جائزة خليفة الدولية لنخيل التمر والابتكار الزراعي
KHALIFA INTERNATIONAL AWARD FOR DATE PALM
AND AGRICULTURAL INNOVATION

CLIMATE CHANGES
and its impact on the agricultural sector

Dr. Abdelouahhab Zaid, Prof.,
Secretary General of Khalifa Int'l Award
for Date Palm and Agricultural Innovation

Eng. Emad Saad
Sustainability and Climate Change Expert.

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Climate changes and its impact on the agricultural sector

This book is dedicated to the participation of Khalifa International Award for Dare Palm and Agricultural Innovation in the activities of the International Conference of the United Nations for Climate Change (COP28).

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We dedicate this book: "Climate changes and its impact on the agricultural sector", to H.H. Sheikh Mohamed bin Zayed Al Nahyan, President of the United Arab Emirates, "May God protect him", and H.H. Sheikh Mansour bin Zayed Al Nahyan, UAE Vice President and Deputy Prime Minister, Minister of the Presidential Court, the first supporter of date palm cultivation. The authors also extend their thanks and appreciation to H.E. Sheikh Nahayan Mabarak Al Nahyan, Minister of Tolerance and Coexistence, Chairman of the Award's Board of Trustees.

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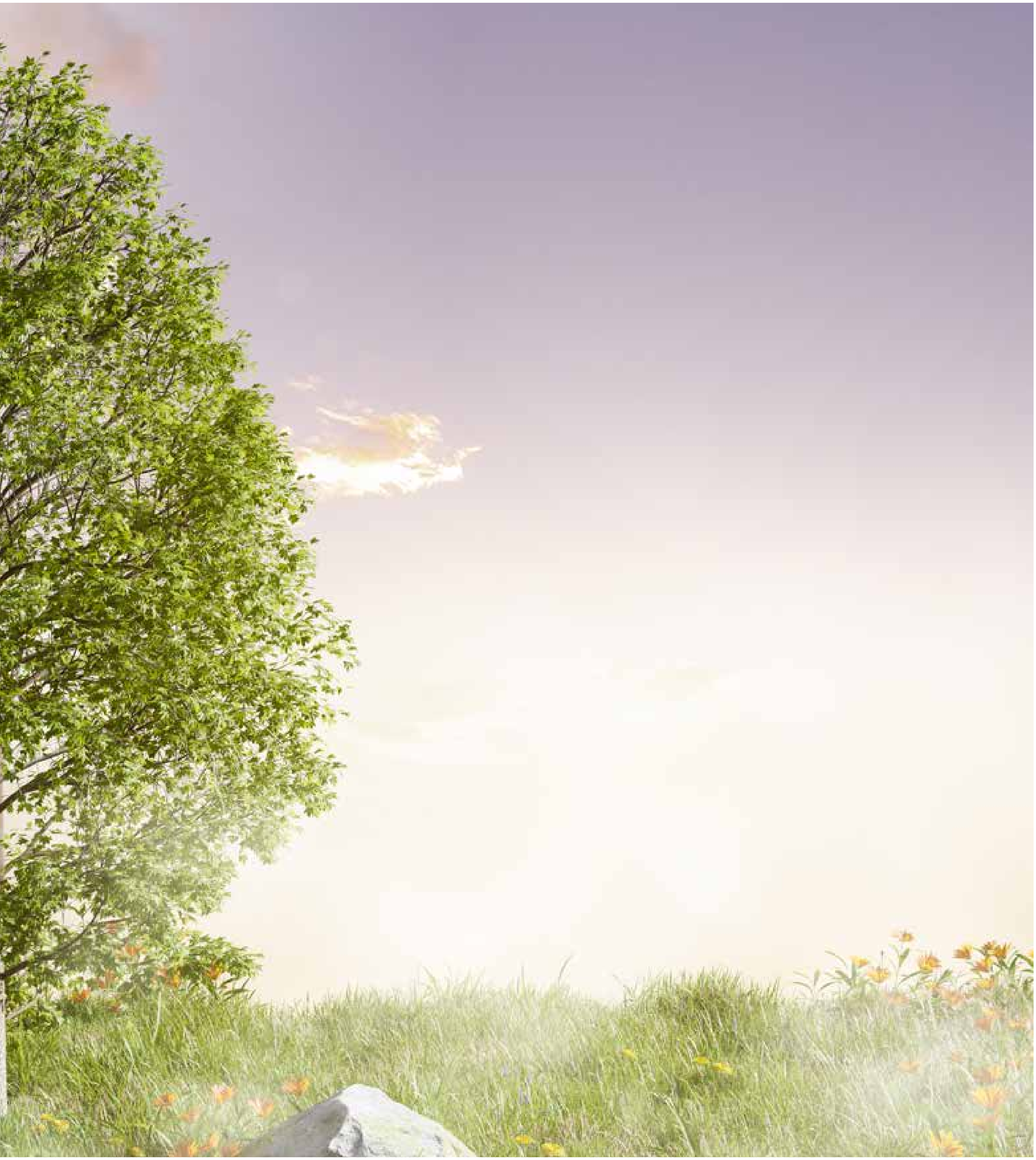

Climate Changes and its Impact on the Agricultural Sector

Dr. Abdelouahhab Zaid, Prof.

Secretary General, Khalifa International Award for Date Palm and Agricultural Innovation.

Climate Changes and its impact on the agricultural sector aim to adapt and reduce the impact of agriculture on climate change, which comes in response to the challenges facing the agricultural sector in general, as a result of increasing climatic changes, such as temperature increase, rainfall fluctuations, natural disasters, etc. Climatic agriculture aims to promote food production in a sustainable and climate-resistant manner, to improve farmers' sustainability and increase their resilience to increasing climatic challenges. Such agriculture is an important part of responding to the climate change crisis and ensuring the world's food security, facing increasing climatic challenges.

Climatic agriculture includes a range of practices, techniques and procedures, including selecting climatic varieties that has tolerance to high temperatures or rely on lower amounts of irrigation water, improving water consumption using effective irrigation techniques to conserve water, improving soil management and using agricultural techniques that promote soil health and improve its ability to store water and organic matter, reducing greenhouse gas emissions by lowering the use of pesticides and chemical fertilizers, planting trees to absorb carbon dioxide, and using modern technologies, such as the use of sensors, and information and communication technology to monitor and manage farms more effectively, as well as promote biodiversity.

As a result of these climatic changes, the agricultural sector in general is currently facing many important challenges, including rising temperatures that can negatively affect plants and crops. High temperatures may also increase the evaporation of water from the soil and reduce the efficiency of water use in plants. This is in addition to water shortages, resulting from climate changes, whether due to interruption of rainfall or changes in rainfall patterns. This can cause crops and farmland degradation, as fluctuations in the rainfall pattern can make it difficult to plan for agriculture and rely on traditional growing seasons.

While climate change may increase the frequency and severity of natural disasters such as droughts, floods and hurricanes, leading to significant losses of crops and agricultural resources, as well as increasing carbon emissions, as a result of agriculture with unsustainable methods that can increase carbon emissions, contributing to an increase in greenhouse gases and climate change in general. Declining biodiversity, which in return leads to the loss of certain varieties of crops and plants on which agriculture depends. Not to mention, climate change can also increase the spread of diseases and pests that affect crops and cultivated plants.

Stakeholders in the agricultural sector also play a crucial role in addressing the challenges of climate change, and this sector is one of the most affected by biodiversity loss. All competent authorities in the agricultural sector plan and organize to develop strategies and policies adaptive to climate change. Where they contribute to the development of a framework for sustainable agriculture, setting environmental goals and standards, developing effective strategies for water resources management and increasing water use efficiency in agriculture, while governments and stakeholders in agriculture must cooperate at the national, regional and international levels, to address the challenges of climate change through the exchange of knowledge, expertise and technology between countries to achieve better adaptation to climate change.

Research organizations and universities should provide the necessary research and technology to improve sustainable farming practices, and develop agricultural varieties adapted to changing climatic conditions. In addition to educating farmers and workers in the agricultural sector about the effects of climate change, and how to adapt to them. Stakeholders can also assist in providing awareness training courses and specialized workshops. Providing financial support, is also crucial, as agriculture needs significant investments to adopt adaptive technologies and improve infrastructure. Governments and financial actors can provide financial support to farmers and sustainable agricultural projects. It is critical to monitor the impact of climate change on agriculture and assess its response. Stakeholders can also contribute to the collection and analysis of data and information to determine the effectiveness of adaptive actions.

The present book, published by the General Secretariat of Khalifa International Award for Date Palm and Agricultural Innovation, is part of the Award's participation in the Climate Change Conference (COP28), hosted by the United Arab Emirates, from the 30th of November to the 12th of December, 2023, with the participation of a group of concerned experts.

Artificial Intelligence and the Agricultural Sector

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Sustainability and Climate Change Expert.

Although humans are still better than Artificial Intelligence (AI) in many things, the world today cannot abandon it, despite the dangers that have accompanied its use so far, but scientific research and technical development are moving rapidly and strongly to overcome gaps and opportunities for improvement, towards a better future for humans and the environment.

Artificial Intelligence, will enable people to do any task, especially in the agricultural sector, more efficiently, as it is a horizontal science that intersects with all life sciences, society, and even business. It also has a clear and strong relationship with the agricultural sector in general, as it contributes to enhancing the ability of this sector to adapt to the challenges faced by climate change, as well as increasing productivity and efficiency in the sector, which contributes to achieving food security and environmental sustainability. AI also plays a critical role in supporting the agricultural sector in addressing climate challenges by providing technological solutions and improvements. It provides tremendous opportunities to improve the productivity and sustainability of the agricultural sector and helps it address climate challenges.

According to the Food and Agriculture Organization of the United Nations (FAO), the world's population is expected to grow up to 10 billion, by 2050, and with such increase, new methods of agricultural production are needed in order to meet growing food needs. Digital technologies, especially Artificial Intelligence, plays an important role in enhancing the ability to produce food, facilitate the efficient use of natural resources, and help improve crops and agricultural assets, as well as saving time and labor costs, etc.

Artificial Intelligence can also contribute to changing the future of agriculture, as it has already been inserted into all agricultural operations: starting from soil inspection, to the detection of pests diseases, to smart irrigation, etc. Where some of the ways in which AI can contribute in this regard is as follows:

Improve productivity: AI can help farmers improve their productivity by providing accurate guidance on when and how to grow crops and manage farms effectively. It can increase the efficiency of agriculture and increase production.

Resource management: AI can help improve the management of resources such as water, land, and fertilizers, reducing resource consumption, and improving efficiency.

Pests and diseases control: AI can develop predictive models to monitor and analyze data to effectively combat agricultural pests and diseases, and guide farmers in taking immediate preventive or remedial action to combat them, contributing to crop protection and reducing production losses.

Weather and climate forecasting: AI can analyze weather and climate data from multiple sources, such as satellites and monitoring stations to improve weather forecasting and weather phenomena. This enables farmers to better plan their farming and manage their resources effectively.

Improve crop quality: AI can improve crop quality and increase the production of value-added products.

Save time and effort: AI can allow farmers to control farming operations more effectively and save time and effort.

Sustainable agriculture: AI can be used to develop sustainable agricultural practices, that reduce the impacts of agriculture on the environment.

Smart irrigation: AI can improve irrigation systems by monitoring land and weather conditions in real time. This reduces water consumption and improves irrigation efficiency.

Inventory and supply management: AI can analyze data to improve inventory management and distribution of agricultural products, contributing to reduced waste and improve efficiency.

Developing climate-resilient crops: Artificial intelligence can use genetic engineering techniques in scientific research to develop new crops that are more resistant to climate change, and withstand harsh environmental conditions.

Agricultural Data Analysis: Artificial intelligence can be used in analyzing large quantities of big agricultural data, to derive patterns and guidance useful to farmers.

On the other hand, mitigation and adaptation are essential parts in supporting the agricultural sector in facing climate change, as mitigation refers to taking action to reduce greenhouse gas emissions and adverse environmental impacts caused by human activity. In the agricultural sector, mitigation can include: moving to more sustainable agricultural practices such as the use of organic farming and improving manure management, and developing technologies to reduce greenhouse gas emissions from agricultural production, such as the development of smart irrigation systems, and the use of alternative energy in agriculture.

Adaptation is about developing strategies and techniques to help the agricultural sector deal with anticipated climate change. Adaptation can include: Adopting crops that are more resistant to extreme weather conditions such as drought or flooding. Improve irrigation systems to cope with changes in rainfall pattern. Provide training and support to farmers to understand and implement adaptation practices.

