wastewater Produce pastoral and fodder biomass Erect forest plantations to protect against silting	Oasis in the vicinity of a wastewater treatment plant
7. Recovery and reuse of drainage water Produce pastoral and fodder biomass Erect forest plantations to protect against the silting of structures	All oases
ENERGY	
8. Widespread use of solar electricity Pumping stations Cold storage for dates and date-packing stations	All oases

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2.3 Greenhouse gas emissions from Tunisia's oasis landscapes

According to Tunisia's GHG inventory for 2021, gross direct GHG emissions totaled 51 $MtCO_2e$ (Table 4). The energy sector was the largest contributor to gross direct GHG emissions (59.7 percent of the gross national emissions) based on heat and electricity production, oil refining, and fuel processing. The energy sector was followed by the AFOLU sector, with more than 11 $MtCO_2e$, or about 24 percent of gross emissions.

Only the AFOLU sector has absorption capacity due to the absorption of carbon dioxide by biomass, particularly forests and trees. These emissions removals were estimated at about 15.9 $MtCO_2e$ for 2021. Methane and nitrous oxide emissions made up 25 percent and 18 percent of the AFOLU sector's total emissions, respectively, when considering their CO_2 equivalent amount.

Table 4: *Greenhouse gas emissions balance and removals in Tunisia in 2021*

Sector	Direct gross emissions (including all GHGs) $MtCO_2e$	Removals (CO_2) $MtCO_2e$	Net balance/ emissions $MtCO_2e$
Energy	30,616	0	30,616
Industrial processes	6,276	0	6,276
AFOLU	10,733	-15,892	-5,159
Waste	3,633	0	3,633
TOTAL	**51,258**	**-15,892**	**35,366**

* Million tons of carbon dioxide equivalent

Source: Republic of Tunisia, 2022b.

GHG emissions in oasis ecosystems originate mainly from the AFOLU sector, followed by the energy and waste sectors. The main sources of GHG emissions in oasis ecosystems are emissions generated by livestock activities, nitrous oxide emissions from mineral fertilizers and pesticides, and the burning of biomass. Livestock-related emissions are primarily methane emissions related to enteric fermentation in ruminants and, secondarily, nitrous oxide emissions from manure and the burning of biomass and other wastes.

Livestock—especially pastoral livestock associated with small-scale traditional breeding—has some importance in oasis environments. The emissions of nitrous oxide from mineral fertilizers and pesticides are minimal in oasis ecosystems due to the low use of chemical nitrogen fertilizers. The use of manure, on the other hand, is quite common.

GHG removals are solely the result of the AFOLU sector. Carbon fluxes (mainly carbon dioxide) can be positive (emissions) or negative (removals) and result from:

- **Plant growth on cultivated land**, mainly arboriculture, forests, and pastoral plantations
- **Changes in land use** such as afforestation, land artificialization, and deforestation
- **Land degradation** due to the decomposition of soil organic matter (either biologically or due to the sun's ultraviolet rays)
- **The burning of biomass waste**.

Table 5 provides a summary of GHG emissions and removals for the AFOLU sector in Tunisia's oasis landscapes. This data shows that oasis landscapes are net GHG emitters, despite estimated removals of 164,725 tCO_2e by oasis crops, mainly date palms. Most of the emissions come from the exploitation of grazing lands, which cover more than 1.6 million hectares (ha), 10 percent of which would have been developed under various previous projects.[8]

8 Among other projects financed by IFAD (the International Fund for Agricultural Development).

Table 5: *Summary of greenhouse gas emissions from the agriculture, forestry, and other land use sector in oasis ecosystems (expressed in tCO_2e)*

Sector Sources of emissions	Direct gross emissions (All greenhouse gases)	CO_2 removals	Balance sheet: net CO_2 emissioans	Other non-CO_2 emissions
Livestock (total)	9,308	–	–	9,308
Enteric fermentation	8,728	–	–	8,728
Manure management	579	–	–	579
Land use (total)	504,518	-164,724	339,794	*
Forests		-28,831	-28,831	
Crops		–	–	
Date palm	0	-68,284	-68,284	*
Miscellaneous fruit growing	0	-308	-308	*
Rangelands and pastures	504,518	-67,301	437,217	
Wetlands		–	–	
Other aggregated sources of non-CO_2 emissions from land (total)	9,351	–	9,351	755
Emissions from biomass burning	9,351	–	9,351	701
Direct emissions of nitrous oxide from managed soils		–	–	40.5
Indirect emissions of nitrous oxide from managed soils		–	–	13.4
Other (total)	21,285	–	21,285	–
Harvested wood energy	21,285	–	21,285	–
TOTAL	**544,462**	**-164,725**	**379,737**	**10,063**

Source: Compiled for oasis landscapes based on Republic of Tunisia (2022b).

Energy sector emissions attributable to the agricultural sector are due mainly to the consumption of electricity for water pumps, refrigeration, and the packaging of dates. Pumping emissions are estimated at 29,492 tCO_2e per year (Table 6). These results show heterogeneity in the level of reported emissions per hectare, especially between the Governorate of Kébili and the governorates of Gabès and Tozeur.

According to available data from the Interprofessional Date Producer Group (GID, 2023), there are 473 cold storage warehouses for dates in oasis regions, totaling 810 cold rooms with a total capacity of 77,010 tons. On this basis, electricity consumption for the cold storage of dates amounts to 26,888,796 kilowatt-hours (kWh) per year, with an average of 116 kWh per ton of dates. This corresponds to emissions of 145.9 kilograms (kg) of CO_2 equivalent per ton stored, or a total of 11,240 tCO_2e.

Wastewater treatment plants use electricity to pump and circulate water. Thus, according to the annual activity report of the National Sanitation Office (ONAS, 2021), the energy consumption of wastewater treatment plants in oasis governorates was 7,159,645 kWh per year. At a rate of 0.418 kg of CO_2 equivalent per kWh, this consumption corresponds to the emission of 2,993 tCO_2e per year.

Table 6: *Greenhouse gas emissions due to the use of electrical energy for pumping*

Governorate	Area (ha)	Emissions per ha (tCO_2e)	Total tCO_2e emissions	Comments
Gabès	6,382	1.21	7,717	Estimate based on installed power of pump units and their flow rates
Kébili	7,636	0.73	5,589	Estimate based on energy expenditure for pumping
Tozeur	9,574	1.35	12,909	Estimate based on installed power of pump units and their flow rates
Gafsa	2,950	1.11	3,278	Estimate based on the average of the other three governorates
TOTAL	**26,542**	**1.11 (average)**	**29,492**	

Considering the above developments and referring to oasis ecosystems, most of the options and actions considered in the updated NDC can be applied to oases (with approximations). Table 7 summarizes the balance of GHG emissions in oasis ecosystems for the year 2021. This report shows the predominance of the AFOLU sector, both in terms of emissions and GHG removals.

Table 7: Greenhouse gas emissions balance and removals in oasis ecosystems in 2021 (in $ktCO_2e$)

Sector	Emissions	Absorption	Balance
Agriculture, forestry, and other land use	544,462	-164,725	379,737
Energy sector			
Pumping	29,492	0	29,492
Stores	11,240	0	11,240
Wastewater treatment plants	2,993	0	2,993
Waste sector	N/A		
TOTAL	**588,187**	**-164,725**	**423,462**

2.4 Greenhouse gas mitigation potential

The set of mitigation options and actions advocated in the updated NDC can be divided into two subsets: (i) integrated and territorial options to be applied to different types of agricultural, forest, and pastoral landscapes, such as good agricultural practices, soil improvement through biochar, and organic farming, and (ii) "generic" options that have a horizontal character with extensions in different sectors of socioeconomic life, such as energy efficiency options. The integrated and territorial options do not cover oasis ecosystems, although these are an integral part of the steppe pastoral landscapes of southern Tunisia. This is because the extent of oasis ecosystems is tiny compared to the landscapes that encompass them, representing barely 1 percent of cultivated agricultural land.

To further analyze the GHG mitigation potential of oases in Tunisia, the interventions proposed in the NDC were grouped into eight comprehensive options that allow for a detailed assessment of the carbon sequestration potential (and thus possible GHG emission reductions). The potential co-benefits, particularly in terms of job creation, were also assessed. Chapter 3 provides more detail on the job-creation aspect of these options.

Integrated and participatory development of collective rangelands

This option consists of developing and implementing management plans for rangelands, which largely define the landscapes around oases and occupy up to 74 percent of the useful agricultural area in southern Tunisia. This option is also recommended in the Tunisian Strategy for Climate-Neutral and Resilient Development to 2050.

Integrated management plans could be developed in a participatory manner by involving livestock farmers, management consultants, and the communities concerned. Such plans typically focus on integrating fodder trees and shrubs according to agroecological zones, reseeding indigenous pastoral species, promoting pastoral byproducts (such as wool and milk), and promoting new income opportunities such as local aromatic plants.

Implementing this option is complex and depends on the agroecological conditions of each area, as well as its socioeconomic and land context. This implies the need to develop technical models, management methods, and specific development projects for each oasis or group of oases.

Anticipated impacts: An estimated 1.3 tCO_2e per hectare per year of soil organic carbon (SOC) would be sequestered. Co-benefits relate to increased fodder and therefore meat production, as well as biodiversity conservation. An estimated 14 jobs would be created for every 1,000 ha developed. Implementing this option would cost TD 1,000 per hectare and generate an added value of TD 760.5 per hectare per year (approximately US$246).

Multilayered cultivation

This option consists of the gradual conversion of "modern" date palm groves, which largely produce only Deglet Nour date palms, into a multilayered cultivation system that would more closely resemble the practices in traditional oases. This conversion to a multilayered cultivation system would require the following:

Equipping farms with water-efficient irrigation systems

Introducing fruit trees, fodder, vegetables, and medicinal and aromatic plants, together with livestock and aquaculture

Valorizing the agricultural and livestock products of the oasis

Strengthening awareness, information, and training in agroecology within the oasis system.

This proposal aims to plant 50 to 70 plants of different fruit tree varieties and to grow seasonal or annual crops (vegetables and others) in a quarter of the area, twice per season. This option could be applied to old date palm groves in the governorates of Tozeur and Kébili, as well as unregulated expanded date palm plantations in the Governorate of Kébili.

Anticipated impacts: This option is expected to bring various benefits. Ecologically, this approach is expected to strengthen the so-called "oasis effect", which will see three climatic elements (luminosity, wind turbulence, and evaporation) attenuated compared to the Saharan climate. The environmental aspect mainly manifests in the increase of the stock of above-ground biomass in the arboreal layer—which represents a form of atmospheric carbon sequestration—and an increase of SOC due to the accumulation of underground biomass from tree roots and herbaceous crop residues. This option depends on sufficient water resources (such as water towers and streams), investments to establish orchards, and inputs and labor to maintain orchards and manage annual crops. More importantly, it requires farmers to adopt these techniques.

Brahim et al. (2021) showed that the amounts of SOC in the soils of traditional oases are much higher than in the soils of modern oases, and that the amounts of carbon in the soils of chotts and natural rangelands around oases are much lower, especially in the surface layer [0–30 centimeters (cm)] (Table 8).