The combination of mitigation and adaptation can be hugely beneficial to support the agricultural sector in facing climate change. For example, mitigation through the use of emission reduction techniques and improved resource management can reduce the impact of agriculture on the climate. While adaptation can help increase the resilience of the agricultural sector and farmers to growing climate challenges.


GPS
ph

Geo-Spatial Modelling of Carbon Stock Assessment of Date Palm at Different Age Stages:

Integrated Approach of Fieldwork, Remote Sensing and GIS

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Abstract

The aim of this study is to develop a geospatial model for the assessment and mapping of carbon stock (CS) of date palms (DP) in Abu Dhabi, at three age stages: mature, medium and young. The approach relied on the use of correlated remote sensing predictors tested and derived from Landsat-8 imagery over the study period to estimate CS. Multiple predictors including single bands, vegetation indices (VIs) and their combination were used in linear and non-linear regression models to identify the best performing predictors and regression models for DP. Mature DP, older than 10 years, attained the most significant correlation when using a second-order polynomial model with the tasseled cap for wetness as a predictor, yielding R^2 of 0.7643. For non-mature DP, less than 10 years, the exponential regression model using renormalized difference vegetation index (RDVI) as a predictor provided the most significant correlation for AGB estimation with R^2 of 0.4987. The study demonstrated that moderate-resolution Landsat-8 OLI imagery has the potential to estimate the CS in DP of drylands at different age stages. This is the first attempt to estimate CS in DP using geospatial technologies with minimal fieldwork hence, expanding our approach to other remote and less-studied drylands.

1. INTRODUCTION

Vegetation in arid lands provides important ecosystem services contributing substantially to the global carbon cycle (Lal, 2004). Furthermore, biomass constitutes a fundamental parameter that describes vegetation composition and purpose (Li *et al*. 2019; West, 2009). For instance, it contains the bulk of carbon sequestered terrestrially through the process of capturing and storing CO_2 in the stems, roots, and soil. Estimating biomass plays a vital role in determining the storage, balance, and cycling of carbon locally as well as globally. A large number of studies describing various approaches for estimating biomass and carbon in forests and plantations have been published (Dahy *et al*. 2020; Issa *et al*. 2020a; Araujo *et al*. 2023). However, regardless of their high sensitivity to climate alteration and the major role they play in their societies, arid lands have received little attention in these studies, compared to other ecosystem regions such as humid and tropical regions).

Above-ground biomass (AGB) represents the biggest component of the total living biomass in the vegetation cover and does not present major logistical problems in the field work, making its estimating easier (IPCC, 2007). AGB estimation has received considerable attention because of its role in carbon cycle processes combined with the increased awareness of climate change. Furthermore, AGB can be used to estimate biomass amount stored in the root system (below-ground biomass), generally around 20% of AGB (Mokany *et al*., 2006). It can also be used to predict dead wood / litter biomass, generally estimated at 10%–20% of AGB (Houghton *et al*., 2009).

Three main approaches are used to estimate and predict forest AGB: process-based models, field measurements, and remotely sensed data combined with forest inventory (Safari *et al*., 2017). The field measurement methods are the most accurate; however, their lack of spatial and temporal coverage make them labor-intensive and impractical for extended areas and time periods (H Nguyen *et al*., 2020). The remote-sensing-based methods have been used in the last decades through modelling of forest parameters based on measured spectral variables (Dahy *et al*. 2020, 2019; Issa *et al*. 2020a; Chang *et al*. 2023). Several vegetation parameters can be predicted from the reflected remote sensing region including: VIs (e.g. normalized difference vegetation index, enhanced vegetation index, etc.), leaf area index, absorbed photosynthetically active radiation (APAR), and different image transformations (Duarte *et al*., 2018; Habib and Al-Ghamdi, 2021). Images acquired by multispectral sensors are used to derive spectral information that can be correlated with forest inventory AGB data (Kumar *et al*. 2015; Abbas *et al*. 2020). Commonly used variables include spectral bands, VIs, image transformations, and texture images (Kelsey and Neff, 2014; Zhu and Liu, 2015). The Landsat program was the first to provide scientists worldwide with a long record of space-based consistent data of the land surface at moderate spatial resolution free of charge. The Landsat data time-series (1972-present) has provided ecosystem monitoring systems with two important elements: the spatial and temporal coverag-

es that lacked in the field measurement approach. It is worth noting that the spatial dimension of this data*set al*lows the detection and assessing of both environmental and human effects in the study area. While its temporal dimension enables historical change analysis over more than four decades. The free data policy introduced by the Landsat program in 2008 has revolutionized forest studies and monitoring in general, and for estimating AGB specifically.

Particularly important to our research is the process of estimating the amount of carbon stock in date palms (DP), believed to have substantial capability of sequestering terrestrial carbon in both vegetation and soil compartments (Betemariyam and Kefalew 2022). DP (*Phoenix dactylifera* L.), major crop in arid lands, are resilient, productive, and have multiuse benefits (Jaradat and Zaid, 2004). Particularly, in the United Arab Emirates (UAE), DP have been a vital component of the agricultural system. The records show that the number of DP in the world exceed 120 million, distributed across 30 different countries (FAOSTAT, 2013). They produce about 7.5 million tons of dates annually, 70% of which come from Middle East and North Africa region (MENA). UAE alone contributes to more than 50% of MENA date production.

The topic of this study was carefully chosen for many reasons, not the least are: the abundance of DP in the study area, which has numerous socio-economic benefits, making it a valuable resource to the local population; use of geospatial technologies to estimate and model CS in DP, for the first time, in the region; apply and use the outcomes of the study as a quick and reliable input in support of a long-term strategy for land resources management, which is especially important given the UAE government's significant investment in greening the country. Finally, the CS by these DP was a plus, not planned for when deciding to green the country half a century ago.

The main objective of the current study is to build a RS-based biomass model to predict and map CS distribution in DP of the arid lands of Abu Dhabi (UAE) at three age stages: mature, medium, and young DP.

2. MATERIALS AND METHODS

2.1 Study area

The study area encompasses the whole emirate of Abu Dhabi, the largest of the seven emirates composing UAE. It is bounded by 22° 55´ to 24° 48´ N, and 51° 30´ E to 56° 00´ E and extends over a land area of 67,340 km^2. Sand dunes make up about 2/3 of the study area with nearly 5 million hectares (Fig. 1). The Emirate, which hosts the capital city of Abu Dhabi, has undergone extensive land conversions, supported, and subsidized by substantial oil revenues, to become an urbanized modern state. Besides, local authorities have extensively engaged in large greening projects, to the extent that by the end of 2017, more than 540 afforested areas covering an estimated surface of 242,000 ha, and mainly planted with DP, have been realized (Abu Dhabi State of Environment Report, 2007; Issa *et al*., 2019)and aboveground biomass (AGB. The geographic and environmental settings of the study area are summarized in Table 1.

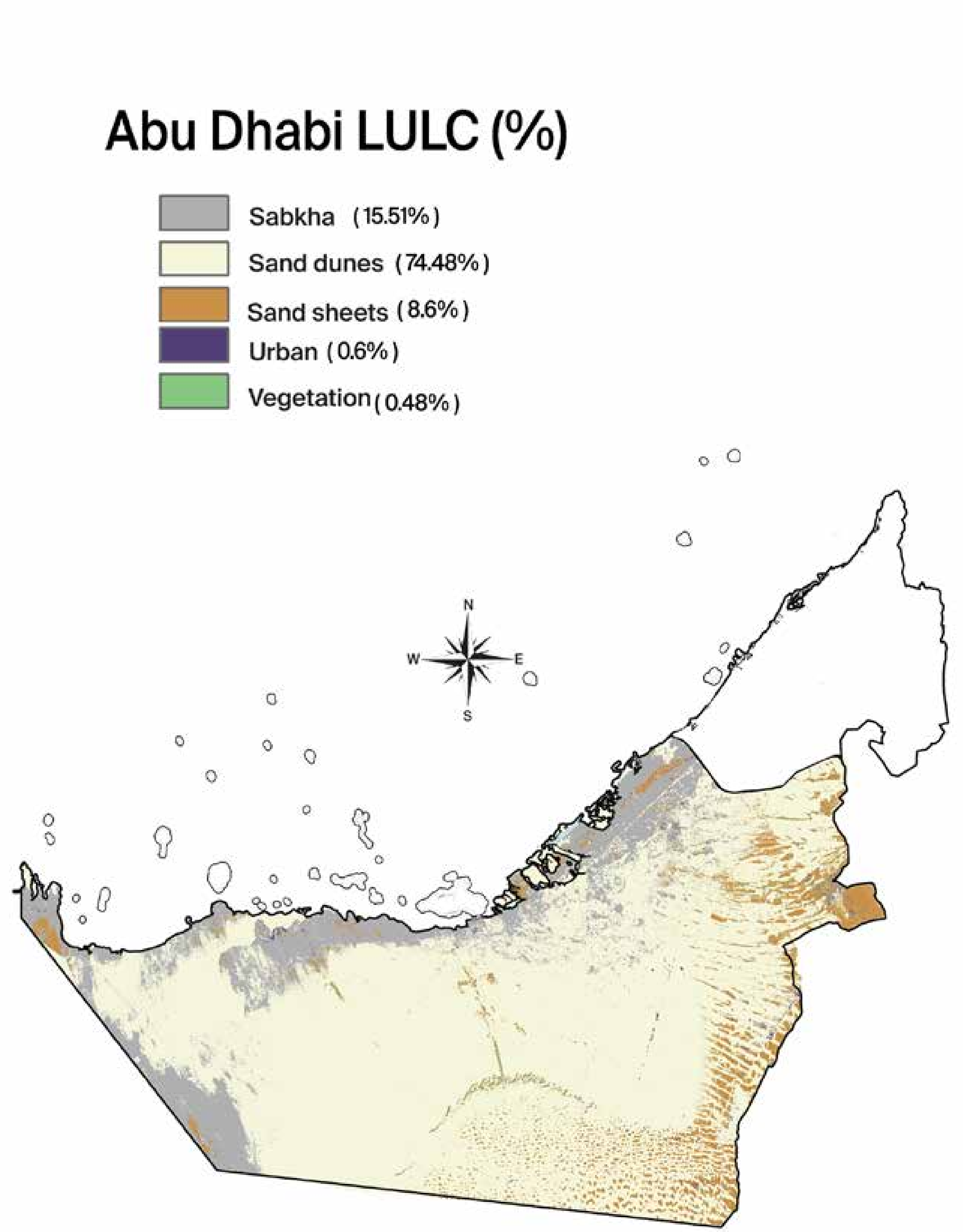

Figure 1: The study area and its main land cover classes.

Table 1: Geographic and environmental settings of the study area.

Elevation	0 – 200 m
Geomorphology	sand dunes, inter-dunal sands, coastal and inland sabkhas and exposed rocks.
Climate	The Köppen Climate subtype is "BWh" (Tropical/Subtropical Desert Climate)
Seasons	two seasons: summer (April - Sept) and winter (Oct - Mar).
Temperature	from 35° to 45 C in summer and from 10 to 24°C in winter.
Relative humidity	high in the coasts (reach 90%) and extremely dry in western and southern deserts.
Rainfall	variable among years. Occurs in winter and reaches 12 cm annually
Groundwater	low with large amount of salinity levels
Soils	sandy, sandy calcareous, gypsiferous, saline, salinegypsiferous and hard pan soils
Vegetation	~ 60% are annuals species and germinate from Feb to April, generally and the perennial species flower from Jan to early May, and some in Sept and Nov.

2.2 Methods

The flowchart of the methodology used to develop and validate the RS-based biomass model is presented in Fig.2. It shows the main components of the model: (1) identification of RS predictors that can be used to estimate AGB; (2) selection of sample plots representing different age classes of DP (mature, medium, and young); (3) collection of field data necessary to estimate AGB using the DP-specific biomass allometric equations; (4) building the RS-based biomass estimation model using various regression methods and validating it by using different statistical metrics and (5) producing a map showing CS distribution throughout the emirate, by creating the AGB distribution map first, then converting it into CS distribution map. Our model was developed and implemented using ERDAS Imagine 2020, and ArcGIS 10.7 software packages.

2.2.1. Field Data Collection

DP plantations in the study area were classified according to their age into three classes: mature date palm (MDP) (more than 10 years), medium date palm (MeDP) (5-10 years), and young date palm (YDP) (less than 5 years). Two extensive field visits were conducted at the end of summer and during winter of 2018 targeting farms with different age stages plantations, to collect data from sample units representing the three DP age stages. The first visit took place from 10th to 18th September and the second from 14th to 6th December. In all, 54 plots of DP plantations were selected using a randomized probability sampling design (stratified random design) according to their age stage (MDP, MeDP, and YDP). The plot survey included 17 representing MDP, 19 representing MeDP, and 18 representing YDP. The dimension of the plots were 40 m × 40 m, to ensure that one Landsat 30 x 30 meter pixel fell within each plot (Fig. 3) (Issa *et al*., 2019). The coordinates of the plot's center and the number of DP in each of the 54 plots were recorded. The mean values of these variables (single bands and VIs) for all plots were calculated using a 3 × 3 window centered over each plot and consequently used in the model development. 3x3 window was used to reduce the uncertainties in RS data resulting from plot positioning errors that could be created because of the mismatching of sample plots with the image pixels introduced when the x and y coordinates of sample plots were located using GPS (Fig. 3).

Figure 3. The 40 × 40 m plot design. The red window delimits the nine Landsat pixels covering the plot (Issa *et al*. 2019).

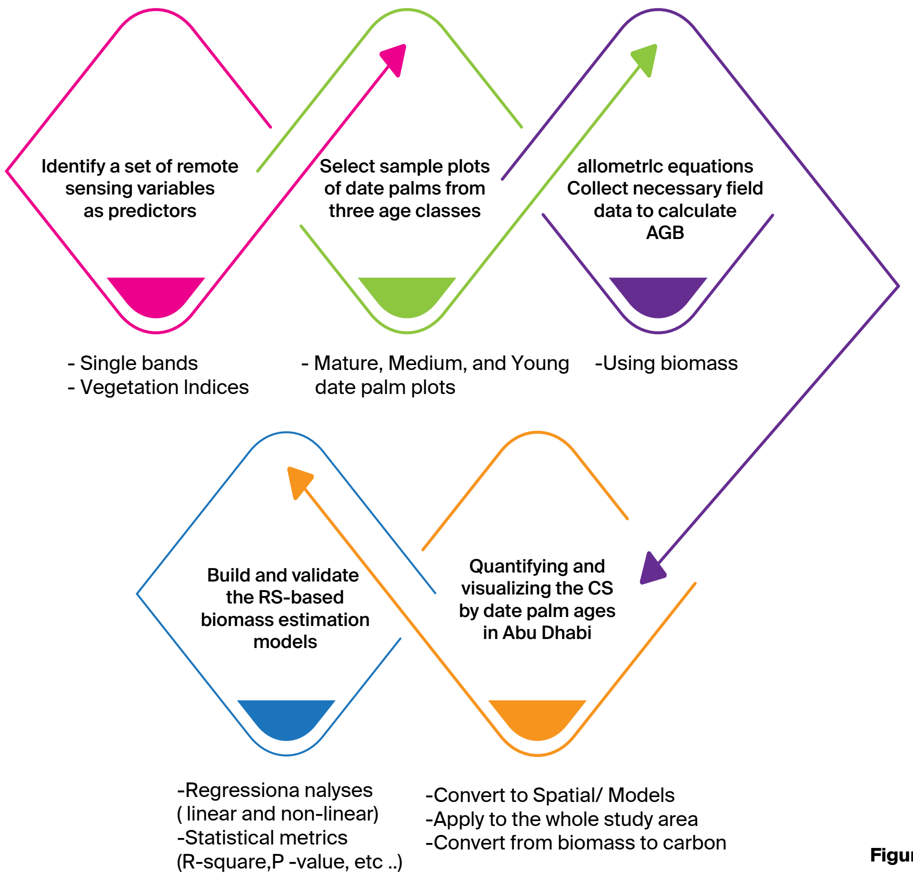

Figure 2: Methodology flowchart.

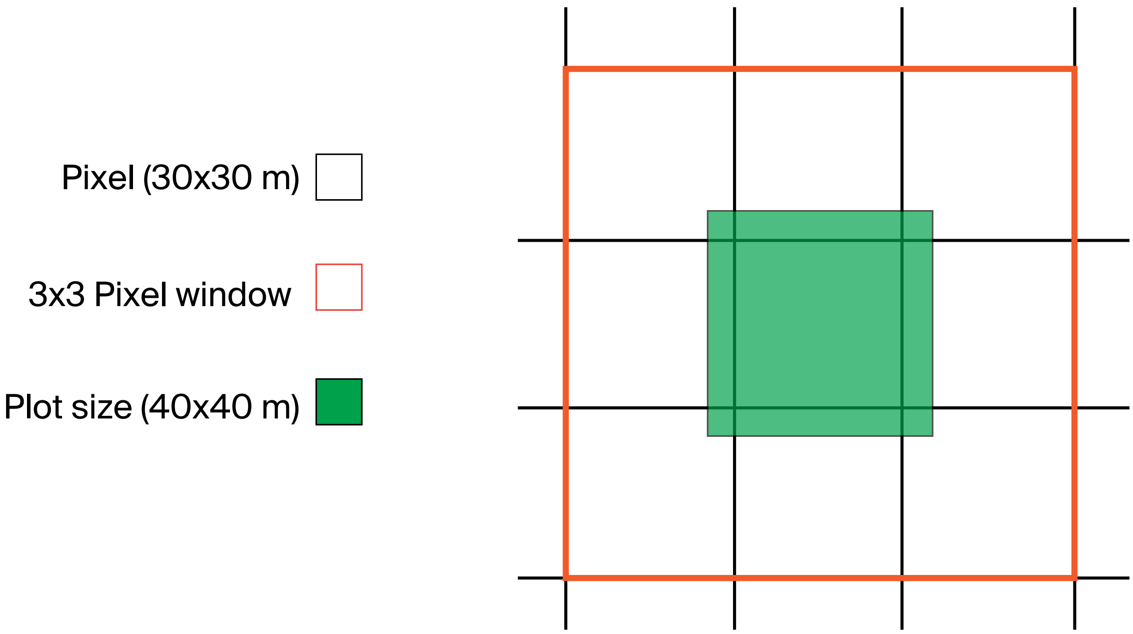

Figure 3: The 40 × 40 m plot design. The red window delimits the nine Landsat pixels covering the plot (Issa *et al*. 2019).

Trunk height (Ht) and crown diameter (CD) for each palm were measured and subsequently used to calculate its crown area (CA), assuming a spherical palm crown (CA = π CD2/4). It is worth mentioning that we initially selected 83 field plots for surveying but had to exclude 29 of them leaving 54 only. The reasons for exclusion were: (1) sparse distribution of DP per plot (< 20 palm per plot), (2) suffering of DP from abiotic stresses (e.g., drought: direct observation in the field or/and through discussion with the farmers as some DP were deliberately not irrigated to get rid of them), and (3) the large level of heterogeneity not representing, accurately, the age stage class (mature, medium, and young).

2.2.2. Field Estimation of AGB and its Carbon Content

The AGB at the plot level was estimated by using DP biomass allometric equations previously developed, specifically for DP of Abu Dhabi under arid land ecosystem conditions (Issa *et al*. 2020b). AGB for each DP was first estimated by adding crown biomass (CB) and trunk biomass (TB) using the equations presented in Table 2. AGB at the plot level was then predicted by summing the AGB for all palms in the plot and converting the results to biomass density in tons per hectare (t. ha^{-1}).

Table 2: The Crown and Trunk biomass equations used for AGB (kg. palm−1) estimation of DP in study area.

Biomass Component	Allometric Equation	R^2	P-value	Reference
CB	= 14.034 × 1.057CA	0.8354	0.001	(Issa et al. 2020b)the authors demonstrated that combinations of visible and short wave single bands (Red, SWIR1, SWIR2
TB	= 40.725 × Ht0.9719	0.8276	0.0004	
AGB	= CB + TB			

where CB is crown biomass, TB is trunk biomass, AGB (= CB+TB) is the above-ground biomass, CA is crown area (m^2), Ht is trunk height, R^2 is coefficient of determination.

2.2.3. Identifying RS Variables (Predictors)

Atmospherically corrected (Level-2) Landsat 8 OLI scenes, were used to build the RS-based model. The data which comprised different types of DP plantations were geo-registered to the UTM coordinate system (Zone 40, WGS 84). Seven bands were selected, stacked, and stored using ERDAS software package (Table 3).

Table 3: Details of dataset used in the current research.

Scene (Path/ Row)	Date (2017)	Landsat 8 OLI Level 2 Bands (μm)	Resolution/ Swath
160/43	24th April	Coastal (B1): 0.433–0.453,	30 meters. Swath area is 185 km.
160/44	26th May	Blue (B): 0.450–0.515,	
161/43	15th April	Green (G): 0.525–0.600	
161/44	15th April	Red (R): 0.630–0.680,	
162/43	22nd April	NIR: 0.845–0.885,	
162/44	22nd April	SWIR1: 1.560–1.660, and SWIR2: 2.100–2.300	

A combination of individual reflective bands and VIs were used as remote sensing predictors to estimate AGB. Both reflective bands listed in Table 3, and modified VIs listed in Table 4 were tested.

Table 4: Selected Landsat 8 OLI-derived vegetation indices (VIs).

VIs	Equation	Source
SR	NIR/R	(Birth and McVey, 1968)
RVI	R/NIR	(Pearson and Miller, 1972)
DVI	NIR–R	(Tucker, 1979)
NDGI	(G-R)/(G+R)	(Courel et al., 1991)
NDVI	(NIR-R)/(NIR+R)	(Rouse, 1974)
TVI	$\sqrt{}$(NDVI +1)	(Srestasathiern and Rakwatin, 2014)
GNDVI	(NIR-G)/(NIR+G)	(Gitelson et al., 1996)
RDVI	(NIR – R)/$\sqrt{}$(NIR + R)	(Roujean and Breon, 1995)
SAVI	(1.5 × (NIR – R))/(NIR + R + 0.5)	(Huete, 1988)
MSAVI	$0.5 \times [2 R_{NIR} + 1 - \sqrt{}((2 R_{NIR} + 1)2 - 8 (R_{NIR} - R_{red}))]$	(Qi et al., 1994)however, the L factor should vary inversely with the amount of vegetation present. A modified SAVI (MSAVI
TCG	−0.2941 × B − 0.2430 × G −0.5424 × R + 0.7276 × NIR + 0.0713 × SWIR1 − 0.1608 × SWIR2	(Baig et al., 2014)
TCB	0.3029 × B + 0.2786 × G + 0.4733 × R + 0.5599 × NIR + 0.5080 × SWIR1 + 0.1872× SWIR2	(Baig et al., 2014)
TCW	0.1511 × B + 0.1973 × G + 0.3283 × R + 0.3407 × NIR – 0.7117 × SWIR1 −0.4559 × SWIR2	(Baig et al., 2014)

where SR is the simple ratio, RVI is the ratio vegetation index, DVI is the difference vegetation index, NDGI is the normalized difference greenness index, NDVI is the normalized difference vegetation index, TVI is the transformed vegetation index, GNDVI is the green normalized difference vegetation index, RDVI is the renormalized difference vegetation index, SAVI is the soil-adjusted vegetation index, MSAVI is the modified soil adjusted vegetation index, TCG is the tasseled cap transformation index for greenness, TCB for brightness and TCW for wetness.

2.2.4. Building The RS-based Model for AGB Estimation

Different regression types (linear and non-linear) were considered to evaluate the relationships between RS predictors and AGB values for each plot predicted from ground measurements and allometric equations (Table 2). Linear regression model was first tested, and their performance assessed based on their coefficients of determination (R^2) and significance (P-value < 0.05). A stepwise multiple linear regression analysis, involving several single bands and VIs, was subsequently applied to achieve improved correlation.

2.2.5. Model Evaluation

The AGB estimation model was assessed using cross-validation for each plot; Root Mean Square Error (RMSE), RMSE%, and the systematic prediction error (SPEr)s, were estimated in percentage after randomly splitting the plot measurements dataset into a calibration dataset (80%), and a validation dataset (20%). The RMSE, RMSE%, and SPEr were estimated using the equations 1, 2, and 3.

$$\textbf{RMSE} = \sqrt{\frac{\sum(\hat{y}_i - y_i)^2}{n}} \qquad \textbf{Equation} \quad \textbf{(7)}$$

$$\textbf{RMSE \%} = 100 \times \frac{RMSE}{\bar{y}} \qquad \textbf{Equation} \quad \textbf{(8)}$$

$$\textbf{SPEr} = \hat{y}_i - \bar{y}_i \qquad \textbf{Equation} \quad \textbf{(9)}$$

where (ŷi) is the predicted AĜB of the ith plot, (yi) is the observed AGB of the ith plot, (ӯ) is the mean of predicted AĜB, and () is the mean observed AGB.