Table 8: *Soil organic carbon (SOC) content in different types of oases, rangelands, and chotts*

	Depth (cm)	Organic matter (%)	SOC content (%)	Quantity organic matter (t/ha)	Quantity of SOC (t/ha)
Traditional oasis	0–30	1.87	1.085	85.55	49.64
	0–60	1.81	1.05	165.6	96.08
Modern oasis	0–30	0.97	0.563	44.38	25.76
	0–60	0.74	0.429	76.95	44.64
Natural route around the oases	0–30	0.03	0.017	1.37	0.78
	0–60	0.08	0.046	4.95	2.84
Chott or wetland	0–30	0.14	0.081	6.405	3.71
	0–60	0.12	0.07	11.7	6.80

Source: Brahim et al., 2021

While it can be assumed that the gradual conversion of modern palm groves would increase (double) the storage of SOC, it is difficult to estimate the time over which this might occur. Considering a period of at least 20 years for SOC accumulation, an average annual SOC storage of 1.19 tons of carbon per hectare can be estimated. The conversion of palm groves into multilayered cultivation systems should allow for the storage of 23.88 tons of carbon per hectare during the first 20 years and the sequestration of 0.34 tons of carbon per hectare per year through above- and below-ground biomass. The implementation of this option would cost about TD 4,450 per hectare without livestock and would generate an estimated additional gross income of TD 7,500 per year (approximately US$2,427) from the start of tree-layer production.

Adoption and dissemination of sustainable land and water management practices

This would involve adopting and disseminating good agricultural practices aimed at strengthening the climate resilience of oasis farms through improved irrigation water management, the integration of hedgerows, organic farming, and soil amendment by biochar.

Strengthening irrigation water management

Introducing a precision irrigation system that effectively controls the amount of water applied to each palm tree or plot would reduce water losses. However, the lack of recent studies on date palms in Tunisia makes it difficult to estimate the volume that could be saved. In general, studies estimate that introducing a precision irrigation system (two nozzles with a flow rate of 100 liters per hectare per date palm tree) could save up to 50 percent of the irrigation water and make it possible to increase the irrigated area by intercropping perennial or annual crops. This option is technically and economically feasible but requires investment and a water policy that encourages water savings. It will also be necessary to maintain drainage systems and to carefully manage salt accumulation and soil drainage. In terms of costs and benefits, this practice is equivalent to transforming modern oases into multilayered oases.

Anticipated impacts: The impact of the option may include a saving of up to 40 percent of irrigation water, or 6,266 cubic meters per hectare per year at a cost of TD 752, or TD 0.12 per cubic meter. A reduction in the pumping time would reduce electricity costs estimated by TD 186 per hectare per year (approximately US$60.10). The water savings achieved by limiting water loss, especially in cases where the aquifer is overexploited, should make it possible to maintain or even restore the static level of the water table and strengthen the sustainability of the operation.


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Integration of hedgerows

This practice involves planting rows of hedges using shrubs and plants such as alfalfa (*Medicago arborea*), perennial grasses such as vetiver (*Chrysopogon zizanioides*), or panicum maximum (*Megathyrsus maximus*). Once planted, the hedgerows can be used (and maintained) by periodically cutting the biomass for livestock. In general, hedges have many functions, such as marking the boundaries of fields and plots, regulating water and protecting soil, and acting as a wind break. In this way they limit the risks and effects of climate change-driven droughts, produce fodder and biomass, conserve biodiversity, and promote pollination.

Anticipated impacts: This option is simple and could be facilitated by conducting demonstration plots and evaluating its effects and impacts. Environmental benefits include soil fixation, windbreak effects, and increases in SOC due to the accumulation of underground biomass from the roots of the plants used. In the case of vetiver, the hedges can act as a barrier against certain pests. Socioeconomic benefits include the production of fodder for livestock and the provision of additional working days. In the case of using vetiver, a hedge 1 meter long with two lines of vetiver, staggered at a distance of 15 centimeters between the plants and the lines, would sequester 5.28 kg of carbon dioxide equivalent per linear meter at the end of the third year and produce 1.33 fodder units per square meter per year.

Organic farming and integrated pest management

This practice avoids the use of synthetic chemical fertilizers and pesticides through various crop- and soil-management techniques such as the use of compost, organic manure, compost juice, or biochar. Organic farming in Tunisia enjoys a favorable regulatory context with some financial incentives. In 2021, organic crops represented 2.9 percent of usable agricultural area (279,389 ha), most of which were organic olive trees (260,408 ha) (Paull, 2024).

Table 9 shows the evolution of the area under organic farming in oasis governorates. This progression points to significant potential to transition to organic farming for date palms. The cost of implementing this practice is estimated at TD 800 per hectare per year (approximately US$259).

Anticipated impacts: This option's impact lies in avoiding GHG emissions from the production and use of chemical fertilizers and synthetic pesticides. This reduction is estimated at 1.6 tCO_2e per hectare per year. In addition, the income gains on the export price of certified organic dates (10 percent, which is passed on to producers) is estimated at TD 1,705 per hectare per year (approximately US$551.70). In terms of employment, this option could generate 10 to 15 working days per year for the cleaning of plots, setting up and control of traps and, if necessary, phytosanitary treatment with biopesticides. Implementing this option is relatively simple and does not require any specific technical knowledge. In addition, its implementation could be supported by conducting demonstration plots and evaluating its effects and impacts.

Table 9: *Organic farming in oasis governorates, in hectares*

Governorate	Year			
	2015	2016	2017	2018
Gabès	391	125	152	394
Gafsa	3,772	5,437	5,656	5,085
Tozeur	530	565	706	672
Kébili	1,126	1,041	1,898	1,926
TOTAL	**5,819**	**7,168**	**8,412**	**8,077**
of which date palms	**1,200**	**1,701**	**2,946**	**2,789**

Soil amendment by biochar

Biochar is non-activated charcoal obtained from the pyrolysis of plant biomass of various origins (such as agricultural residues, forestry residues, and small pruned cuttings). Biochar can improve the physical, chemical, and microbiological properties of soils, including: (i) porosity, bulk density, water- and nutrient-holding capacity, hydraulic conductivity, and aggregate stability; (ii) cation exchange capacity and soil pH; and (iii) microbial composition and activity. However, using biochar in areas with less than 350 millimeters of annual rainfall is not advisable unless there is irrigation. Particularly poor soils may benefit from biochar—in sandy soils, biochar retains water and makes minerals available to plant roots, while in clay soils biochar allows water to infiltrate and remain in the soil, preventing mineral losses through runoff and leaching. Biochar can also be combined with composting operations or mixed with compost. When mixed with manure, biochar captures ammonia and converts it to nitrate.

Biochar is applied at a rate of 5 to 50 tons per hectare (depending on soil type), staggered over time. Incorporating biochar into ruminant diets as a feed additive would reduce methane emissions. However, the use of biochar has a major drawback: Its physicochemical properties vary due to the nature of the biomass used and the method of its production (pyrolysis temperature, treatment time, and additives).

Anticipated impacts: Oases produce large quantities of plant biomass as byproducts, especially pruning waste from palm and small fruit trees, which could be recovered through biochar production or composting. Given the potential functionalities of biochar in terms of GHG mitigation and the restoration of degraded soils in oases and given the lack of Tunisian references in this field, implementing this option would have an "applied research" character.

Biochar would increase crop yields through its effects on soil biological activity, soil fertility, improved soil water-retention capacity and, in some cases, through plant protection (Haddad, 2018). Carbon sequestration would amount to an estimated 3.66 tCO_2e per ton used, and increase crop yields by at least 30 percent, resulting in additional production of about TD 4,500 per hectare per year from the fifth year (calculated on the basis of an average annual gross product of TD 15,000 per hectare of oases). The costs are estimated at TD 3,985 per ton (approximately US$1,290), corresponding to the acquisition of biochar (TD 3,600, at a rate of TD 240 per ton), its inoculation with manure (three tons of manure at TD 50 per ton), and incorporation into the soil (TD 135 for machines and labor).

Valorization of date palm byproducts

Byproducts consist mainly of dry matter from the annual pruning of date palms (the volume of which can be estimated at 70,513 tons per year), date waste sorted at the time of harvest, (estimated at 35,000 tons), date pedicels (estimated at 2,600 tons), and wood biomass from the trunks of dead or renewed palm trees. Depending on their nature, these byproducts are currently utilized in the following ways, among others: (i) composting of palm trunks and stalks; (ii) construction of palm plot fencing; (iii) using the palm trunk (kernaf) as an energy source in traditional brick kilns; (iv) carpentry from the trunk wood; (v) basketry from palm leaves and the heart of the palm tree; and (vi) the production of vinegar from dates, as well as cattle feed from date waste and peduncles, and so on. Therefore, four sub-options were selected, namely compost production, animal feed production, non-activated biological charcoal (biochar) production and, incidentally, the renewal of old palm trees.

Compost production

Composting is a process of aerobic transformation of organic waste to obtain a stabilized fertilizer, rich in humus. It is widely used in agriculture to enrich and maintain agricultural soils and improve soil organic matter. Byproducts suitable for composting include dried palm and date stalks, palm trunk cleaning waste, and wood pruned from fruit trees. The typical composting process includes grinding, windrowing on a hardened and shaded surface, and regular temperature control.

This option is technically and economically feasible. Its implementation requires preliminary studies to assess the profitability of investments related to the collection and cost of the raw material (biomass waste), the purchase of equipment, and the operation of the production process.

Anticipated impacts: The manufacturing of compost decomposes plant waste, which would have otherwise been burned, releasing carbon dioxide, or in some cases, methane, which has 23 times larger GHG warming potential than carbon dioxide. According to some studies, the net impact of composting would be a reduction of 35 kg of carbon dioxide equivalent per ton of wet organic waste composted, or 233 kg of carbon dioxide equivalent per ton of dry organic waste. Compost production also provides opportunities for job creation.

Livestock feed manufacturing

Livestock feed production depends on the availability of raw materials and equipment to mill and blend different components. Depending on the availability of byproducts such as date waste, dry palms, olive pomace, and date pits, animal feed could be produced to support livestock activities. It is already practiced on a small scale and has been the subject of pilot studies in the region by the Food and Agriculture Organization, among others (Najar, 2013; Najar and Nasr, 2017; Najar and Nasr, 2018). This option is therefore technically and economically feasible because it is already being practiced, albeit in a rudimentary and empirical manner.

Anticipated impacts: This option's impact is socioeconomic in that it results in the manufacture of a product that has market value and creates jobs. From an environmental point of view, this option does not have a significant impact because the byproducts used, such as date waste, are rarely discarded and are traditionally recycled in ways that may technically be less efficient.

Renewal of old date palm trees

The renewal of old palm trees consists of uprooting them and replacing them with young plants. It is part of the normal maintenance of palm groves. However, there has been a slowdown in the rate of palm grove renewal, which has led to a decrease in the productive potential of oases in terms of biomass (fruit and wood), as well as the standing carbon stock of biomass.

According to data from the 2018 Oasis Survey, Tunisian oases have about 5.2 million palm trees, of which 17.2 percent (896,635 palm trees) are more than 50 years old and unproductive (ONAGRI, 2022). Thus, to maintain the current productive potential (and based on a felling age of 60 years) at least 89,600 palm trees should be renewed each year, an average of two date palms per hectare per year.

Anticipated impacts: Renewing 89,600 date palm trees would provide sufficient material for handicraft activities and basketry (about 89,600 tons of wet trunk wood and 448 tons of date palm hearts).

Biochar production

Biochar is a non-activated charcoal of plant origin obtained by pyrolysis of plant biomass. This option is technically feasible but is currently implemented only at the pilot level or research scale. Scaling up biochar production requires preliminary studies to assess the profitability of investments and the potential of the various sources for biochar production.

Producing biochar costs about TD 186.70 per ton (approximately US$60) and the suggested selling price is TD 240 per ton (approximately US$78). Accordingly, it is recommended that a pilot project for the production and use of biochar be prepared and implemented. Such a project would require investments for equipment acquisition and to cover operating costs relating to the collection of raw materials, the production process, and so on. This would determine the competitiveness in terms of cost and benefits for soil fertility and productivity.