2.2.6. Applying The RS-based Biomass Model to Estimate AGB of DP at Different Age Stages

Maps of DP plantations, created in a previously published study (Dahy *et al*., 2021), were used in the model to delineate the location of DP at different age stages. The reported accuracy of these maps was significantly high with overall classification accuracy of 94.5%, and a kappa coefficient of 0.888. They showed that DP plantations covered an area of about 7,588.04 hectares (22.69% for YDP, 22.04% for MeDP, and 55.27% for MDP). Subsets of Landsat 8 OLI images (Table 3) corresponding to DP plantations as defined in the DP maps were extracted using ERDAS imagine and used as input to the RS-based biomass model.

The spatial model that estimates the amount of AGB (t. ha-1) for each Landsat pixel was implemented and run in the Spatial Model Editor within ERDAS Imagine (Fig. 5) to estimate and create an AGB map of the study area. The produced map was subsequently used as input to estimate the density of above-ground carbon (AĜC) for each pixel according to equation 4, based on a previously published carbon content to AGB ratio of 53.87% (Issa *et al*., 2020b).

$$\textbf{A\hat{G}C (t. ha}^{-1}\textbf{) = 0.5387} \times \textbf{A\hat{G}B (t. ha}^{-1}\textbf{)} \qquad \textbf{(4)}$$

To estimate AGB and AGC content (in ton), AĜB and AĜC density values (t. ha-1) produced by the model for each pixel were multiplied by the pixel size using the Attribute Table Function in ERDAS Imagine. AĜB (in ton) was subsequently used to estimate the other carbon components involving biomass as described in section 2.2.7.

2.2.7. CS Estimation from the five components of the DP

The total amount of CS was estimated as the sum of the carbon content of each of the following five biomass components: AGB, below-ground biomass (BGB), litter, woody debris, and soil organic matter (SOM) (Eggleston *et al*., 2006). BGB, litter, and debris were predicted from the estimated AGB value (subsections 2.2.7.1 and 2.2.7.2). The soil organic carbon (SOC) was deduced from the SOM amount which was estimated as 91.38% (subsection 2.2.7.3).

2.2.7.1. Below-ground biomass (BGB)

BGB is generally estimated at 20% of the AGB in several published studies (Cairns *et al*., 1997; Koala *et al*., 2017; Mokany *et al*., 2006; Niether *et al*., 2019). However, we found different ratios among different DP age stages with averages of 0.332, 0.925, and 0.496 for YDP, MeDP, and MDP, respectively (Issa *et al*. 2020b). Therefore, the following equations (5, 6, and 7) were developed to estimate BGB of DP:

$$\textbf{B\hat{G}BMDP (t) = A\hat{G}B (t)} \times \textbf{0.496} \qquad \textbf{(5)}$$

$$\textbf{B\hat{G}BMeDP (t) = A\hat{G}B (t)} \times \textbf{0.92} \qquad \textbf{(6)}$$

$$\textbf{B\hat{G}BYDP (t) = A\hat{G}B (t)} \times \textbf{0.332} \qquad \textbf{(7)}$$

On the other hand, the percentage of carbon content in the root system of DP (BGB) was found to be 51.27% (Issa *et al*., 2020b), which is slightly lower than the carbon content in the AGB. Therefore, below-ground carbon (BĜC) was estimated in tons by multiplying the resulting values from equations 5, 6, or 7 by a factor of 0.5127 (equation 8).

$$B\hat{G}C\,(t) = 0.5127 \times B\hat{G}B\,(t) \qquad (8)$$

2.2.7.2. Litters, and Woody Debris

Carbon content of dead wood or litter and woody debris were assumed to be between 10 and 20% of the AGB (Gibbs *et al*., 2007; Houghton *et al*., 2009; Issa *et al*., 2020a). The borders between dead biomass and litter, and between dead biomass and SOM, are rather subjective (Houghton *et al*., 2009). Based on extensive field visits to DP farms at different age stages, it was observed that litter and debris ratio to AGB of DP varied depending on the palm age stage. The more the palm matures, the more it produces litter and debris. The researchers adopted the following percentages to be applied to predict litter and debris (in ton) from AĜB (in ton), for DP plantations; 10% for YDP, 15% for MeDP, and 20% for MDP.

2.2.7.3. Soil Organic Carbon (SOC)

The DPs contribute about 22.26 tons of SOC per hectare in plantations (Issa *et al*., 2020b)the authors demonstrated that combinations of visible and short wave single bands (Red, SWIR1, SWIR2. This number was calculated by performing the combustion method for 4 hours at 550 on soil samples taken at top soil (10 cm) from underneath the DP canopy, and then deriving of the SOM, and the SOC. Furthermore, the SOC (in ton) of DP for the three age stages were calculated as per equation 9.

$$SOC = Area \times 22.26\ t.\,ha^{-1} \qquad (9)$$

where the total areas of MDP, MeDP, and YDP in the study area were estimated to be 4,193.86 ha, 1,672.14 ha, and 1,722.05 ha, respectively (Dahy *et al*., 2021).

Finally, ERDAS spatial modelling tools were used to produce the AGB map for the whole study area utilizing the selected model built from the RS variables as estimated by the results of our analyses. AGC map (Fig. 6) was then created by multiplying the estimated AGB by 0.5387 as per the equation 4 (subsection 2.2.6).

3. RESULTS

3.1. Descriptive Statistics of the Assessed Field Variables

Structural variables of 2063 palms included in the 54 plots were measured in the field. Statistics about these measurements including the number of DP for each age stage class, average CA, Ht, and densities of DP per hectare, are summarized in Table 5. The average palm CA in meter and its standard error (±SE) of the MDP, MeDP, and YDP plots were 36 (±1.64), 22.51 (±1.22), and 6.65 (±0.67) m^2, respectively. The average palm Ht's of the MDP, MeDP, and YDP plots were 2.89 (±0.22), 1.07 (±0.08), and 0.15 (±0.03) m, respectively. It is obvious that the increase in DP age results in an increase in CA and Ht. The averages of DP number per plot of MDP, MeDP, and YDP were 41, 38, and 35, respectively, which, based on a plot area of 1600 m^2, amounts to around 258, 238, and 221 palm. ha^{-1}, respectively.

Table 5: Crown area (CA), trunk height (Ht), and density values of DP for each age stage.

DP Age Stage	No. Palms	Average CA (m^2)	Average Ht (m)	Avg. Density (palm. ha^{-1})
MDP	701	36 (19.54 – 44.15)	2.89 (1.90 – 5.07)	258 (131 – 600)
MeDP	725	22.51 (11.85 – 32.45)	1.07 (0.39 – 1.64)	238 (131 – 450)
YDP	637	6.65 (2.52 – 13.94)	0.15 (0 – 0.37)	221 (144 – 306)

where MDP is mature date palm, MeDP is medium date palm, and YDP is young date palm. The numbers in the parenthesis represent the minimum and maximum values.

3.2. AGB Estimating of Field Data and the Estimation of its Carbon Content

AĜB was estimated from the field measurement in all 54 plots. Table 6 shows the average and range of AĜB in (t. ha-1) for DP at the three age stages. The largest ĈB was found in MDP plots while the lowest ĈB was found in YDP plots. These outcomes were affected by the average CA of the plots (Table 5). Similarly, TB was affected by the Ht average (Table 5). The averages of AĜB in tons per hectare (±SE) of MDP, MeDP, and YDP were estimated at 59.39 (±7.8), 23.33 (±2.5), and 6.15 (±0.5) t. ha-1, respectively. The AGC in (t. ha-1) was estimated by multiplying the average AĜB in tons per hectare by 0.5387 (see equation 4). Therefore, the averages AĜC (±SE) for MDP, MeDP, and YDP plots were estimated at 31.99 (±4.2), 12.57 (±1.4), and 3.31 (±0.3) t. ha-1.

Table 6: The averages and ranges of AĜB (ĈB and TB) at each DP age stage

DP Age Stages	No. Plots	Biomass ($t. ha^{-1}$)		
		Ĉrown Biomass	**Trunk Biomass**	**AĜB**
MDP	17	29.02 (12.45 – 49.49)	30.37 (11.95 – 106.76)	59.39 (24.41 – 149.35)
MeDP	19	13.34 (5.62 – 27.21)	9.98 (4.18 – 20.63)	23.33 (11.11 – 44.60)
YDP	18	4.85 (2.72 – 8.16)	1.30 (0 – 4.08)	6.15 (2.72 – 9.90)

where MDP is mature date palm, MeDP is medium date palm, YDP is young date palm, and AĜB is the estimated above-ground biomass. The numbers in the parenthesis represent the minimum and maximum values.

3.3. Model Development and RS Variables Importance

As the DP age has an important role in their biomass (Table 6), the regression analysis linking the field variables with the RS predictors was conducted according to the DP age stages defined earlier.

3.3.1. Date palm (mature)

In MDP plots (17 plots), the linear correlation between AGB and single bands was only significant for SWIR bands; at the same time, it was significant for all tested VIs except TCB and TCG. The highest correlation was for SWIR1 and SWIR2 bands with R^2 values of 0.302 and 0.290, respectively. While for VIs, NDGI and SR showed the highest correlation, with R^2 values of 0.609 and 0.545, respectively.

On the other hand, TCW showed the strongest correlation to AGB using a second-order polynomial model. Additionally, stepwise multiple regression analysis on AGB of the MDP revealed that a grouping of single bands or of VIs did not improve the R^2. Therefore, the second-order polynomial model that uses only TCW as RS predictor was found to be the strongest model to estimate the biomass of MDP with R^2 equal 0.7643 and P-value equal of 0.007 (equation 10 and Fig. 4).

$$AGB_{MDP} (t.\ ha^{-1}) = 0.00006\,x + 0.1212\,x + 96.708 \quad (10)$$

3.3.2. Date palm (non-mature)

It was found that R^2 could be improved by considering medium and young DP as one age class, the non-mature class (Non-MDP) (subsection 2.2). Running the regression analysis for Non-MDP (37 plots: the combination of MeDP and YDP) resulted in a stronger correlation between AGB and RS predictors. All of Landsat 8 OLI single bands with the exception of B, G, and NIR, and all the VIs except NGVI, exhibited significant correlation with AGB. The stepwise regression analysis on

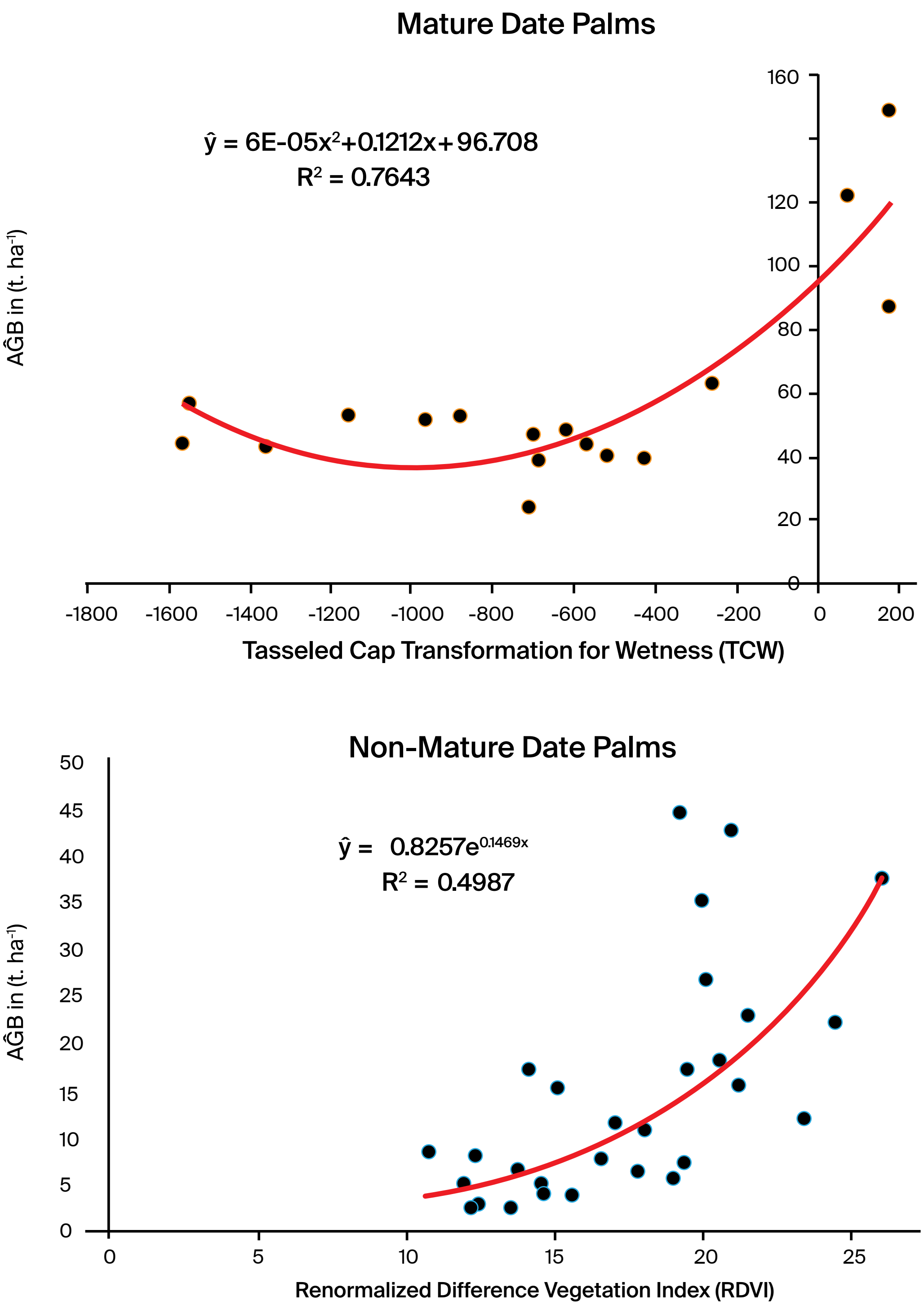

Figure 4: Pipeline of the spatial modeler used to build the two sub-models for calculating CS in DP:
(a) MDP model and (b) Non-MDP Model.

AGB of the Non-MDP revealed that a grouping of single bands or VIs did not improve the R^2. The exponential regression model using RDVI yielded the strongest correlation with an R^2 value of 0.4987 and P-value equals 0.00002 (equation 11 and Fig. 4).

$$AGB_{Non\text{-}MDP}(t.\ ha^{-1}) = 0.8257 \times e^{0.1469 \times RDVI} \quad (11)$$

3.4. *Model Validation*

Field measurements and the statistical accuracy assessment were used to validate the developed AGB model. The accuracy statistics included RMSE, RMSE%, and SPEr as detailed in subsection 2.2.5. Table 7 summarizes the selected regression models for the estimation of the AGB from Landsat 8 OLI single bands and VIs.

Table 7: Model(s) used for AĜB estimation (t. ha-1) for mature and non-mature date palms

Regression Model	DP Class	R^2	P-value	RMSE	RMSE%	SPEr
AĜB= 0.00006(TCW)2 + 0.1212(TCW) + 96.708	Mature	0.764	0.007	6.322	14.912	1.43
AĜB= 0.8257 × 1.1582(RDVI)	Non-mature	0.4987	0.00002	8.040	51.376	-5.04

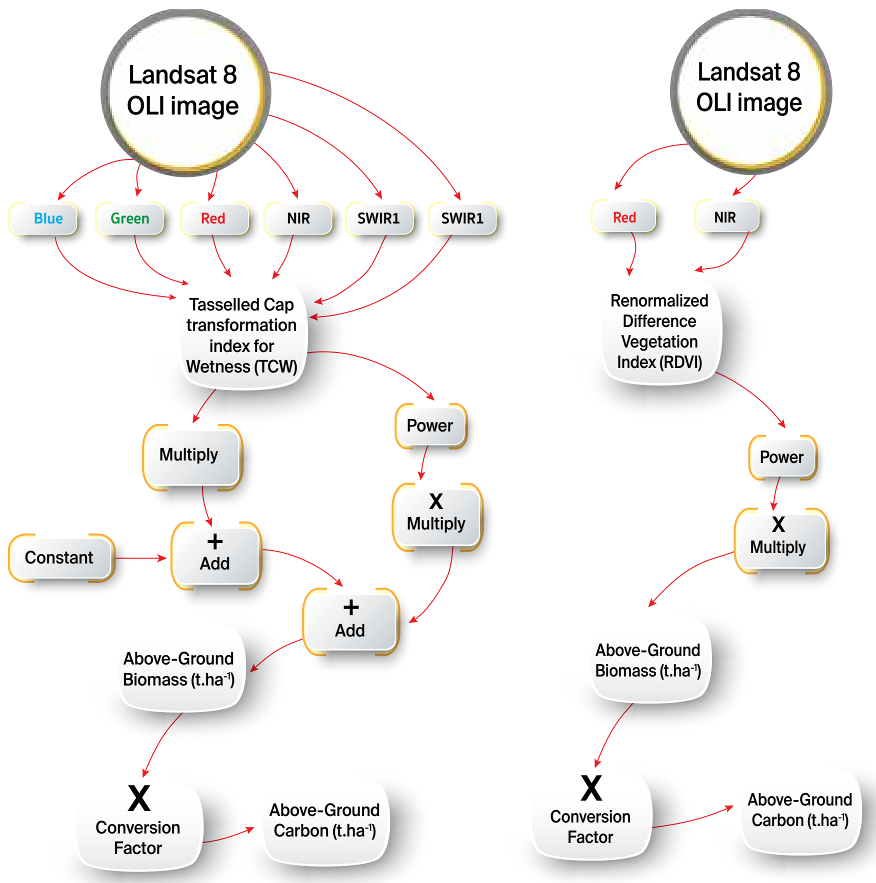

Figure 5: Pipeline of the spatial modeler used to build the two sub-models for calculating CS in DP: (a) MDP model and (b) Non-MDP Model.

3.5. Creation of the AGB Map of DP and Estimation of Total CS in The Study Area

The final AGB map was created using the regression models shown in table 7. The two sub-models that use TWC for MDP and RDVI for Non-MDP are depicted in Fig.5. The map of AGC, shown in Fig. 6, is predicted from AGB map using equation 4.

Figure 6: The above-ground carbon (AGC) map of DP in the study area (Abu Dhabi). Two areas were zoomed where the different shades of greyscale are obvious: (a) Liwa and (b) Al Ain. The lighter pixels (digital number), the more amount of AGC (t. ha-1). The black color represents areas without DP.

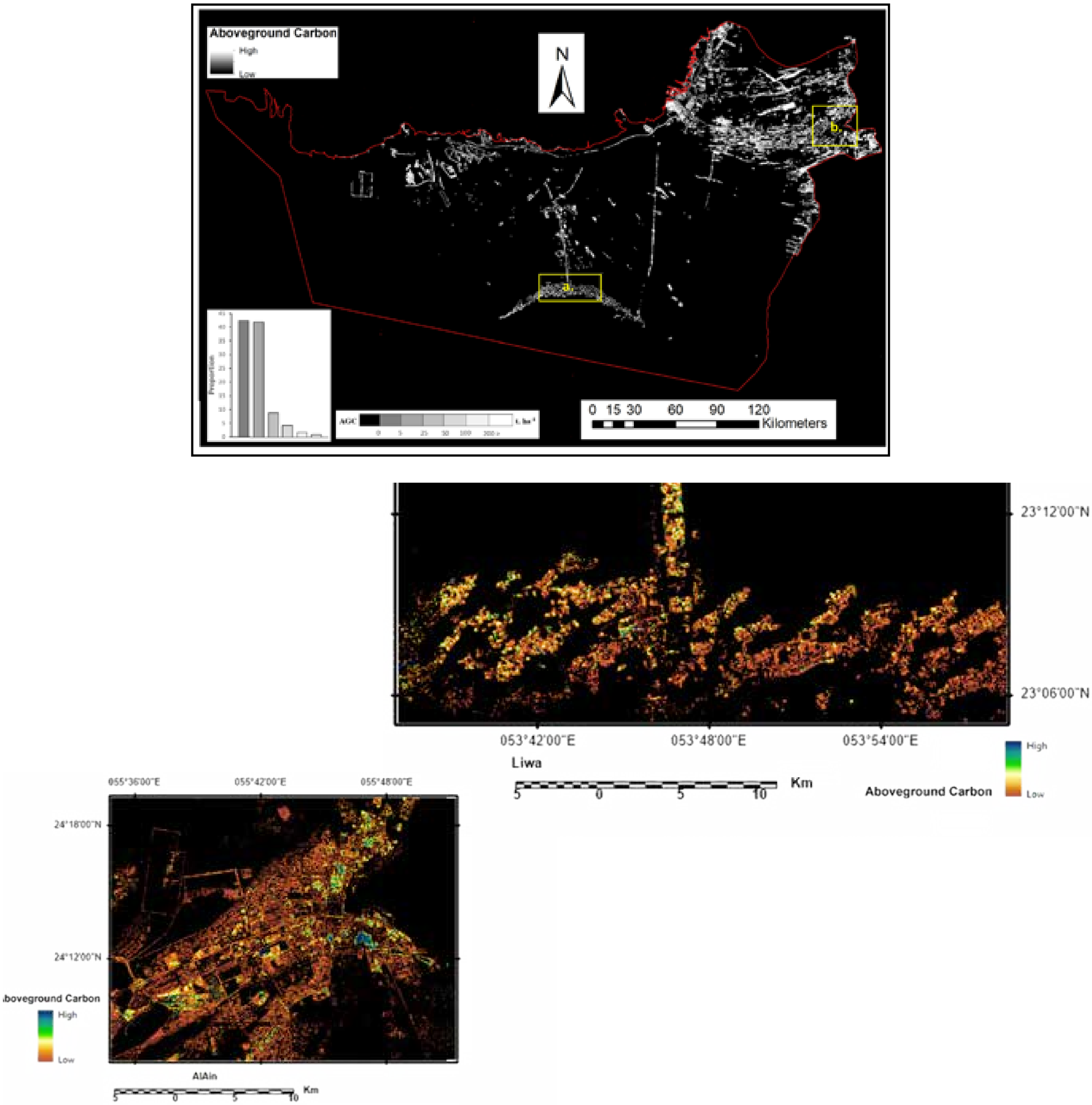

Table 8 summarizes the results of the CS analysis. We found that the overall CS by DP plantations in Abu Dhabi was 2,447,856.87 tons.

Table 8: The total ĈS (in Mt) by DP plantations in Abu Dhabi, UAE.

DP Class	Above-Ground		Below-Ground		Litter & Debris		SOC	Total
	AĜB	AĜC	BĜB	BĜC	Biomass	Ĉ		
MDP	1.210	0.652	0.600	0.308	0.242	0.130	0.093	1,183
MeDP	0.384	0.207	0.356	0.182	0.058	0.031	0.037	0.458
YDP	1.008	0.543	0.335	0.172	0.101	0.054	0.038	0.807
Total	2.602	1.402	1.290	0.662	0.400	0.216	0.169	2.448

1 Mt = 1 million tons.

4. DISCUSSION

The main purpose of the current study is to build a geospatial model for the estimation of carbon stock (CS) of date palms (DP) and mapping its geographical distribution in the emirate of Abu Dhabi (UAE), at three age stages: mature, medium and young. It is worth noting that parts of our findings have already been published. However, the novelty in the current study is reflected in many aspects including, the scope and objectives, the sample sizes, the datasets used, the model built, and the results and visualization. Indeed, the current study has been extended to cover the whole emirate involving larger sample sizes and comprising most cultivars of UAE's date palms. The integration between the finer resolution WV-2 scenes, which served at depicting and mapping all DP plantations at different age stages (Dahy *et al*., 2021), with Landsat Level 2 dataset to identify and measure more accurate RS predictors, allowed to build our final improved model.