Anticipated impacts: The environmental benefits revolve around the reduction of GHG emissions due to the recovery of organic biomass waste from oases through the manufacture of biochar, estimated at 2.86 tCO_2e per ton of biochar produced

Recovery and reuse of treated wastewater

This option consists of valorizing existing treated wastewater to rehabilitate and extend certain irrigated public perimeters (PPI), create new perimeters near future wastewater treatment plants, and substitute and mix drilling water with treated wastewater in oases or PPI near wastewater treatment plants. This option has been considered in the National Master Plan for the Reuse of Treated Wastewater in Tunisia by 2050, which is in line with the NDC. According to this master plan, increasing the reuse of treated wastewater in southern Tunisia will not have a significant impact on the regional water deficit. However, high local water demand may justify establishing small agricultural irrigation projects near wastewater treatment plants. In the four targeted oasis governorates, 2,157 ha of new irrigated land could be created using the 6,452,000 cubic meters of water from local wastewater treatment plants. The remaining volume of water produced could be used for other applications, such as industrial purposes or irrigating urban green spaces and sports areas.

Anticipated impacts: The new plantations of olive trees and other fruit species planned on 677 ha under various projects (MARHP and AFD, 2023) would contribute to GHG mitigation. The 2,157 ha of new irrigated land created using treated wastewater would include 677 ha of new plantations of olive trees and other fruit species and 1,480 ha of rehabilitated or protected oases, resulting in a 40 percent increase in production. These new and rehabilitated plantations would create jobs at an estimated rate of 117 days per hectare for new areas and 67 days per hectare for rehabilitated areas.


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Recovery and reuse of drainage water

Saline wastewater is used by farmers in several countries, including the United States, Spain, India, China, Pakistan, Iraq, Iran, Egypt, and most of Central Asia. In India, for example, saline drainage water is used to irrigate crops such as wheat, millet, and sorghum. The salts accumulated in the soil by the saline water are then leached out by the monsoon rains.

There are two options for using saline drainage water for agricultural production. The cyclic strategy uses drainage water and non-saline irrigation water in moderately sensitive and salt-tolerant crop rotation. This involves mixing saline drainage water with non-saline water before or during irrigation. Thus, different water qualities are obtained depending on the availability of each quality and quantity of irrigation water between or during irrigation periods. The second option applies relatively good quality water to crops with the lowest salt tolerance and then uses drainage water from that field to irrigate crops with higher salt tolerance.

Three options were identified to valorize saline drainage water from irrigated areas: (i) aquaculture to produce fish; (ii) planting fodder shrubs; and (iii) planting and irrigating forest species and date palm pollinators.

Despite its potential in terms of environmental and socioeconomic benefits, the use of saline drainage water is limited by the seasonal variability of drainage water volumes, the salinity of drainage water, and the lack of knowledge or experience in this area, which determines the predisposition of oasis populations to adopt the identified measures. There are many other areas and opportunities for such valorization outside agricultural production, especially in industry.

This option is technically and economically feasible. However, its implementation will require a pragmatic approach of concerted planning for the management of oasis territories, which would consider the specific context of each group or type of oasis, especially regarding the land issue and the management of the achievements in this field.

Anticipated impacts: An ecological and environmental benefit is the sequestration of atmospheric carbon in the above and below ground biomass of forest plantations, while socioeconomic benefits are related to job creation. The economic potential of the recovery and reuse of saline wastewater includes fish production by establishing aquaculture farms and the production of forage.

Widespread use of solar electricity (photovoltaics)

This option involves substituting fossil-fuel grid electricity with photovoltaic (solar) electric energy at water pumping stations, date cold stores, and sewage treatment plants in the area. These facilities could be equipped with solar electricity production systems connected to the national electricity grid. Although this option is technically and economically feasible in the current situation, its implementation and upscale would be confronted by the current regulatory context governing the production of renewable energy, which would benefit from being reviewed and reformed.

Anticipated impacts: This option would prevent 0.374 kg of carbon dioxide equivalent being emitted for each kWh of electricity substituted by solar electricity. Compared to GHG emissions from electricity produced in gas-fired power plants, the total emission reduction would be 36,454 tCO_2e (including 26,395 tCO_2e currently emitted from pumping and 10,059 tCO_2e currently emitted by refrigeration).

2.5 Challenges and opportunities for climate change mitigation in oasis landscapes

Oasis ecosystems have important ecological, economic, and livelihood functions for southern Tunisia, but are at risk of experiencing significant degradation in the long term due to overexploitation of groundwater resources and the increasingly felt impacts of climate change. Oasis ecosystems therefore play an important role in Tunisia's NDC, particularly in terms of their potential to mitigate climate change and create jobs. In practice, the above options are feasible and show that the NDC can be translated into practical climate change mitigation options.

The options identified are mainly based on improving and rationalizing existing natural resource management practices, such as the use of water resources, agricultural practices, irrigation techniques, land use, valorization of products and byproducts, and the restoration and integrated management of degraded landscapes. To this end, most of these options are based on a "transformational" approach aimed at changing or transforming current practices and strengthening the resilience of oasis ecosystems. The integrated development of natural rangelands, compost production, and fodder production would benefit from further technical studies. The production and large-scale implementation of biochar as a soil amendment also requires further research. Table 10 and Table 11 outline the various mitigation options described in this section, summarizing their impacts in terms of GHG mitigation and co-benefits, their feasibility, and their areas of application.

Table 10: *Summary of different greenhouse gas mitigation options in oases*[10]

Option	Impacts		Feasibility	Fields of application
	Greenhouse gas mitigation	Co-benefits		
1. Integrated and participatory development of collective rangelands	1.3 tCO_2e/ha/year	Fodder production Local biodiversity conservation Job creation	Medium, depending on the agroecological and socioeconomic conditions of each oasis	To be studied on a case-by-case basis
2. Multilayered cultivation	87 tCO_2e/ha in soil after first 20 years	Diversification Increase in employment: 75 to 100 working days/ha Added value of TD 3,600/ha/year	Medium, dependent on available water resources, available investments and support by the regulatory framework	Modern oases
3. Adoption and dissemination of sustainable land and water management practices				
3.1. Strengthening irrigation water management	Reducing emissions from water pumping	Reduced energy costs	Medium, subject to maximizing benefits from water savings	All oases
3.2. Hedgerows of trees, alfalfa, or vetiver	Windbreak effect Carbon sequestration in the soil	Fodder production: 3.55 units/m^2/ year or 2,450 units/ha Improving employment	Strong, because this practice is simple to implement	Traditional oases and converted modern oases
3.3. Organic farming and integrated pest management	Reduction of GHG emissions from synthetic fertilizers and pesticides	8 to 10 workdays/ha/year Possible 10% capital gain on the producer prices of organic dates	Medium, subject to favorable regulatory context	All oases
3.4. Soil amendment by biochar	Potential for soil carbon sequestration: 3.66 tCO_2e per ton used	Improvement of soil fertility and crop yields by about 35%	Low to medium as it is a new practice	One or more sites depending on the main soil types
4. Valorization of byproducts				
4.1. Compost production	Reduction of GHG emissions	Recovery of plant waste Creating green jobs	Medium, but requires preliminary feasibility studies	All oases
4.2 Livestock feed manufacturing	Negligible	Recovery of byproducts Creating green jobs	Strong, but requires preliminary feasibility studies	All oases
4.3. Renewal of old palm trees	Maintain or even increase the standing carbon stock	Strong because it is part of traditional practices in oases	All oases	
4.4. Biochar production	Reduction of GHG emissions at a rate of 2.86 tCO_2e per ton produced	Recovery of plant waste Creating green jobs	Low to medium, but limited short-term feasibility	
5. Recovery and reuse of treated wastewater	Reduction of GHG emissions in tree biomass	Increase in production Creation of green jobs	Strong, but should be part of master plan for water reuse	All oases close to wastewater treatment plants
6. Recovery and reuse of drainage water	Reduction of GHG emissions by pastoral plantations	Increased fodder availability Aquaculture (freshwater fish)	Low, but condition to robust planning in oasis landscapes	All oases
7. Widespread use of solar electricity	GHG emission reduction of 0.374 $kgCO_2e$ per kilowatt-hour	Creation of green jobs	Strong, but requires regulatory support and investments	All oases

10 Tables 10 and 11 were adapted from Table 3 (NDC table) for the purposes of this study.

Table 11: *Results of the assessment of different greenhouse gas mitigation options in oases*

Option	GHG mitigation	Improving resilience	Increased production or yields	Increased revenue or reduced costs	Job creation or improvement	Conservation or enhancement of Biodiversity
1. Integrated and participatory development of collective rangelands	1.3 tCO_2e/ha/year	++	++	++	+	++
2. Multilayered cultivation	87.6 tCO_2e/ha in soil after 20 years	++	++	++	++	++
3. Adoption and dissemination of sustainable land and water management practices						
3.1 Strengthening irrigation water management	Emission reduction of 0.44 tCO_2e/ha	++	Production increased by 40%	++	+	±
3.2 Hedgerows of trees, alfalfa, or vetiver	+	+	+		+	+
3.3 Organic farming and integrated pest management	+	+		+	±	±
3.4 Soil amendment by biochar	3.66 tCO_2e per ton of biochar used	++	+++	+	+	+
4. Valorization of byproducts						
4.1 Compost production	+	+		+	+	+
4.2 Livestock feed manufacturing	±	+		+	+	+
4.3 Renewal of old palm trees	+	+	+	+	+	±
4.4 Biochar production	2.86 tCO_2e per ton produced	++	+++	+	1.54 working days per ton of biochar produced+	+
5. Recovery and reuse of treated wastewater	+	++	++	+	+	+
6. Recovery and reuse of drainage water	+	+	+	+	+	+
7. Widespread use of solar electricity	++	+		+	++	+
±: Negligible potential; +: Low/limited potential; ++: Average potential; +++: Strong potential.						

The increased uptake of solar electricity would create a number of service jobs (for example, equipment installation and maintenance), as would the possible expansion of irrigation systems, which would be made possible by a substantial reduction in water losses. Land rehabilitation would create jobs in compost production and related services. In addition, overcoming farmer absenteeism and dispersed ownership would revitalize oasis-based livelihoods, increase investment, and sustain or create new jobs. Opportunities also lie in encouraging small and medium-sized service enterprises to carry out agricultural work. Services could include plot cleaning, plantation maintenance, pollen harvesting and palm pollination, and date harvesting. Date pollination, in particular, requires skilled labor and is an important factor for the quality of dates.

Successfully implementing the above climate change mitigation and job creation options will depend on addressing the following management and natural resource governance issues, among others:

- Implementing the NDC in oasis ecosystems would require, and benefit from, **reducing water losses from existing irrigation systems, regulating boreholes, and addressing the unregulated expansion of date palm plantations** as part of a participatory, responsible, and sustainable co-management approach to groundwater. In addition, electric water pumping is becoming increasingly expensive for agricultural development groups (GDAs), which remain indebted to the national electricity utility. This is straining their operating budgets.

- **Access to land, especially communal land in the Kébili Governorate, remains a bottleneck for many interventions.** While land tenure is well understood in the oases of Gabès, Tozeur, and Gafsa governorates, it remains a challenge in the Kébili Governorate because the oases are located on communal land. In addition, the fragmentation of land tenure and the abandonment of small plots or farms limits acceptance.

- **The conversion of so-called "modern" palm groves to fruit trees, herbaceous, and annual crops will largely depend on farmer acceptance.** Introducing new practices will require considerable effort in terms of training, supervision, and monitoring.

Valorizing palm wood byproducts (palms, wood, and so on) carries a **risk of competitiveness due to the variety of uses and forms of exploitation** of these byproducts. The operationalization of the updated NDC and related strategies should capitalize on previous achievements, particularly those that relate to research activities and local knowledge about the rehabilitation and sustainable management of oasis ecosystems.

It will also be necessary to establish a promising institutional and legal framework that is better adapted to the context and specificities of oasis landscapes and conducive to the convergence of sectoral policies. The regulatory environment for water and agricultural land use needs to be updated, while the national investment code should also consider the specific needs of oases. Finally, the necessary conditions for the sustainable development of oasis ecosystems should be facilitated in terms of governance, the balanced and equitable use of natural resources (water and land), and the goods and services they provide.

Oasis ecosystems have important ecological, economic, and livelihood functions for southern Tunisia but are at risk of experiencing significant degradation due to overexploitation of groundwater resources and the impacts of climate change

3

Job creation potential

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There are many opportunities for creating green jobs in oases, which can also be linked to the GHG mitigation options advocated in the NDC. In addition to their impact on reducing emissions, these options have co-benefits that contribute to improving and creating green jobs.

These opportunities are based on overcoming challenges, diversification, better valuation of oasis products, and using natural and cultural heritage assets. Ten potential opportunities for creating green jobs were identified in three main areas of intervention.

Eight of these opportunities are related to GHG mitigation options with two other opportunities related to the valorization of oasis products and the valorization of the intangible assets of oasis landscapes (natural and cultural heritage). These last two options have been added to strengthen the economic and social resilience of oasis landscapes. The opportunities are listed in Table 12, indicating the type of oasis concerned.

Table 12: *Job creation opportunities identified*

Area of intervention Measures		Type of oasis concerned	Sector of activity
ENABLING SUSTAINABLE NATURAL RESOURCES MANAGEMENT			
1.	Strengthening irrigation water management	All oases managed by GDAs	AFOLU
2.	Recovery and reuse of treated wastewater		
3.	Recovery and reuse of drainage water		
4.	Widespread use of solar electricity		Energy
	Water pumping		
	Cold storage and packing stations	Managed by private actors for all oasis types	
5.	Integrated and participatory development of collective rangelands	Traditional	AFOLU
	Valorize desert biodiversity		
	Create fodder reserves		
	Create forest and pastoral plantations with drainage water		
VALORIZATION OF OASIS PRODUCTS			
6.	Multilayered cultivation	Modern	AFOLU
7.	Valorization of byproducts	All oases managed by GDAs	Waste
	Compost production		
	Livestock feed manufacturing		
	Biochar production		
	Renewal of old palm trees		
	Mechanized agricultural service units		
8.	Optimization of oasis farm management		
VALORIZATION OF NATURAL AND CULTURAL ASSETS			
9.	Benefit from natural and cultural heritage	Traditional	Tourism
	Oasis cottages, agritourism, and culinary tourism		
	Development of ecotourism circuits		

3.1 Opportunities related to enabling sustainable natural resource management

Oasis ecosystems face many challenges, including water overexploitation, water losses in irrigation systems, and high pumping costs that burden local communities and administrations. The lack of maintenance in oases has also become increasingly problematic and is closely linked to absenteeism, the abandonment of small plots, the disenchantment of young people with oasis agriculture, the aging of farmers, and the inadequacy of the regulatory and legal framework for agriculture. To overcome the perceived gap in the production potential of oases, strengthening specific production and introducing new methods can provide an opportunity for sustainable natural resource management and job creation.

Strengthening irrigation water management

Reducing pumping time in traditional oases would mean a reduction in production costs and more sustainable water use, with an estimated saving of TD 163 per hectare per year. Using the water savings to further intensify production by introducing a multilayered cultivation system in modern oases would generate 67 working days per hectare per year and an additional value estimated at TD 3,600 per hectare per year (approximately US$1,165 equivalent). In terms of cost, this option requires an initial investment estimated between TD 2,500 and TD 4,450 per hectare (approximately between US$809 and US$1,440). It should be noted that this intervention requires restoring and maintaining drainage systems to ensure the removal of saline water.

Recovery and reuse of treated wastewater

Reusing treated wastewater, as described in the previous chapter, was selected as an option to mitigate GHG emissions and improve the resilience of oasis economies. Based on the four oasis governments, this option would create or rehabilitate 2,157 ha of oases by 2050. This area would be developed to irrigate 677 ha of olive and fruit trees, 940 ha of palm grove without vegetable crops, and 540 ha of fodder crops. This option should eventually generate 117 working days per hectare per year, corresponding to 841 direct jobs and an estimated added value of TD 18,000 per hectare per year (approximately US$ 5,825).

Recovery and reuse of drainage water

The recovery of saline drainage water has been selected as an option to reduce GHG emissions and to improve the resilience of the oasis economy. Although this option has significant environmental and socioeconomic impacts, the lack of data on the availability and quality of the drainage water does not allow for an assessment of the potential impacts and requires further study.

Widespread use of solar electricity (photovoltaics)

This opportunity concerns water pumping stations in oases as well as cold storage for dates. Systematically equipping water pumping stations with photovoltaic electricity production systems should eventually create a certain number of jobs in the photovoltaic sector and reduce costs for the government and farmers. Based on Tunisian experience in the field of photovoltaics, the installation of an estimated 70.5 MW of photovoltaic electricity generation per year would create 916.5 jobs, of which 246.75 are upstream jobs (manufacturing and distribution), and 669.75 are downstream jobs (installation, maintenance, and so on). Installing such a capacity should reduce emissions to 3,097 tCO_2e per year, a reduction of 26,395 tCO_2e per year. The investment cost is estimated at TD 7,428 per hectare (approximately US$2,404).

Similarly, equipping cold storage for dates with photovoltaic electricity production would also create a certain number of jobs in the photovoltaic sector and reduce GHG emissions. Cold storage consumes an estimated 26,889 MW per year. The installation of photovoltaic electricity would provide 350 jobs, including 94 upstream jobs and 255 jobs downstream in oasis governorates. The installation should reduce GHG emissions to 1,180 tCO_2e per year which is a reduction of 10,059 tCO_2e per year. Investment costs are estimated at TD 977 per ton (approximately US$316) of refrigeration capacity.

Integrated and participatory development of collective rangelands

This opportunity is linked to the GHG mitigation option identified and described in Chapter 2. Implementing this option should improve rangeland productivity for fodder production and strengthen the related downstream sector. Referring to the experience of previous similar projects in southern Tunisia, this option should create 14.1 full time equivalent (FTE) jobs per 1,000 ha developed, based on an investment cost of TD 1,000 per hectare and an average direct job creation cost of TD 71,236 (approximately US$23,052).

3.2 Opportunities related to the valorization of oasis products

The valorization of products and services from oases provides income and opportunities for job creation. The options presented here are largely based on the options presented in Chapter 2 for GHG mitigation.

Multilayered cultivation

This option is linked to the same option described in Chapter 2. It includes planting 70 plants per hectare, introducing small ruminants based on fodder produced on 0.25 ha, and growing vegetable crops on 0.2 ha at a rate of two crops per season. This option requires investment and working capital for the management of annual crops and tree plantations, estimated at TD 4,450 per hectare (approximately US$1,440), including TD 1,300 for fruit tree planting, TD 2,650 for irrigation, and TD 500 for operation. Implementing this option should allow additional production estimated at TD 7,500 per hectare per year (approximately US$2,427) from the eighth year onwards. It is estimated that between 75 and 100 working days per hectare per year of employment would be generated for the conversion of palm plantations into multilayered cultivation systems similar to those of traditional oases.

Valorization of byproducts

This opportunity includes, among other activities, composting, livestock feed production, biochar production, and renewing old palms, and is related to the options described in Chapter 2. Establishing mechanized agricultural service units, as described, provides a possible fifth sub-option.

Compost production

Compost production is practiced by a limited number of actors, including the Association for the Safeguarding of the Chenini Oasis, which sells compost at TD 1 per kilogram. Currently, farmers still seem to prefer manure but some farmers (for instance, in Hazoua, Tozeur Governorate) have started to switch to compost instead.

Livestock feed manufacturing

The traditional oasis communities Zaafrane and Midès, which manufacture livestock feed, have recently received support for the acquisition of a feed crusher for the grinding of date scrap.

Biochar production

This is a new activity in Tunisia and would benefit from being conducted on a pilot basis. In terms of impact, the implementation is expected to reduce cumulative GHG emissions by 2.86 tCO_2e per ton, generate 1.61 working days per ton produced (that is, 40 jobs for a production unit of 7,500 tons per year), and generate an estimated pre-tax profit of TD 144,000 per year (approximately US$46,598) for the producer.

Renewal of old palm trees

This practice is already applied in all oases, but not in an organized way. The main objective will be to standardize the practice and ensure that it is carried out systematically.

Mechanized agricultural service units

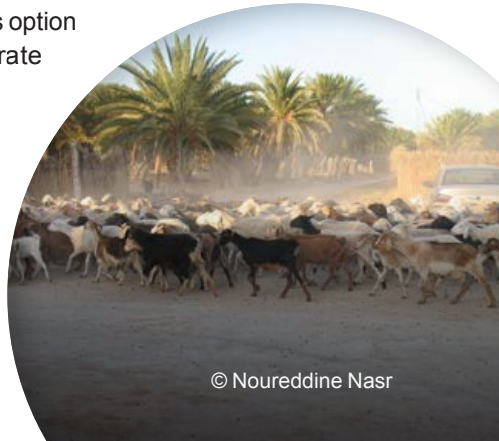
Many oasis owners face serious problems each year in mobilizing qualified labor for tasks such as tilling, cleaning plots, pruning palm trees, phytosanitary treatment, pollination, installation of mosquito nets, harvesting, and so on. It is therefore recommended that farmers and communities be given the opportunity to organize themselves cooperatively (for example, by creating or strengthening existing GDAs) to provide agricultural services.

While this initiative does not create many jobs in the short term, it would help overcome shortages of skilled labor in future and increase productivity by establishing mechanized units. Several options for promoting mechanized units have been tested and should now be rolled out in an integrated manner involving the GDAs. In terms of impact, the number of jobs created would be 94, including 68 permanent jobs (including one university graduate) and 26 temporary jobs (7,770 working days).

Optimization of oasis farm management

This opportunity concerns traditional oases and some modern oases, and involves preparing and implementing multiyear farm management plans to optimize the use of available production factors (water, labor, agrobiodiversity, and capital). It could involve optimizing density, diversifying crops, integrating animal production, or reducing pesticide emissions. Ideally, this option should be supported by software that can strengthen farm management and also facilitated by local communities and specialized engineering firms.

In terms of investment, the cost of introducing this option is estimated at TD 250,000 (approximately US$80,900), including TD 150,000 to design the tool, TD 75,000 to train potential users, and TD 25,000 for miscellaneous costs. Assuming a modest contribution from farmers or communities of TD 250 per hectare per year, this option would eventually generate one job per 300 ha.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3.3 Opportunities related to the valorization of natural and cultural assets

There are numerous opportunities related to exploiting the natural and cultural heritage of the oases in southern Tunisia. So far, only a few opportunities have been explored, such as small tourist excursions and festive and cultural tourism. Other opportunities may arise as oasis landscapes of southern Tunisia are recognized as Intangible Cultural Heritage of Humanity by UNESCO.

Tourism development offers a unique opportunity to create jobs and strengthen the livelihoods of oasis communities by creating an attractive environment for tourists, valorizing and conserving various resources, and integrating agritourism and culinary tourism. However, given the problems that many oases face in terms of uncontrolled urbanization ("land artificialization"), it requires a solid regulatory framework with spatial planning and environmental impact management.

This option will require a prefeasibility study and extensive consultations with municipalities, regional authorities, and relevant ministerial departments (that is, the Ministry of Agriculture, the Ministry of State Domain and Land Affairs, and the Ministry of Tourism). The scope of this opportunity will concern traditional oases, mountain oases, and urban oases (Gabès, Gafsa, and Tozeur). Integrated ecotourism products would include a combination of site-specific development activities (including oasis cottages, agritourism, and culinary tourism) as well as hiking and nature tourism to ancient traditional oases, mountain oases, and urban oases (Gabès, Gafsa, Kébili, and Tozeur). Implementing this option requires a certain amount of investment for rehabilitating certain structures, as well as the design and development of hiking trails. Implementation will require significant investments and has broad potential for job creation depending on the specific investment case.