Another novelty of the current research is that the generally adopted ratio of BGB estimated at 20% of the AGB in several published studies (Cairns *et al*., 1997; Koala *et al*., 2017; Mokany *et al*., 2006; Niether *et al*., 2019), was not valid for our model. Instead, our results showed different ratios among different DP age stages with averages of 0.332, 0.925, and 0.496 for YDP, MeDP, and MDP, respectively (Issa *et al*., 2020b). Therefore, equations (5, 6, and 7) were developed and implemented to estimate BGB of DP instead. On the other hand, the percentage of carbon content in the root system of DP (BGB) was found to be 51.27% (Issa *et al*., 2020b), which is slightly lower than the carbon content in the AGB. Therefore, below-ground carbon (BĜC) was estimated in tons by multiplying the resulting values from equations 5, 6, or 7 by a factor of 0.5127 (equation 8). Furthermore, carbon content of dead wood or litter and woody debris are usually assumed to be between 10 and 20% of the AGB (Gibbs *et al*., 2007; Houghton *et al*., 2009; Issa *et al*., 2020a). However, based on extensive field visits to DP farms at different age stages, it was observed that litter and debris ratio to AGB of DP varied depending on the palm age stage. The more the palm matures, the more it produces litter and debris. The researchers adopted the following percentages to be applied to predict litter and debris (in ton) from AĜB (in ton), for DP plantations; 10% for YDP, 15% for MeDP, and 20% for MDP.

Three models were initially built to estimate AGB for the three age stages: mature, medium, and young. However, the large contribution of background reflectance in the study area reduced the accuracy of separating the young and medium DP. This, in turn, weakened the statistical relationship between AGB of medium and young DP with RS variables derived from Landsat-8 OLI. Subsequently, young, and medium DP classes were merged to form one non-mature DP (Non-MDP) class, substantially improving the statistical relationship between AGB and RS variables. Therefore, we opted for the creation of two sub-models only: one for Non-MDP and another for MDP.

Our study showed that when using single band to predict AGB, the SWIR bands of Landsat OLI produced the highest and most significant correlation for both MDP and Non-MDP plantations. These results were in line with findings from a previous study in Tajikistan where the authors found that SWIR1, 2 of Landsat 8 were convenient in detecting arid land's vegetation (Zandler *et al*., 2015). While our work on AGB of the MDP showed that a grouping of single bands or VIs does not improve the R^2, it was noticed that VIs provided better predictors of AGB than single bands. Our results were also consistent with other studies that used Landsat imagery to estimate biomass in different regions such as the study reported in (Günlü *et al*., 2014). The decision of selecting the effectively performing VIs is function of the type of ecosystem, environmental conditions, and spectral characteristics of the sensor. Spectral band saturation, for instance, is a well-recognized problem and can affect VI performance and lead to inaccurate estimation of AGB (Zhao *et al*., 2016). However, this was not a major factor in our study region.

Observed structural differences in DP plantations influenced the calculation of AGB. Indeed, varied palms spacing were found in some plots; while sparse distribution of DP with no regular spacing, caused by human interferences, were found in others. It was also noted that regardless of the DP age, other factors affected date palm's CA and Ht and consequently the palm's capacity to accumulate biomass and sequester carbon. Cultivar and land management practices are examples of such factors. The largest average of DP density was found on MDP plots. In two cases of MDP plots, the number of DP reached 88 and 96 palms per plot which corresponds to around 550 and 600 palm.ha-1, respectively. This could be attributed to the old farming systems, where MDP were planted irregularly in the farm with short spacing among palms to benefit from the traditional irrigation systems (e.g. Aflaj irrigation systems). Nowadays, the palms are distributed in a more organized manner with wider spacing among them (7m×7m, 8m×8m, and 9m×9m) leading to lower densities, allowing agricultural tractors and machinery to navigate more easily. It is noticeable that an overlap between the crown area ranges of MDP and MeDP is found in some cases. This is due to regular pruning of DP fronds practiced in new plantations. The pruning process aims to keep a specific number of fronds in the palm allowing more carbohydrates to go to the fruits (dates) than the fronds. It is rare to find Ht of DP taller than 5 meters in modern DP farms as the farmers tend to remove tall palms reaching certain height, as they are more difficult to maintain and manage. However, during field measurement, the researchers observed some DP that exceeded 5 meters, and some were extremely tall with very high Ht reached up to 15.2 m especially in the oases. In contrast, it was found that most YDP had Ht equal to zero and some of them had CA equal 0.07 m^2 since their fronds were attached by cord with no trunk. These structural variations impacted the performance of spectral bands and VIs as predictors, affected the estimation of AGB and influenced the choice of estimation model.

The approach implemented aimed at selecting the most appropriate regression model among the tested models to estimate AGB of DP at multiple age stages. It considered the use of linear and non-linear regression models with multiple single band, single VIs, and stepwise multivariate regression to estimate the most appropriate model from the tested models based on correlation, significance and RMSE. The model that provided the best estimate of AGB in the case of MDP, consisted in the use of a second-order polynomial where TCW served as the only RS predictor. This model yielded the strongest correlation and significance with R^2 equal to 0.7643 and a P-value equal to 0.007 with RMSE of 6.322 t.ha-1. For Non-MDP, an exponential model that uses RDVI as RS predictor provided the strongest estimate of biomass with R^2 equal to 0.4987 and P-value equal to 0.00002, while the model validation showed RMSE of 8.040 t.ha-1. These results were consistent with published literature for other species and study areas where Landsat 8 was used for mapping and predicting AGB in woodlands (Karlson *et al*., 2015).

The DP age stage class derived from the WV-2 data was processed to select the proper model from the tested models to use when estimating AGB. The resulting map was an emirate wide map of AGB that was subsequently used to predict CS. This step highlights the strength and uniqueness of our approach where RS-based model, once calibrated, enabled the creation of CS maps from remote sensing data without the need for additional field measurements.

The accurate total carbon stock estimation of DP plantations in Abu Dhabi depends on the accurate estimation of its biomass, specifically AGB that is predicted by using biomass allometric equations. Therefore, one source of uncertainty could come from the equations themselves. To overcome this issue, the authors used published allometric equations developed from represented field samples of DP considering the different varieties as well as the three different age stages in the study area. The other source of uncertainty for the estimation of the biomass of DP, hence their carbon stock, could come from RS models that were built during the current study. The authors identified and selected a number of plot samples representing homogenous DP plantations with strict criteria excluding the plots that have a sparse distribution of DP/plot, stressed DP, large level of heterogeneity, and not representing the age stage class (see subsection 2.2.1). The plot design with 40m × 40m dimension ensured that the area on the ground occupied at least one full pixel of Landsat 8 OLI image with a 30-m pixel resolution (Issa *et al*., 2019). Landsat 8 OLI spectral variables (mean values) for all the plots were extracted for a 3 × 3 window centered over each plot to reduce the uncertainties in RS data resulting from plot positioning errors that could be created because of the mismatching of sample plots with the image pixels introduced when the x and y coordinates of sample plots were located using GPS (D. Lu *et al*., 2002). The RS models for estimating DP biomass were estimated from Level 2 product of Landsat to identify and measure more accurate RS predictors, however, Landsat with moderate spatial resolution, was not able to differentiate and map DP at all age stages. Therefore, we used accurate maps of DP at all age stages derived from fine-resolution WV-2 scenes as input to our final biomass models (Dahy *et al*., 2021). Hence, we succeeded in predicting and visualizing the amounts of CS in all DP plantations in the whole study area.

5. CONCLUSION & RECOMMENDATIONS

A geospatial model of carbon stock assessment of date palm at different age stages was developed. Allometric equations, previously developed and published by the authors, were utilized to design, calibrate, and implement the model to predict the amounts of AGB and AGC in DP. Different types of regression analysis (single and multiple) were tested to create relationships linking the AGB to RS predictors. Using an expanded number of 54 field plots showed that TCW has the most significant correlation estimated using a second-order polynomial model to estimate the biomass of MDP with R^2 equal to 0.7643 and P-value equal to 0.007. On the other hand, the exponential regression model that used RDVI as RS predictor provided the strongest correlation with AGB of Non-MDP, with an R^2 value of 0.4987 and a P-value of 0.00002. The development of a remote sensing-based biomass and carbon estimation model enabled the prediction and visualization of CS over extended areas with minimum fieldwork. Using previously produced DP age classification maps, the RS-based model was applied to Landsat-8 imagery to map and predict the CS of DP in Abu Dhabi. The total CS in DP plantations was estimated as the sum of the estimated CS in the five components: AGB, BGB, litter, debris, and SOC. The overall CS by DP plantations in Abu Dhabi predicted from this map amounted to 2,447,856.87 tons.

The main limitation is related to the use of moderate spatial resolution RS product to estimate the biomass and CS amounts. Landsat with moderate spatial resolution was not able to accurately differentiate and map DP at all age stages. Therefore, we used accurate maps of DP at all age stages derived from fine-resolution WV-2 scenes as input to our final biomass models. Consequently, a weak statistical relationship between AGB of medium and young DP with RS variables derived from Landsat-8 OLI was observed. Subsequently, young, and medium DP classes were merged to form one non-mature DP (Non-MDP) class. To overcome this challenge one suggested solution is to use finer spatial resolution of satellite imagery for the building the DP biomass model.

Finally, our applied methods used in this project can be generalized to other areas in the Gulf region with minimal cost. It can also be modified to use other publicly available moderate resolution imagery such as Sentinel-2. RS-based biomass estimating model for DP were built for a quick and reliable method for the creation and visualization of a standard DP CS map for the Emirate of Abu Dhabi. Thus, it can be further employed to boost the decision-taking process on durable and sustainable management of CS in other similar ecosystems.

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Climate Change and Women in Agriculture :

Women's Empowerment

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Abstract

Despite being the backbone of many communities, rural women still encounter barriers to reaching their full potential. Their suffering is exacerbated by the catastrophic repercussions of climate change. Approximately one-third of women worldwide are employed in the agriculture industry. Although they till the land, gather food, water, and essential fuel, and provide for entire homes, women do not have equal access to markets, decision-making centers, money, or equipment.

These disparities are getting worse due to climate change, which is further disadvantageous for rural women and girls. Between 2006 and 2016, the agricultural sector in developing nations accounted for 25% of all damages and losses from climate-related disasters, with women bearing a disproportionate share of the burden. Rural ladies are also extremely knowledgeable.

Women are essential to the adoption of both traditional and modern strategies for coping with climate shocks and variability, including heat waves, droughts, and excessive rainfall, because they are farmers and producers. To raise awareness of climate change and encourage government, business, and community leaders to take action, it is imperative that rural women's voices be heard and that

their experiences be taken seriously. Rural women are a formidable force that can propel global growth since they are the first to adopt new agricultural techniques, the first to act in times of disaster, and the first to start green energy businesses (NU, 2019).

What is the problem?

One of the biggest problems of our day is the combination of gender inequality with the climate disaster. It puts women's and girls' lives, livelihoods, health, safety, and security at risk globally (UN-Women, 2022a).

A growing number of climate-related calamities, such as droughts, floods, and altered weather and rainfall patterns, are upsetting rural people, ruining harvests, and upending livelihoods reliant on the agricultural industry. Although they contribute significantly to agriculture throughout Asia and the Pacific, women's contributions are frequently disregarded and underestimated. In addition to being largely underrepresented in agriculture and climate change policy and decision-making, women's labor in agriculture is not officially recognized. Nonetheless, agriculture serves as a life support system and a source of resources, employment, and food for billions of women.

Women are recognized to be disproportionately affected by the negative effects of climate change due to gender inequality; however, the social, political, and economic obstacles that increase women's exposure to these impacts are shifting. Therefore, tackling the rising levels of vulnerability experienced by women and empowering them in the face of climate change requires a gender-responsive strategy for both climate resilience and economic resilience in the agricultural sector (UN-Women, 2022b).

The distinct effects of climate change on women that are particularly pertinent to the agricultural industries are depicted in Figure 1. It highlights the different social, political, economic, and environmental elements that affect adaptability and vulnerability and may increase the susceptibility of women as a group to unfavorable developments.

Climate change impacts	Impacts exacerbate gender inequalities
Crop failure	Household food provision; increasing work load
Fuel shortage	Household fuel provision; more time for fuelwood collection
Water scarcity	Household water provision; contaminated water; more time for water collection
Natural disasters	Women's greater incidence of mortality
Disease	Lack of access to health care; women's burden as care givers
Displacement	Forced migration Increases women's vulnerabiltty
Conflict	Loss of lives; violence against women

Figure 1: Gender-differentiated impacts of climate change on women
(**Source**: World Bank, FAO, 2017).

Shocking facts

Everyone is impacted by the changing climate, but those who are most vulnerable and impoverished worldwide—women and girls in particular—bear the burden of social, economic, and environmental shocks. However, these same women and girls are also among the first to adopt new farming methods, are crucial decision-makers about waste and energy at home, and are first responders in times of emergency. Without women, there can be no sustained or successful climate action.

Women's leadership has been praised by the UN Secretary-General for their special capacity to act as "drivers of solutions" when given the necessary authority. According to UN data, men and women are more vulnerable to the effects of climate change and have different coping strategies. Therefore, it should come as no surprise that gender dynamics are taken into account when developing and putting into practice measures for climate change adaptation (UN, 2022).

The UN trains women to be change agents by educating them on how to incorporate climate-smart solutions into their employment. Women are the focus of this initiative worldwide. In addition to being good for the environment, these community-driven strategies also enable women to enhance the standard of living for their families and communities and promote sustainable development (UN, 2022).

Women comprise 70% of the agricultural workforce in Côte d'Ivoire, for instance, although they only own 3% of the land they work. Women in the nation's well-known shea butter sector found it difficult to turn a profit using their labor-intensive, traditional ways. They were able to scale up production to create a superior product that also allowed them to meet competitive standards in the market and increase their profit margins when UN Women, working with local partners, established a program that helped women modernize the process with an emphasis on reducing deforestation (UN, 2022).

The rising degradation of the land and natural resources in Mali was discouraging to women since it jeopardized their ability to make a living via agriculture. Sustainable agriculture methods were introduced through a UN initiative, which assisted them in modernizing farming methods and learning ecologically friendly conservation measures. These abilities also significantly lessen the likelihood that women will become more vulnerable and prone to poverty in a nation where women make up half of those working in agriculture (UN, 2022).

Biogas helps mitigate the consequences of climate change in rural Cambodia. In places where opposition to change is strong, UN Women and UN Environment have assisted these women in becoming the first to accept new technology and information because they have prioritized gender equality and human rights as the cornerstones of climate action and disaster risk reduction. New solutions are now more widely accepted, and people are becoming more conscious of their capacity to drive change (UN, 2022).

Key facts

Approximately 160 Intended Nationally Determined Contributions (INDCs), representing 190 nations, were filed to meet the requirements for conformity with the United Nations Framework Convention on Climate Change (UNFCCC), which was developed in Paris in 2015 (COP 21). The Consortium of International Agricultural Research Centers (CGIAR) Research Program on Climate Change, Agriculture and Food Security (CCAFS) analyzed these INDCs and found that, out of 162 INDCs, 119 aim to reduce emissions in agriculture, and 127 list agriculture as a priority for adaptation. In their submissions, 65 countries refer to gender (35 in the context of adaptation and 18 in connection to mitigation). Several other nations mentioned gender in general terms, but not in terms of mitigation or adaptation. Gender was only included in 15 nations. (UNDP, 2016; CCAFS, 2016).

The economies of the Asia-Pacific region greatly benefit from agriculture; between 2005 and 2018, the GDP of the Association of Southeast Asian Nations (ASEAN) accounted for 10.3% of the region's overall GDP (The ASEAN Secretariat, 2019). While in 2020, it was discovered that the GDPs of Afghanistan, Nepal, Cambodia, and Viet Nam were all at 27%, 14.9%, 14.9%, 12.6%, Bangladesh, Samoa, and the Philippines were at 10.3%, 10.2%, and 18. 3%, respectively, from agriculture, forestry, and fishing (World Bank, 2021).

As such, the region's food insecurity and poverty will worsen as a result of climate change's effects on agricultural production. This is especially troubling because, according to Islam and Braun (2008), 85% of Asians who live on less than $1 per day reside in rural areas, where poverty is currently concentrated. Furthermore, it is estimated that South Asia will lose 8.8 percent by 2100 and 1.8 percent by 2050 if appropriate climate adaptation measures are not taken, which would have a significant negative influence on people who depend heavily on agriculture (Ahmed and Suphachalasai, 2014). The Asia-Pacific region's largest employment industry is still agriculture. This industry accounted for 41.8 percent of all employment in South Asia and 24.8 percent of all employment in East Asia and the Pacific in 2019 (World Bank, 2021). Women make up a sizable share of this labor force; throughout Asia and the Pacific, agriculture employs over 58% of female labor force workers (UN Women & UNEP, 2020), highlighting the crucial role that women play in rural economies.

Rural women and agricultural activities

The repercussions of climate change are already being seen in the daily lives of rural women in developing nations. They are witnessing changes in weather patterns and the decline of once-dependable crops. Extreme weather disasters are wiping out their livelihoods, and because they have less access to resources than men, they find it more difficult to recover. Climate disasters put them at higher risk of gender-based violence (IFAD, 2022). Since they frequently provide food for the family, they are aware when a range of nutrient-dense foods becomes unavailable or too expensive. Above all, though, they are aware of the actions that must be taken to support their families and communities in becoming resilient to climate change (IFAD, 2022).

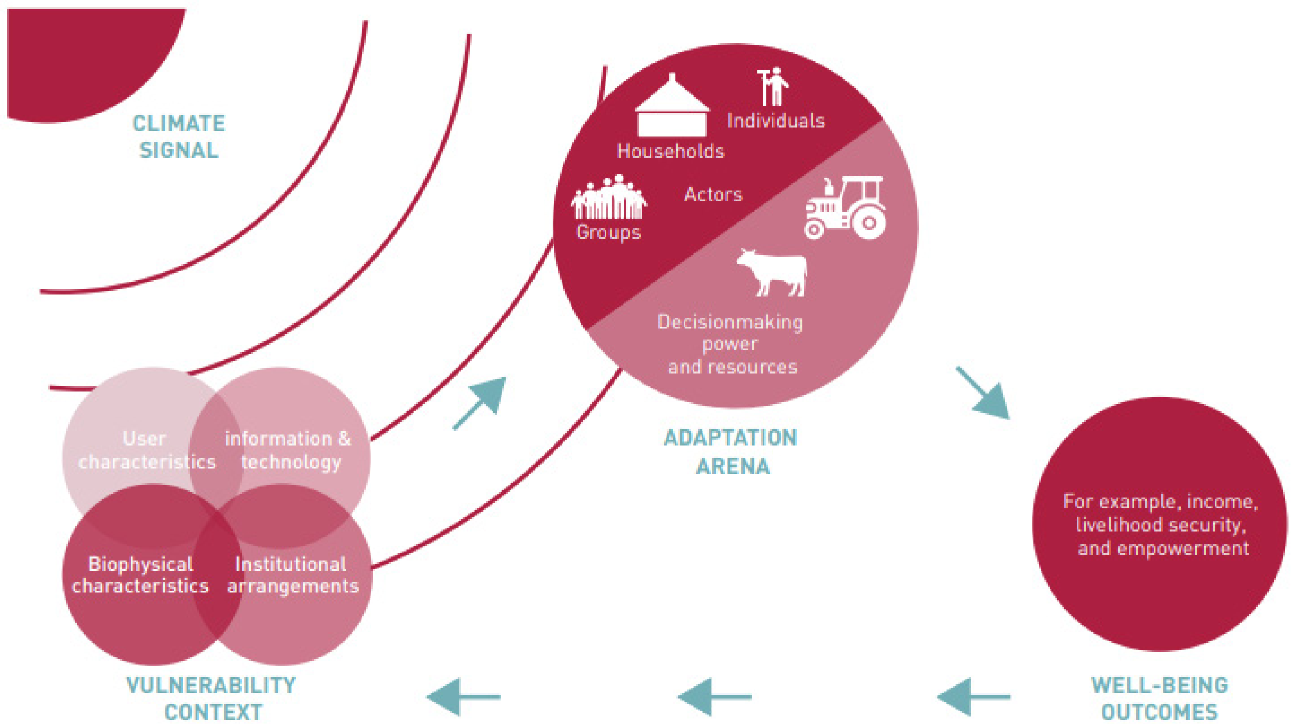


Figure 2: An integrated framework on gender and climate change in agriculture (**Source**: Behrman *et al*. 2014).

Furthermore, according to the Ministry of Finance, Government of India (2020), women make up 65 percent of the agricultural workforce, with 79 percent of rural women working in agriculture. In India, up to 70 percent of rural households still rely primarily on agriculture for their income. Additionally, 82 percent of farmers are small-scale and marginal. This emphasizes even further how women's livelihoods are mostly dependent on natural resources, which puts them at a higher risk of climate change.

The International Food Policy Research Institute's research program on Climate Change, Collective Action, and Women's Assets has developed a useful analytical framework for examining the intersection of gender, agricultural development and climate change (Figure 2) (Behrman *et al*. 2014).

Important political, social, and economic obstacles affect women in agriculture and raise questions about the fulfillment of their human rights. These human rights encompass both procedural and substantive rights, such as the right to tools and climate information, the right to be consulted on climate adaptation and mitigation measures, and the right to food, health, and decent livelihoods (UN Women, 2021). Furthermore, patrilineal land tenure, weak property rights, gender norms, and a lack of accountability mechanisms all work against women owning land, which keeps them from accessing credit, inputs, extension services, investing in or receiving agricultural training, and so on (UN Women, 2021). This therefore reduces the productivity of women in agriculture and their overall economic empowerment (Kelkar and Krishnaraj, 2013).

For instance, restrictions on plot size, quality, and ownership may prevent women from progressing to high-value crops. Due to social conventions that dictate women are primarily responsible for household food production and food security, women are more likely to plant subsistence crops. Domestic caregiving is mostly the responsibility of women, taking up a significant amount of their productive time. Because they lack collateral or financial awareness, women frequently find it difficult to obtain credit from financial organizations. Women don't have access to the networks that would enable them to expand and enter markets. Due to discriminatory attitudes and behaviors, women are frequently left out of the profitable phases of value chains (UN Women & FAO, 2014).

Lastly, women's capability to scale up crop production and develop resilience to climate shocks and stressors is hampered by insufficient access to agricultural extension services, tools, and technology for climate change adaptation (UN Women and FAO, 2014). For instance, in Vietnam, 71 percent of rural laboring women and 60 percent of rural laboring men have not had access to training (UN Women and FAO, 2014). Furthermore, women's access to vocational agricultural training tends to be limited in duration and focus mostly on conventional skills, which exacerbates gender disparities in the adoption of modern technologies (UN Women & FAO, 2014).

Women will therefore be most affected by the detrimental effects of climate change on agricultural production since they labor in an industry where conditions are particularly hazardous, paying less, and providing less prospects for a living. The majority of rural poor people are women and young people, which limits their ability to adjust economically to changing agricultural opportunities and constraints in a changing environment. Therefore, women in agriculture must be given more opportunities to advance efficient and sustainable solutions for climate adaptation, as well as to ensure improved food security, reduce poverty, and promote economic development and GDP (UN-Women, 2022).

Rural women and smart agriculture

The only sustainable path ahead for the planet's resilience and the security of food and nutrition is Climate Smart Agriculture (CSA). However, we must ensure that the policies, technology, and instruments about climate-smart agriculture also help women, who, although making up a sizable portion of global farmers, suffer considerable barriers to reaping the rewards associated with CSA.

The World Bank has put a lot of effort into making sure that investments in the food and agriculture sectors are commensurate with the severity of the climate catastrophe throughout the years. Projects related to agriculture also heavily incorporate women and their significant roles in the rural economy. Globally, women account for 43% of the agricultural workforce, according to FAO statistics. It rises to more than 60% in the least developed nations.

Women are working longer hours and taking on more responsibilities, particularly in areas where young people and men are leaving due to climate change. For instance, women's workloads increased in rainfed agricultural households in Maharashtra, India, as a result of higher travel lengths for fuel, livestock fodder, water, and variable crop yields. Fearing an increase in workload, women in agriculture may also be reluctant to adopt new adaptation methods.

It is crucial to guarantee that women have equal access to technologies that lighten their workload, boost their productivity, and, in some situations, expand agricultural diversity, which enhances nutrition in the home. Across the world, women have less access to technologies, information, resources, and funding for their agricultural endeavors. How much does the gender productivity gap cost?

The success of climate-smart agriculture depends heavily on women. The allure of climate-smart agriculture lies in its well-rounded strategy to enhance livelihoods, bolstering the resilience and productivity of impoverished populations, particularly rural women, while simultaneously offering benefits related to mitigation (FAO, 2013). However, as previously said, gender disparities in agriculture mean that women may be less likely than men to take part in and gain from site-specific climate initiatives locally (Nelson and Huyer, 2016). Given that a variety of intricate sociocultural, structural, and institutional injustices contribute to gender-differentiated vulnerabilities to the effects of climate change (UNDP, 2011), climate-smart agriculture and related initiatives should aim to strengthen women's resource bases and guarantee that women's contributions to productivity and food security are recognized.