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3.4 Summary of green jobs creation potential

The assessment showed that there are intrinsic links between climate change mitigation options (see Chapter 2) and green job creation opportunities. Particularly in the AFOLU sector, mitigation options have many co-benefits, including job creation and improving the climate and socioeconomic resilience of production systems. By reconciling the results, it was possible to group the different GHG mitigation options and job creation opportunities into nine main options, assess combined climate change mitigation and job creation impacts, and estimate potential investment needs. Table 13 summarizes the different opportunities and potentials for green jobs creation in oases, including a cost estimate. In summary, the AFOLU sector could be beneficial on all fronts—that is, in terms of GHG mitigation, job creation, and co-benefits.

However, beyond the technical issues related to the methodology for assessing the impacts of each option, implementation remains complex. This is due to the multidimensional nature of the challenges faced in each case. These include political, institutional, and regulatory challenges; socioeconomic issues; and environmental concerns. Options in the energy sector have significant cost implications and depend on the prevailing policy context for the energy sector, particularly regarding the production and development of renewable energy solutions. Options in the waste sector, which mainly relate to the recovery of plant waste from oases, require additional studies. The options related to the enhancement of natural and cultural assets (tourism development) have a moderate impact on job creation and should be assessed further.

Table 13: *Outcome of the assessment of green employment opportunities in oasis ecosystems*

	Opportunity	Employment potential	Types of jobs created	Unit costs
ENABLING SUSTAINABLE NATURAL RESOURCES MANAGEMENT				
1.	Strengthening irrigation water management	67 workdays/ha/year	Mainly agricultural labor, some skilled jobs (supervision, advice)	TD 2,500–4,450/ha
2.	Recovery and reuse of treated wastewater	109 workdays/ha		TD 4,600–6,800/ha excl. National Sanitation Authority investment
3.	Recovery and reuse of drainage water	Limited potential		Feasibility study
4.	Widespread use of solar electricity	8.5 to 17.5 jobs per MW installed	Skilled employment: engineers, technicians and trades people	
	Pumping stations			TD 7,428/ha (investment)
	Cold storage and date-packing stations			TD 977/T (investment)
5.	Integrated and participatory development of collective rangelands	14 jobs/1,000 ha	A lot of agricultural work, some skilled jobs	TD 1,000/ha
VALORIZATION OF OASIS PRODUCTS				
6.	Multilayered cultivation	75 to 100 workdays/ha converted	A lot of agricultural work, some skilled jobs	TD 4,450/ha without livestock
7.	Valorization of byproducts	Creation of a company for every 450 ha of oasis on average with the creation of 94 jobs	For each company: 1 engineer or 1 manager, 2 admin. jobs, 65 skilled workers and 26 temporary jobs	TD 102,100/job created (Additional feasibility studies required)
	Compost production			
	Livestock feed manufacturing			
	Biochar production			
	Renewal of old palm trees			
	Mechanized agricultural service units			
8.	Optimization of oasis farm management	Limited potential	1 engineer for 600 ha	Feasibility study
VALORIZATION OF NATURAL AND CULTURAL ASSETS				
9.	Benefit from natural and cultural heritage	Limited potential for direct employment and medium potential for indirect employment	Variable: engineers and managers, admin. jobs, technicians, skilled workers (tourism, construction)	Preliminary studies are required
	Oasis cottages, agritourism, and culinary tourism			
	Development of ecotourism circuits			

The identification of green job opportunities is an important part of the process. These opportunities should include vulnerable groups, especially young people and women, in the context of developing value chains across the different sectors and around valorizing goods and services provided by oasis ecosystems. Previous projects have shown that successful integration of young people (women and men), especially young graduates, requires the creation of conditions adapted to the social context and socioeconomic situations of this target group.

Establishing a specific support fund for promoting income-generating activities or creating small- and medium-sized enterprises, requires flexibility and transparency, as well as the involvement of local and regional actors. The funding scheme should be adapted to the target group (young people), who often lack their own financial resources. It will therefore be important to have a transparent process for targeting beneficiaries, which aims to involve all stakeholders and promotes sustainability. Other issues to be considered include a targeted communication plan, capacity building and support for project managers, and an appropriate monitoring system.

Table 14: *Summary of the assessment of consolidated options in terms of impacts, costs, and economic benefits*

Consolidated options Sub-options	Potential Impact		Present value		Net present value (NPV)[11]		Benefit/Cost Ratio
	Mitigation ($ktCO_2e$)	Jobs (WD)	Cost (TD)	Advantage (TD)	Cost (TD)	Advantage (TD)	
1. Integrated and participatory development of collective rangelands	1.3 tCO_2e/ha/year	14 jobs/1,000 ha	TD 1,000/ha	TD 761/ha	TD 2,012/ha	TD 2,378/ha	**1.18**
2. Multilayered cultivation	87.6 tCO_2e/ ha	75 to 100 WD/ ha	TD 4,450/ha	TD 7,500/ha	TD 31,475/ha	TD 51,800/ha	**1.65**
3. Adoption and dissemination ofsustainable land and water management practices							
3.1. Strengthening irrigation water management							
3.1.1 Traditional oases (18,586 ha)	0.44 tCO_2e/ha		TD 2,500/ha	TD 938 /ha	TD 3,809/ha	TD 5,765/ha	**1.51**
3.1.2 Modern oases (39,098 ha)	±	67 WD/ha	TD 4,450/ha	TD 7,500/ha	TD 31,475/ha	TD 51,800/ha	**1.65**
3.2. Hedgerows	5.86 tCO_2e/ha	3 WD/ha	TD 1,868/ha	TD 372/ha	TD 2,497/ha	TD 3,169/ha	**1.27**
3.3. Organic farming	1.6 tCO_2e/ha/year	10 WD/ha/year	TD 800/ha	TD 1,705/ha			**2.13**
3.4. Soil amendment by biochar	3.66 tCO_2e/t used	0.25 WD/T	TD 3,985/ha	TD 4,500/ha	TD 3,623/ha	TD 9,587/ha	**2.65**
4. Valorization of byproducts							
4.1. Compost production	+	94 jobs for 450 ha of oasis as part of the creation of a company	Additional studies required at a cost of TD 1 million				
4.2 Livestock feed manufacturing	±						
4.3. Renewal of old palm trees	+		TD 3,516,474	TD 4,112,091	TD 9,598,025	TD 10,381,479	**1.08**
4.4. Mechanized agricultural service units	±						
4.5. Biochar production (IRR: 38%)	2.86 tCO_2e/t						

Table 14: *Summary of the assessment of consolidated options in terms of impacts, costs, and economic benefits*

Consolidated options Sub-options	Potential Impact		Present value		Net present value (NPV)[11]		Benefit/Cost Ratio
	Mitigation ($ktCO_2e$)	Jobs (WD)	Cost (TD)	Advantage (TD	Cost (TD)	Advantage (TD)	
5. Recovery and reuse of treated wastewater							
5.1 Olive tree planting (⅔) and fruit growing (⅓)	6.26 tCO_2e/ha/year	117 WD/ha	TD 6,850/ha	TD 21,000/ha	TD 54,987	TD 119,223/ha	**2.2**
5.2 Public irrigated perimeter and oasis rehabilitation	±	67 WD/ha	TD 4,667/ha	TD 10,608/ha	TD 28,201/ha	TD 47,689/ha	**1.7**
6. Recovery and reuse of drainage water	+	+	Additional studies required				
7. Widespread use of solar electricity							
7.1. Pumping stations	0.99 tCO_2e/ha/year	8.5 to 17.5 jobs/MW	TD 7,428/ha	TD 466/ha	TD 9,703/ha	TD 6,562/ha	**0.7**
7.2. Cold storage for dates	0.144 tCO_2e/Tc	±	TD 977/Tc	TD 147/Tc	TD 1,110/Tc	TD 1,331/Tc	**1.2**
8. Optimization of oasis farm management	+	1 job/600 ha	TD 250,000				
9. Valorization of natural and cultural assets							
9.1. Oasis cottages, agritourism, and culinary tourism	+	++	Additional studies required				
9.2. Development of ecotourism circuits	+	++					
±: Negligible potential; +: Low/limited potential; ++: Average potential; +++: Strong potential.							

11 NPV was calculated for an investment term of 25 years for Option 7, five years for Option 4, and 10 to 20 years for other options, with a discount rate of 5 percent for Option 7 and 10 percent for all options.

4

Scenarios for oasis landscapes development

Following a broad consultation with the agricultural and oasis development stakeholders of the Gabès, Tozeur, Kébili, and Gafsa governorates, the NDC commitments were assessed in terms of greenhouse gas (GHG) emission mitigation potential and opportunities for green jobs creation.

Two scenarios have been chosen to (i) project and extrapolate the different climate change mitigation and job creation options and (ii) estimate their potential impacts for 2030, 2040, and 2050. These scenarios include:

1. **Scenario 1: Trend Scenario.** This is a baseline scenario that admits the continuation of current trends in the political, institutional, and regulatory environment without rapid changes in systemic, institutional, and individual capacities.

2. **Scenario 2: Proactive Scenario.** This is a proactive scenario that would allow the removal of all barriers and challenges (political, institutional, and regulatory) that hinder the utilization of the full potential of oases.

3. **Scenario 3:** An additional scenario has been proposed and is related only to the optimization of farm management practices. Scenario 3 is equivalent to Scenario 2 but with a higher impact on job creation.

4.1 Extrapolation of development options

Across three emitting sectors (AFOLU, energy, and waste), eight GHG mitigation options (see Chapter 2) and 10 job creation options (see Chapter 3) have been identified and their feasibility analyzed. The results are presented here as nine consolidated options for oasis development. The consolidated options are: (1) integrated and participatory development of collective rangelands; (2) multilayered cultivation; (3) adoption and dissemination of sustainable land and water management practices; (4) valorization of byproducts; (5) recovery and reuse of treated wastewater; (6) recovery and reuse of drainage water; (7) widespread use of solar electricity; (8) optimization of farm management; and (9) valorization of natural and cultural assets.

The impact in terms of job creation and GHG mitigation as well as costs and benefits with the time horizon 2050 are presented below and summarized in Table 19 for Scenario 1 and in Table 20 for Scenario 2. The GHG mitigation and job creation opportunities were assessed toward their potential impact for 2030, 2040, and 2050.

For three of these options, multiple scenarios were considered.

- Option 1 related to the integrated and participatory development of collective rangelands
- Option 2 related to the introduction of multilayered cultivation
- Option 3 related to the optimization of farm management practices.

For the six other options, a single scaling hypothesis was proposed, because these options are either straightforward and feasible, have an innovative and pioneering character in Tunisia (particularly in terms of the production and use of biochar for soil enhancement, hedgerows, and similar applications), or because of their immediate and significant economic impacts.

Integrated and participatory development of collective rangelands

This option consists of the development and implementation of integrated rangeland management, with the potential to cover 1.44 million ha in total. Rangeland management plans would be developed in a participatory manner—involving pastoralists, management councils, and affected communities—and would focus on integrating fodder trees and shrubs; reseeding indigenous species; marketing livestock byproducts such as milk, hides, and wool; and conserving biodiversity. It is one of the three options to which the Trend Scenario (Scenario 1) and the Proactive Scenario (Scenario 2) have been applied because it builds on about 20 years of continued experience with similar initiatives. Extensive experience has been gained in relation to the integrated development of rangelands. However, a number of complexities related to land, the availability of finance, and the regulatory environment may hamper final implementation of integrated rangeland management.

Scenario 1 considers the current trends and challenges for implementation, assuming that 936,000 ha would be managed in an integrated approach by 2050. Scenario 2 is contingent on a substantial improvement of the regulatory environment, further decentralization, and the establishment of a dedicated entity that would support oasis development. Table 15 summarizes the results of the extrapolation according to the Trend and Proactive scenarios.

Table 15: *Extrapolation of the integrated development of natural rangelands according to Trend and Proactive scenarios*

Scenarios	Impacts by 2050			
	Mitigation ($ktCO_2e$)	Jobs created (FTE)	Costs (TD million)	Benefits (TD million)
1. Trend Scenario	6,458	10,152	1,883	2,226
2. Proactive Scenario	12,917	20,304	2,897	3,424

Multilayered cultivation systems

This option involves a gradual transformation of Deglet Nour date palm plantations into multilayered, multicrop oases that follow ecosystem principles, similar to traditional oases. There is high potential for all Deglet Nour date palm plantations to be transformed into multilayered cultivation systems, with 141 such plantations, comprising 39,098 ha in total. To realistically estimate the potential for scaling up multilayered cropping, both the Trend Scenario (Scenario 1) and the Proactive Scenario (Scenario 2) were considered. While there are no technical challenges to the implementation of multilayered cultivation, much depends on local ownership, possible investments, and available labor.

The Trend Scenario considers the current institutional and regulatory environment, as well as the fact that many farmers may continue to find that the benefits of modern date plantations outweigh the costs. In the absence of support from various projects and initiatives, the expansion of multilayered cultivation may be constrained. The success of this endeavor hinges on the extent to which farmers organized into GDAs can be reached with awareness campaigns and motivated to adopt multilayer cropping practices. The Proactive Scenario (Scenario 2) anticipates a more substantial shift, influenced by a favorable regulatory environment characterized by the promotion of sustainable land and water management practices, agricultural incentives, and capacity building. Under this scenario, it is projected that 10 percent of date plantations will be converted to multilayered cropping by 2050, amounting to a total of 3,900 ha at a rate of 150 ha per year. The gradual conversion of 26,000 ha at a rate of 1,000 ha per year is the preferred option, to be implemented first in old date palm plantations (modern oases) in the Tozeur and Kébili governorates (which are already organized in GDAs), and then in the unmanaged extensions in Kébili Governorate. Table 16 summarizes the results of the extrapolation for the Trend and Proactive scenarios.

Table 16: *Extrapolation of the introduction of multilayered cultivation according to the Trend and Proactive scenarios*

Scenarios	Impacts by 2050			
	Mitigation ($ktCO_2e$)	Jobs created (FTE)	Costs (TD million)	Benefits (TD million)
1. Trend Scenario	341	1,138	123	202.5
2. Proactive Scenario	2,277	7,583	818	1,347

Adoption and dissemination of sustainable land and water management practices

This would involve adopting and disseminating good agricultural practices aimed at strengthening the climate resilience of oasis farms through improved irrigation water management, the integration of hedgerows, organic farming, and soil amendment by biochar.

Strengthening irrigation water management

Strengthening irrigation water management practices refer to the introduction of localized, efficient irrigation systems that would reduce water consumption by approximately 50 percent. Irrigation water savings may support different intercropping or multilayered cropping systems (as discussed earlier) or reduce water pumping costs, so generating energy savings. The water savings associated with reducing pumping costs in the 18,586 ha of traditional oases are estimated at TD 186 per hectare per year (approximately US$60) and are equivalent to reduced greenhouse gas emissions of 0.176 tCO_2e per hectare per year. In the case of converted oases, an increase in production value estimated at TD 7,500 per hectare per year (approximately US$ 2,427) can be assumed.

While the integration of water-saving irrigation techniques is recommended for all oases, it is not yet widely implemented. This is due to factors such as traditional practices, land tenure, and farming techniques, which hinder the adoption of modern, water-saving irrigation systems. Despite Tunisia investing in awareness campaigns to drive the modernization of irrigation systems, only the Trend Scenario was used for the adoption of sustainable land and water management practices. Estimates were made separately for traditional and converted date plantations. The total area that could be considered is 26,452 ha at a rate of 1,250 ha per year. Activities would include awareness-raising activities, strengthening the regulatory environment for groundwater use, promoting water-saving irrigation techniques, and encouraging agricultural investment.

For traditional oases, the cumulative GHG reduction/sequestration would be 3,271 $ktCO_2e$ by 2045, a reduction in water pumping costs, ultimately estimated at TD 3.46 million per year (approximately US$1.12 million), and savings of 6,266 m^3 of water per hectare per year—a total of almost 116.5 million m^3 per year at a value of TD 14.98 million (approximately US$ 4.85 million).

For converted modern oases/date plantations, the cumulative GHG reduction/sequestration can be estimated at 1,400 $ktCO_2e$ in 2045, with 1,777 jobs created. Additional production, at an estimated value of TD 412 million (about US$133 million) in 2045, is achievable for an additional investment of TD 250 million (approximately US$81 million).

Integration of hedgerows

Planting hedgerows could reduce GHG emissions by a small margin of about 1.85 tCO_2e per hectare per year while producing 2,450 fodder units per hectare per year at a value of TD 735 (approximately US$ 238). Scaling up would require considerable effort in terms of information dissemination and awareness-raising, as well as providing farmers with seeds, seedlings, or cuttings of the recommended species. Given this, it is proposed that the scaling-up of the practice for 2050 could be done at a rate of 509 hectares per year. Accordingly, the impact of the option can be determined as follows:

- Cumulative reduction of GHG emissions: 349 $ktCO_2e$ by 2050
- 265 jobs created
- 473,700 fodder units produced per year worth TD 0.189 million—a total of TD 42 million (approximately US$ 13.6 million) of additional feed production at a cost of TD 33 million (approximately US$ 10.7 million).

Organic farming and integrated pest management

Organic farming has grown significantly, particularly in the oasis governorates, where the practice has increased by an average of approximately 10 percent per year in recent years. In light of the steady growth of organic farming practices, it is assumed that the trend will continue under the Trend Scenario (Scenario 1). The Proactive Scenario (Scenario 2) was not considered for this option. The cumulative impact by 2050 is estimated to be as follows:

- Cumulative reduction in GHG emissions: 235.6 $ktCO_2e$ by 2050
- 384 jobs created
- Additional income estimated at TD 1,705 per hectare per year (approximately US$ 552) at an annual cost of TD 800 per hectare (approximately US$ 259)
- Implementation cost estimated at TD 10.6 million (approximately US$ 3.4 million), generating additional income of TD 22.6 million (approximately US$ 7.3 million).

Soil amendment by biochar

While the use of biochar was recommended by Tunisia's National Strategy for Carbon Neutrality and Resilience to Climate Change 2050, the practice is not yet widely used and is still in an experimental phase. This option involves introducing biochar to improve the physical, chemical, and microbiological properties of the soil at ranges from 5 to 50 tons per hectare, depending on the soil's properties. Given the lack of Tunisian references in this field, implementing this option will be akin to applied research. Scaling up this option to 2050 could be possible from 2030 at a rate of 500 ha per year, using an estimated 15 tons of biochar per hectare. The biochar requirement would therefore be 7,500 tons per year, corresponding to about 25,000 tons of biomass waste. On this basis, 10,000 ha could be amended in this way by 2050. Considering the somewhat experimental character of this option, only the Trend Scenario (Scenario 1) was considered. The cumulative impact by 2050 is estimated to be as follows:

- Cumulative reduction in GHG emissions: 549 $ktCO_2e$ by 2050
- 125 jobs created
- 30 percent increase in crop yield, or an additional production value of TD 4,500 per hectare per year (approximately US$1,456) in the fifth year
- Additional production will be valued at TD 958 million in 2050 (approximately US$ 213 million), against an estimated cost of TD 362 million (approximately US$ 117 million).

Valorization of date palm byproducts and provision of agricultural services

The valorization of byproducts from date palm production aims to stimulate and catalyze small businesses, for example through mutual agricultural service organizations or *Sociétés Mutuelles de Services Agricoles* (SMSAs), building on the GDAs and based on appropriate cooperative business models. Five promising product streams were identified: the production of compost from plant waste, the production of animal feed, the production of biochar, the systematic renewal of old palm trees, and the provision of agricultural services.

Based on the available data, it was estimated that one SMSA could be established for every 450 ha of oases, permanently employing an average of 86 people and providing 7,700 days of temporary work per year. Considering the total area (26,452 ha) of oases managed by GDAs, up to 59 SMSAs could be established, potentially creating 5,695 permanent jobs, including 59 engineering jobs. Mechanization would reduce labor requirements by 20 to 80 percent, depending on the nature of the task. However, these estimates remain largely theoretical and need to be further substantiated through business surveys and feasibility studies.

This option is likely to have a significant impact, both in terms of mitigation and green job creation. Although no specific scenarios have been considered for the introduction of byproduct valorization, implementation of this option would depend largely on:

- Carrying out technical and economic feasibility studies for the creation of viable SMSAs that would be able to realize the potential impacts of different activities and promote agricultural services
- Capacity-building through awareness-raising, training, and technical assistance
- Adapting agricultural investment incentives to the specific features of oasis ecosystems.

Recovery and reuse of treated wastewater

This option, which is included in the National Master Plan for the Reuse of Treated Wastewater in Tunisia, would create or rehabilitate 2,157 ha of irrigated land. The impacts of implementing this option would be as follows:

- Cumulative reduction in GHG emissions: 176 $ktCO_2e$ through the planting of olive and fruit trees on 677 ha of irrigated land
- 1,172 jobs created, including 841 through plantations and 331 jobs in public irrigation perimeters (PPIs) and rehabilitated oases
- Estimated additional production valued at TD 151 million per year (approximately US$ 9 million) over the long term, including TD 80.7 million (approximately US$4.8 million) in new plantations and TD 70.6 million (approximately US$4.2 million) in rehabilitated irrigated public perimeters and oases.

Recovery and reuse of drainage water

The recovery and reuse of saline drainage water has been selected as an option to mitigate GHG emissions and improve the resilience of the oasis economy. Although this option would generate significant ecological, environmental, and socioeconomic benefits, the lack of complete data and documented references on this issue does not allow for an assessment of the option. Further investigations and studies are needed.

Widespread use of solar electricity (photovoltaics)

This option proposes equipping water pumping stations and date cold stores with solar electricity generation systems. This option would involve traditional and modern oases managed by GDAs (26,500 ha) and public and private date cold storage facilities (refrigerated warehouses) with a total storage capacity of about 77,000 tons. This expansion depends on revising regulations governing the production of renewable energy in Tunisia to allow producers easier access to solar power. Importantly, this would need to be accompanied by measures to ensure sustainable groundwater resource management and avoid overexploitation of this resource. The potential impacts under the Trend Scenario (Scenario 1) are summarized in Table 17.

Table 17: *Extrapolation of substituting conventional electricity with solar electricity*

	Water pumping stations	Refrigerated warehouses
Greenhouse gas mitigation	Cumulative reduction of 92 $ktCO_2e$ by 2030 and 622 $ktCO_2e$ by 2050	Cumulative reduction of 38 $ktCO_2e$ by 2030 and 255 $ktCO_2e$ by 2050
Jobs	916 jobs by 2030	350 jobs by 2030
Other benefits	Estimated reduction in energy expenditure of TD 457 per hectare per year	A saving on energy consumption estimated at TD 147 per ton of storage per year
Investment costs	TD 258 million	TD 85 million
Benefits	TD 174 million	TD 103 million

Optimization of oasis farm management

This option supports the development and implementation of software-based farm management plans for traditional and modern oases. It aims to optimize the use of available production factors (water, fertilizer, labor, agrobiodiversity, and capital), although its implementation depends largely on the willingness of oasis operators to participate and implement actions. The activity could easily be scaled up. So, in addition to the Trend and Proactive scenarios, a third scenario has been considered. The optimization of farm management practices is specifically aimed at job creation and, to a lesser extent, at GHG emission reduction.

1. **Scenario 1:** Coverage of half of the traditional oases from 2025 to 2030 (9,276 ha). This scenario would create 15 jobs.
2. **Scenario 2:** Coverage of traditional oases plus oases converted to scale from 2025 to 2030 (26,452 ha). This scenario would create 44 jobs.
3. **Scenario 3:** Like Scenario 2, but with all oases covered by 2045 or 2050. This scenario would create 96 jobs.

Valorization of natural and cultural assets

Potential activities in this area can be grouped into two sets of sub-options: promoting oasis regions, agritourism, and culinary tourism, and developing ecotourism circuits focusing on enhancing historical and cultural heritage. These sub-options offer many opportunities in terms of job creation, income-generating activities, enhancing local biodiversity, and improving the resilience of the oasis economy in general.

4.2 Comparing scenarios for oasis development

When comparing the Trend Scenario (Scenario 1) and Proactive Scenario (Scenario 2), there are notable differences with regard to (i) the impact in terms of GHG emission reductions and job creation, and (ii) the investments required per ton of carbon reduced and job created.

The investment cost per ton of carbon dioxide equivalent sequestered in Scenario 1 (TD 224 per ton, approximately US$72) is slightly higher (3.5 percent) than in Scenario 2 (TD 216 per ton, approximately US$70). However, the investment cost per job created in Scenario 1 (TD 0.209 million per job, approximately US$ 0.068 million) is much higher (36 percent) than in Scenario 2 (TD 0.153 million per job (approximately US$ 0.05 million). The ratio of additional income to investment remains the same, with a slight difference in favor of Scenario 1 (this additional income is expressed as the value of the increase in production). A comparison of the two scenarios is presented in Table 20. Scenario 3 is not included in the table because it is relevant only to job creation related to farm management practices.

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Table 18: *Status of scaling consolidated options under Trend Scenario (Scenario 1)*

Options /sub-option	Oasis	Scaling		Impacts						Investment TD (million)	Additional income (TD (million)
				2030		2040		2045 or 2050			
Sub-option		Scope	Period	Mitigation ($ktCO_2e$)	Jobs (FTE)	Mitigation ($ktCO_2e$)	Jobs (FTE)	Mitigation ($ktCO_2e$)	Jobs (FTE)		
1. Integrated and participatory development of collective rangelands	Traditional	936,000 ha	2025–2050	**1,379**	2,538	**4,844**	5,076	**6,458**	10,152	**1,883**	**2,226**
2. Multilayered cultivation	Modern	3,910	2025–2050	**79**	263	**210**	438	**341**	1,138	**123**	**202.5**
3. Adoption and dissemination of sustainable land and water management practices											
3.1. Strengthening irrigation water management											
3.1.1 Traditional oases (18,586 ha)	Traditional	18,586 ha	2025–2045	**755**	±	**2,013**	±	**3,271**	±	**70.8**	**107.14**
3.1.2 Modern oases (39,098 ha)	Modern	7,956 ha	2025–2046	**323**	410	**862**	683	**1,400**	1,777	**250.4**	**412.1**
3.2. Hedgerows	Traditional & converted modern	13,223 ha	2025–2050	**81**	61	**215**	102	**349**	265	**33**	**42**
3.3. Organic farming		13,234 ha	2025–2050	**6.5**	122	**142**	296	**235**	384	**10.6**	**22.6**
3.4. Soil amendment by biochar	Traditional and modern	100,000 ha	2031–2050			**274**	65.5	**549**	125	**362.3**	**958.7**
4. Valorization of byproducts											
4.1. Compost production	4 sets of oases in each governorate	(1,800 ha) Creation of 4 pilot companies	2025–2030	**±**	376					**38.4**	**41.41**
4.2 Livestock feed manufacturing											
4.3. Renewal of old palm trees											
4.4. Mechanized agricultural service units											
4.5. Biochar production (IRR: 38%)											

Table 18: *Status of scaling consolidated options under Trend Scenario (Scenario 1)*

Options /sub-option	Oasis	Scaling		Impacts						Investment TD (million)	Additional income (TD (million)
				2030		2040		2045 or 2050			
Sub-option		Scope	Period	Mitigation ($ktCO_2e$)	Jobs (FTE)	Mitigation ($ktCO_2e$)	Jobs (FTE)	Mitigation ($ktCO_2e$)	Jobs (FTE)		
5. Recovery and reuse treated wastewater											
5.1 Olive tree planting (2/3) and fruit growing	New PPI	677 ha	2023–2050	**5**	218	**65**	530	**176**	841	**37.2**	**80.7**
5.2 Public irrigated perimeter and oasis rehabilitation	PPI & rehab. oases	1,480 ha	2023–2050	**±**	86	**±**	208	**±**	331	**41.7**	**70.6**
6. Recovery and reuse of drainage water	All oases	57,000 ha	2026–2040	**+**	+	**++**	++				
7. Widespread use of solar electricity											
7.1. Pumping stations	Traditional and modern	26,542 ha	2026–2030	**92**	916	**357**		**622**		**258**	**174**
7.2. Cold storage for dates		77,010 Tc	2026–2031	**38**	350	**147**		**255**		**85**	**103**
8. Optimization of oasis farm management	Traditional and modern	9,273 ha	2026–2030	**±**	33	**+**		**++**		**0.25**	
9. Valorization of natural and cultural assets											
9.1. Oasis cottages, agritourism, and culinary tourism	Traditional		2027–2050	**±**	+	**+**	++	**+**	++	Additional studies required	
9.2. Development of ecotourism circuits	Traditional		2027–2051	**±**	+	**+**	++	**+**	++		
TOTAL				**2,758.5**	**5,373**	**9,129**	**7,398.5**	**13,108**	**15,013**	**3,194**	**4,440**

±: Negligible potential; +: Low/limited potential; ++: Average potential; +++: Strong potential.

Table 19: *Status of scaling, consolidated options under Proactive Scenario (Scenario 2)*

Options /sub-option	Oasis	Scaling		Impacts						Invest-ment TD (million)	Addition-al income (TD (million)
				2030		2040		2045 or 2050			
Sub-option		Scope	Period	Miti-gation ($ktCO_2e$)	Jobs (FTE)	Miti-gation ($ktCO_2e$)	Jobs (FTE)	Miti-gation ($ktCO_2e$)	Jobs (FTE)		
1. Integrated and participatory development of collective rangelands	Traditional	1,440,000 ha	2027–2047	**3,875**	5,076	**9,688**	10,152	**12,917**	20,304	**2,897**	**3,424**
2. Multilayered cultivation	Modern	26,000 ha	2025–2050	**525**	1,750	**1,401**	2,917	**2,277**	7,583	**818**	**1,347**
3. Adoption and dissemination of sustainable land and water management practices											
3.1. Strengthening irrigation water management											
3.1.1 Traditional oases (18,586 ha)	Traditional	18,586 ha	2025–2045	**755**	±	**2,013**	±	**3,271**	±	**70.8**	**107**
3.1.2 Modern oases (39,098 ha)	Modern	7,956 ha	2025–2046	**323**	410	**862**	683	**1,400**	1,777	**250**	**412**
3.2. Hedgerows	Traditional/ converted	13,223 ha	2025–2050	**81**	61	**215**	102	**349**	265	**33**	**42**
3.3. Organic farming		13,234 ha	2025–2050	**6.5**	122	**142**	296	**235.6**	384	**10.6**	**22.6**
3.4. Soil amendment by biochar	Both	100,000 ha	2031–2050			**274.5**	65	**549**	125	**362**	**958.7**
4. Valorization of byproducts											
4.1. Compost production	All oases organized in GDAs	9,000 ha: Creation of 20 companies	2025–2050	**+**	376	**215**	1,128	**429**	1,880	**192**	**207**
4.2 Livestock feed manufacturing											
4.3. Renewal of old palm trees											
4.4. Mechanized agricultural service units											
4.5. Biochar production (IRR: 38%)		150,000 T	2030–2050								

Table 19: *Status of scaling, consolidated options under Proactive Scenario (Scenario 2)*

Options /sub-option	Oasis	Scaling		Impacts						Invest-ment TD (million)	Addition-al income (TD (million)
				2030		2040		2045 or 2050			
Sub-option		Scope	Period	Miti-gation ($ktCO_2e$)	Jobs (FTE)	Miti-gation ($ktCO_2e$)	Jobs (FTE)	Miti-gation ($ktCO_2e$)	Jobs (FTE)		
5. Recovery and reuse treated wastewater											
5.1 Olive tree planting (⅔) and fruit growing (⅓)	New PPI	677 ha	2023-2050	**5**	218	**65**	530	**176**	841	**37**	**80.7**
5.2 Public irrigation perimeter and oasis rehabilitation	PPI and oasis	1,480 ha	2023–2050	**±**	86	**±**	208	**±**	331	**41.7**	**70.6**
6. Recovery and reuse of drainage water	All	57,000 ha	2026–2040	**+**	+	**++**	++				
7. Widespread use of solar electricity											
7.1. Pumping stations	Traditional and modern	26,542 ha	2026–2030	**92**	916	**357**		**622**		**257.5**	**174**
7.2. Cold storage for dates		77,010 Tc	2026–2031	**38**	350	**147**		**255**		**85.5**	**102**
8. Optimization of oasis farm management	Traditional and modern	26,452 ha	2026–2030	**±**	88	**+**		**++**		**0.25**	
9. Valorization of natural and cultural assets											
9.1. Oasis cottages, agritourism	Traditional		2027–2050	**±**	+	**+**	++	**+**	++	Additional studies required	
9.2. Development of ecotourism circuits			2027–2050	**±**	+	**+**	++	**+**	++		
TOTAL				**5,700.5**	**9,453**	**15,379**	**16,078**	**22,481**	**33,490**	**5,056**	**6,949**

±: Negligible potential; +: Low/limited potential; ++: Average potential; +++: Strong potential.

Table 20: *Consolidated options to scale up balance sheets*

	Impacts							
	2030		2040		2045 or 2050		Investment (TD million)	Additional income (TD million)
	Mitigation ($ktCO_2e$)	Jobs (FTE)	Mitigation ($ktCO_2e$)	Jobs (FTE)	Mitigation ($ktCO_2e$)	Jobs (FTE)		
1. Trend Scenario	2,758	5,373	9,129	7,398	13,108	15,013	3,194	4,440
2. Proactive Scenario	5,700	9,453	15,379	16,078	22,481	33,490	5,056	6,949

The GHG reduction potential is estimated to be at least 13,108 $ktCO_2e$ by 2050, with a total of 15,013 jobs created for the Trend Scenario. The more transformational Proactive Scenario estimates a GHG reduction potential of at least 22,481 $ktCO_2e$ by 2050, with a total of 33,490 jobs created. In the third auxiliary scenario, job creation is estimated at 33,586 jobs. The ratio of additional income to investment remains the same, with a slight difference in favor of the Trend Scenario.

Given the significant gap between these two scenarios in terms of impacts and costs, it is likely that the reality will be somewhere in between. It is clear that implementing the options analyzed should lead to a minimum GHG reduction of 18,000 $ktCO_2e$ and the creation of 24,000 jobs by 2050. (It should be noted that there are options that could not be developed within the framework of the study, in particular, support for the organization of GDAs around the valorization of the byproducts of the oasis and agricultural work, and the valorization of the intangible assets of the oases).

5

Recommendations for sustainable oasis development


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Despite the many challenges facing oases in southern Tunisia, oasis development can build on strong ties to the cultural heritage of the local population and a sense of urgency among local and regional stakeholders to address land degradation.

The existence of a network of local communities committed to the rehabilitation and conservation of oasis ecosystems is important for the successful rehabilitation of oasis landscapes. Oases that have been supported in the past—such as Tameghza, Chebika, and Midès in the governorate of Tozeur; Zarat in the governorate of Gabès; and El Guettar in the governorate of Gafsa—have demonstrated the possibility of involving young people in land rehabilitation.

Some oases have already started implementing measures to address land degradation and create local jobs. In pilot projects, oases have switched to solar electricity, demonstrating the immense potential in this area but also the need to continuously increase awareness on water-saving precision irrigation. Other projects have shown the need to raise awareness to promote crop diversification. In previous projects (for example, the Rjim Maâtoug Development Program), establishing farmer field schools has proven to be an appropriate way to raise awareness. However, without a robust intervention approach combined with voluntary action to conserve oasis ecosystems and landscapes, there is a risk of further degradation—with potentially significant economic impacts.

The study identified several interventions to strengthen the climate resilience of oasis landscapes in southern Tunisia, while revitalizing the green economy and creating green jobs.

These interventions should focus on: (i) the sustainable use of natural resources (water, soil, and vegetation); (ii) the restoration and conservation of oasis landscapes; and (iii) the valorization of goods and services for the benefit of the population and actors in the value chains of the sectors concerned. The expected results include:

- Rehabilitating traditional oasis ecosystems and the transformation of modern date plantations into more climate-resilient and sustainable oasis landscapes
- Adopting good practices for sustainable land and water management
- Disseminating and adopting sustainable land and water management practices (soil fertility management, irrigation techniques and limiting water loss, integration of livestock, generation of solar panels for water pumping)
- Empowering the population and actors in the relevant date value chains
- Empowering local actors and creation of green jobs, especially for women and youth
- Building the capacity of the various actors involved in the development of oasis landscapes.

The study formulated guidelines for the design of interventions tailored to the specificity of the different oasis landscapes. These guidelines consider both the multifunctionality and the specific historical context of different oasis areas, recognizing their important role in the region's natural heritage and as the anchor of any sustainable development policy in Saharan and sub-Saharan areas. Table 21 summarizes the measures and actions to be taken to promote the upscaling of the different options under the most favorable conditions.

Table 21: *Actions to be taken to implement the proposed options*

No.	Option	Proposed actions
1.	**Integrated and participatory development of collective rangelands**	Update regulatory texts governing the management of rangelands Create an entity that will be responsible for overseeing development activities in oasis ecosystems Effectively involve local authorities in the planning and monitoring of the implementation of rural development activities Update the agricultural investment code toward oasis ecosystems
2.	**Multilayered cultivation**	Adopt sustainable land and water management practices Update the agricultural investment code toward oasis ecosystems Build capacity in terms of monitoring and control of water resources
3.	**Adoption and dissemination of sustainable land and water management practices**	
	3.1 Strengthening irrigation water management	Awareness-raising and demonstration efforts Update regulatory texts related to groundwater exploitation Update the agricultural investment code toward oasis ecosystems
	3.2 Hedgerows	Information and awareness raising Provide farmers with plant material and seeds
	3.3 Organic farming	Current context
	3.4 Soil amendment by biochar	Additional feasibility study and awareness program
4.	**Valorization of byproducts**	
	4.1. Compost production	Feasibility studies practices and promote agricultural services Build capacity of GDAs in the field of business plan preparation and management related to the valorization of palm byproducts Adapt measures to encourage agricultural investments to the specificities of oasis ecosystem Update the texts governing the GDA
	4.2. Livestock feed manufacturing	
	4.3. Renewal of old palm trees	
	4.4. Mechanized agricultural service units	
	4.5. Biochar production	
5.	**Recovery and reuse of treated wastewater**	Schedule implementation as part of the master plan for wastewater reuse in Tunisia
6.	**Recovery and reuse of drainage water**	Further studies will be required
7.	**Widespread use of solar electricity**	Revise the regulatory context governing the production of renewable and renewable energies, particularly concerning photovoltaics
8.	**Optimization of oasis farm management**	Information and awareness of oasis operators Financial or fiscal incentives
9.	**Valorization of natural and cultural assets**	
	9.1. Agritourism development	Feasibility and socioenvironmental impact assessments
	9.2. Development of ecotourism circuits	

To assess the various intervention options that support the implementation of Tunisia's most recent NDC in oasis landscapes, it is proposed that a technical inventory or reference list be developed. This would track the options, technical details, and information from future studies, as well as the status of implementation. Such an inventory would benefit from continuous updating in response to changing contexts and technologies, as well as lessons learned from previous projects.

The proposed project inventory is designed to serve as a compendium of options, offering project leaders and oasis communities a diverse array of choices. However, it is essential to adapt this inventory to the unique characteristics of each oasis, ensuring its relevance and effectiveness within the site's specific context. A key focus area should be the enhancement of the organizational and operational capacity of professional agricultural organizations, local authorities, and local private stakeholders and associations.

5.1 Strengthening the governance of oasis landscapes

For four decades, oasis landscapes have been shaped by a policy focused on the production and export of dates, based on the objective of maintaining and strengthening Tunisia's position on the world date market. During this period, the management of water resources has been guided by supply-side management in order to maintain and sustain date palm production systems and to respond to a strong social demand from the communities concerned. This has made it possible to position Tunisia as a leader in date exports. However, this has, to some extent, come at the cost of sustainability. For many years, economic development has depended on the mobilization of groundwater, which has required water to be pumped from greater depths and at higher pumping costs. One of the reasons for this unsustainable development is the lack of a governance, institutional, and legal framework that underscores the importance of oasis landscapes as a national heritage asset and a lever for the development of southern Tunisia.

Strengthening the institutional framework for oasis agriculture

The analysis concluded that a dedicated structure could be created for oasis development. This entity could reorganize existing institutional, human, and material capacities to ensure comprehensive governance of oasis development. It could ideally collaborate with regional and local authorities, and the Southern Development Office. It could also be empowered to establish partnerships with specialized public institutions, civil society, the private sector, and existing professional organizations.

Reviewing and enhancing the regulatory framework

The current situation requires a new form of governance in line with Tunisia's socioeconomic development priorities, its NDC commitments, and the United Nations' Sustainable Development Goals. A robust oasis management policy should consider oases as anchors for the development of southern Tunisia, but also as national natural heritage assets to be preserved and given special status. It should involve all stakeholders in an inclusive approach to community development. In line with the National Strategy for the Sustainable Management of Oases adopted in 2015, this policy should aim to rationalize and optimize the use of groundwater resources, restore and conserve oasis landscapes and ecosystems, and value the goods and services provided by oasis ecosystems.

It will also be important to revise the broader legal and regulatory framework to better rationalize the management of groundwater resources and encourage related investments in oasis areas. These investments should focus on developing rural and agricultural areas, promoting renewable energy, developing agritourism, and organizing agricultural development groups. The planned shift to solar powered irrigation will require accompanying regulatory measures to ensure the sustainable management of groundwater resources.

It will also be important to update the Sustainable Development of Oases and other related strategies and action plans, such as the Date Sector Development Strategy and the Organic Date Promotion Strategy. This should include joint efforts to create a UNESCO biosphere reserve that includes the traditional oases of Chebika, Tameghza, Nefta, and Gafsa, in order to recognize their heritage value.

Capitalizing on successful governance models in oases

Pending the revision of the status of GDAs and the establishment of an appropriate structure to manage oasis development, it is important to learn from existing initiatives and experiences that promote and enable the sustainable development of oases. Such initiatives include:

- The Jemna Oasis in Kébili, which has a governance model that promotes creating "corporate citizens" models in oases
- The Hazoua Oasis in Tozeur, which has a governance model based on a federation of GDAs organized around the production of certified organic and fair-trade dates
- The El Kaâbi Oasis in Tozeur, which has a governance model based on establishing contracts for the management of oasis plots signed by the GDA with absentee owners
- The Rjim Maâtoug project in Kébili, which has a distinct institutional set-up that promotes flexibility and rigorous management.

Creating an enabling environment that promotes innovation in oasis development

The assessment of the different options for sustainable development of oases highlighted the need to promote new and improved land management practices. For example, while biochar has already been applied successfully outside oases in Tunisia, applied research is needed to better adapt these techniques to the local context and to raise awareness among farmers about their use. Applied research and co-creation with farmers will help create farmer awareness and generate technologies truly adapted to the local context. GDAs and extension services will play an important role in facilitating this.

5.2 Promoting integrated development plans for oasis landscapes governance

Interventions should be implemented through a participatory process within each oasis and the areas surrounding each oases, including pastoral areas, cultivated extension areas (date palms and olive trees), wetlands of ecological interest, drainage areas, and oasis towns or villages. The proposed approach aims to enable oasis communities and their local organizations to ensure the effective participation of various stakeholders, especially women and youth, in developing and implementing an integrated oasis development and governance plan. This plan would benefit from lessons learned from previous projects supporting oasis communities. A mechanism for consultation and constructive dialogue between communities and development actors should be initiated to make the integrated and concerted management of oasis landscapes a lever for inclusive territorial development. The principles that could guide the development of a possible project should include:

- Learning from previous oasis development projects in Tunisia and focusing on practical lessons for the implementation of new interventions
- Focusing on synergies with sectoral strategies and other interventions of the public and private sectors, associations, local organizations, local authorities, and technical and financial partners
- Considering all sectoral plans, in particular local climate action plans and the Green Cities Action Plan, which should be prepared by and for all municipalities.

Key priorities

Potential projects and interventions should prioritize measures to: (i) address water losses in irrigation systems and manage uncontrolled groundwater extraction; (ii) increase water use efficiency, strengthen irrigation systems, and mobilize treated wastewater; (iii) increase available funding for the introduction of solar electricity systems for pumping and cooling; and (iv) ensure a participatory approach.

Stakeholder involvement

Given the development challenges of oasis ecosystems, public authorities and other institutions should support stakeholders to give credibility to the envisaged development process. This includes involving these actors in the process of developing and validating future projects and embedding them in the local and regional planning system, especially in community development plans, to serve as reference tools for all stakeholders.

Robust contractual arrangements for project design

Future interventions should be based on robust contractual arrangements involving the government, partners, local authorities, and GDAs. The unifying and integrative nature of the proposed project interventions will require mobilizing additional resources to meet the expectations of the target groups and various actors. It is therefore important to advocate for funding at the relevant government level and with partners. In this context, communication tools should be developed to advocate at different levels.

Monitoring and evaluation

Establishing a participatory monitoring and evaluation system is essential for sound implementation. This system should be an integral part of the overall monitoring and evaluation system and should aim to conduct an annual joint evaluation with beneficiary groups and program signatories to identify the measures to be taken to improve the performance and effectiveness of the interventions.

5.3 Enabling green job creation

Vulnerable communities, women, and youth should be closely involved in identifying and prioritizing green job creation activities and interventions. It will be necessary to establish a transparent approach when selecting direct beneficiaries that includes a mechanism to ensure compliance with this approach. A step-by-step guide should be developed to guide this process. Previous projects have shown that the successful integration of young people, especially young graduates, depends on the creation of a set of conditions adapted to the social context and socioeconomic situation. These conditions include:

- Implementing a communications plan targeting potential beneficiaries to raise awareness about job opportunities, in consultation and cooperation with the institutions concerned (employment offices, vocational training centers, and so on).
- Creating a fund to enable project leaders to be flexible and transparent, while still acting in accordance with an approach shared with local and regional actors.
- Adopting a financing scheme adapted to the capacities and possibilities of the potential beneficiaries, who are often young people who experience challenges in mobilizing their own resources.
- Providing personalized support to project leaders to finalize their business plans, while ensuring their motivation and ownership.
- Establishing an operational system of support, advice, and sustained accompaniment and follow-up of project leaders.

To create long-term employment opportunities, address labor shortages, and enhance farm profitability, a balanced approach to mechanization and optimized farm management is essential. Furthermore, the development of ecotourism potential can contribute to job creation and additional income for farming communities. An enabling environment that builds upon GDAs, extension services, and cooperatives to support and promote ecotourism in oases—for instance through planning guidance, joint tourism promotion, and investment support—can further advance this effort.

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