Women and food security in light of climate change

A more climate-smart food system can be achieved with the aid of climate-smart agriculture (CSA). Does women have to put in more effort as a result of it, though?

The three pillars of climate-smart agriculture—increased climate change adaptation, decreased greenhouse gas emissions, and enhanced agricultural productivity—are objectives that should be seriously pursued. Women's time can be saved by CSA techniques like water harvesting and planting trees that allow easier access to food, fuel, and fodder. However, some tasks, like doing more weeding or spreading mulch, may call for women to work longer hours in the field (Sanna Liisa TAIVALMAA and Eija PEHU, 2015).

The possible effects of CSA on nutrition are the subject of another query. Family nutrition will suffer if adaptation concentrates on staple grains while ignoring pulses, fruits, and vegetables that many women raise to feed their households.

Great consideration must go into how to implement CSA practices to ensure that men and women have equal opportunities to adjust to and profit from them. Men and women are impacted by climate change in various ways, which means that there are differences in the scope and opportunities for adaptation and mitigation. Regretfully, there is no magic pill that guarantees gender-neutral climate-smart practices. When designing and implementing activities, culture, geography, and the agroecological environment must all be taken into consideration. Climate-smart field-level practices are insufficient. Organizations and policies (Sanna Liisa TAIVALMAA and Eija PEHU, 2015).

Gender in Climate-Smart Agriculture, a new publication co-authored by the World Bank, IFAD, and FAO, is intended to assist practitioners in implementing CSA programs in a gender-smart manner. To guarantee that investments in CSA initiatives are gender- and climate-smart, the module offers a wealth of examples and best practices to support project design, execution, monitoring, and assessment. In the framework of CSA, labor-saving technologies are one area on which it provides guidance—to make sure that women's labor burdens aren't raised and that they are freed up to engage in other activities that are essential to them. To all of you, a happy Climate and Gender-Smart Rural Women's Day.

A climate-secure future for rural women

Building resilient ecosystems, businesses, and communities is essential to climate change adaptation. For adaptation to be successful, it is critical to understand that various people are impacted by climate change in different ways and that these effects vary depending on a person's place of residence, source of income, and, in many cases, gender. To provide an effective response, therefore, activity at all levels—from individuals to governments to the international community—is required. To better their employment and future, women must be included in decision-making, particularly in the agricultural sector (Elfanne, 2023).

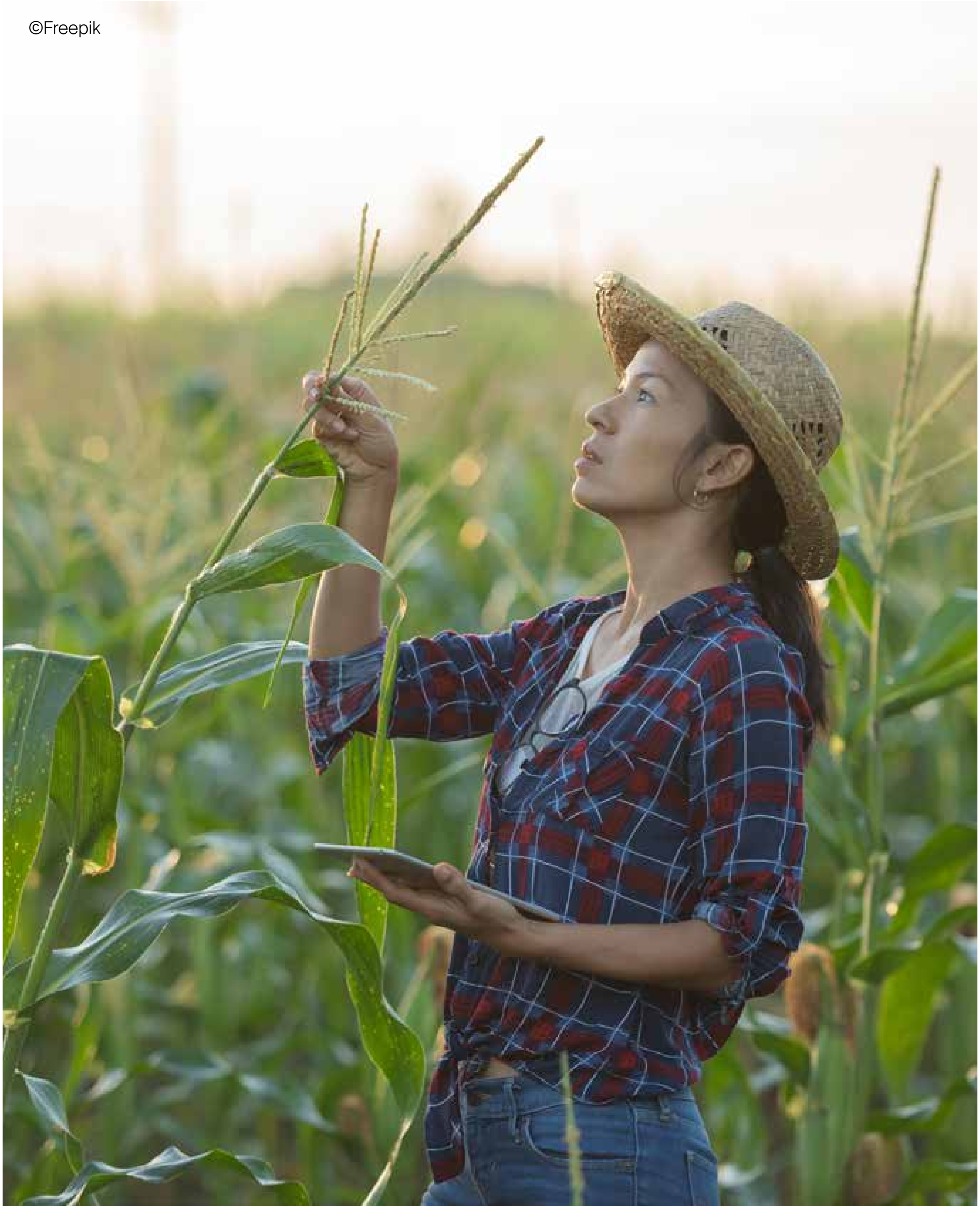
The following four strategies (IFAD, 2022) will empower rural women for a future free from climate change:

1. Listen to women

Almost half of all agricultural workers worldwide are women. They have extensive knowledge of the local resources and environments, notably the abundance of wildlife. However, when and where decisions are made, even in their own homes, their opinions are frequently ignored. Research indicates that when women hold equal decision-making authority, their households and communities are better equipped to adapt to the changing climate. This results in more equitable and just solutions that are also more thorough, inclusive, and effective. The representation of women's voices, agency, viewpoints, and expertise is vital. Women are involved in planning for a large number of IFAD-supported projects, which guarantees that their expertise influences strategies for adapting to climate change. These strategies range from developing climate-smart infrastructure to managing water resources sustainably. For instance, women have long been marginalized and at a disadvantage in the Butana region of Sudan. These days, they're getting together in unofficial groupings, honing their leadership abilities, and managing and guarding communal rangelands against threats like desertification.

2. Invest in women's economic growth

The benefits of women's economic empowerment extend beyond them to their homes and communities. In addition to protecting against environmental and financial disasters, it raises and diversifies revenues. Empowered women are also better able to stop land degradation and preserve natural resources since they have better access to resources and an understanding of climate-smart activities. However, there are still societal, institutional, and legal obstacles that keep rural women from realizing their full potential. A law limiting women's access to the economy is in place in almost 95% of the world's economies.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3. Reduce women's workloads

Rural women take on the majority of the workload, both at home and on the farm, yet they rarely receive recognition or payment for their labor. Women don't have enough time or energy to run a business or participate in decision-making because of these everyday responsibilities.

4. Break down the barriers holding rural women back

Nothing less than a societal transformation is necessary to remove obstacles and power disparities for rural women; the discriminatory social and cultural norms that confine them must be completely rethought. This technique is utilized in Rwanda to enhance neighborly interactions and family dynamics, analyze data to assist communities in addressing climate change and encourage involvement in water management committees. The globe, their homes, their communities, and themselves are all dependent on rural women for climate resilience. It's time for us to follow their lead.

Our Solutions

The Swedish government is a partner in the UN Women and UNEP project "Empowering: Women for Climate Resilient Societies," which has concluded that it offers additional answers (UN-Women, 2022).

Political dedication to gender mainstreaming; guaranteeing that gender integration is incorporated into national policy concerning agriculture and climate change.

Create gender statistics and gather sex-disaggregated data to enhance the nation's current knowledge on the contribution of women to agriculture.

Enhance cooperation among the Ministry of Women's Affairs, Ministry of Labor, and Ministry of Agriculture.

Build the capacity and diversify the sources of income for women and other marginalized groups engaged in agriculture so they can better withstand the economic effects of climate change.

Through greater resource allocation and training, provide gender-responsive climate financing and encourage the development of knowledge on gender mainstreaming within environmental and economic ministries.

Identify access sites by conducting studies, broken down by nation and region, on the gendered implications of climate change on the agriculture industry.

Conclusion

In conclusion, women must be consulted, included in climate change projects, and given a voice. Women's groups must also be protected. Enhance communications. Women are currently underrepresented in decision-making in environmental management. They should have equal representation in decision-making processes so that they can provide their insightful views. Knowledge of climate change issues.

Women's expertise and experience in related fields, such as natural resource management, can be of great value. For example, women in leadership positions in the community, state, and federal government.

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Impact of Climate change on the future of date palm cultivation and fruit quality

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Climate Change

Climate changes occur naturally every certain period of time since the beginning of the geological time scale, and during the industrial revolution the pace of climate changes increased due to human activities. In 1894, the Swedish scientist Svante Arrhenius calculated the increase in the levels of critical gases in the atmosphere as a result of industrial processes, and showed that the quantity of gases had doubled.

Our planet has an integrated system, and any occurrence of climate change in a particular region can affect other regions.

Carbon dioxide in the air causes temperatures to rise by 5-6 degrees Celsius, he confirmed in his book (Worlds in the Making), published in 1906 and translated into English in 1908. Thus, he was the first to predict that carbon dioxide and other greenhouse gases cause global warming.

Global Warming

Means the gradual increase in the temperature of the lowest layers of the atmosphere surrounding the Earth as a result of the increased emission of greenhouse gases, which consist of Water Vapor, Carbon dioxide(CO_2), Methane (CH_4) , Nitrous oxide(N_2O), and Ozone(O_3), which are natural gases that play an important role in earth surface warming so can be lived on and the life continues, without it, the earth's surface temperature may reach between 19 - 15 degrees Celsius below zero, table No. (1) Represents the contribution percentage of natural gases' to the formation of the greenhouse effect.

Table No. 1: Contribution percentage of gases to the formation of the greenhouse effect

Gas	Percentage %
Carbon dioxide CO_2	64%
Methane CH_4	19%
Chlorofluorocarbons CFCs	11%
Nitrous oxide(N_2O)	6%

The effects of climate change are represented in remarkable phenomena, including (High temperatures, low rainfall, and increased carbon dioxide) also, global warming causes a difference in high and low pressure in some areas, and the occurrence of tornadoes, drying of green areas, and the flooding of other areas by heavy rains.

The future forecasts of Intergovernmental Panel on Climate Change(IPCC) confirm that the Arab region will be the most vulnerable to the potential impacts of climate change, because it includes the driest regions of the world, and about 75% of the cultivated areas in it depend on rain-fed agriculture, the productivity of crops grown in rain-fed areas in the Arab world will decrease by about 50% by 2050, this will have a negative impact on limited water resources and agricultural production, which constitutes a threat to water and food security in the Arab region and to social and development repercussions, due to the migration of the population from the affected areas to other less affected areas within one country or to neighboring countries.

The impact of climatic changes at the present time has become more evident in the course of our daily lives, and our lifestyles have also become affected by climatic changes, as the higher the earth's temperature, the greater the environmental damage accordingly, the increases of industrial activity causes the greater emissions of greenhouse gas.

The potential effects of climate change on agricultural production will not depend only on the climate itself, but will depend on the ability of agricultural crops to adapt to climate changes and 10-100% of the variation in agricultural production in the short term is attributed to weather fluctuations, as it was observed that low rates rainfall in Egypt, North African countries, the Kingdom of Saudi Arabia, Jordan, and Syria is at a rate of (20-25%) according to some experts' estimates, which threatens the food security of these countries to a great extent, and decreasing the quantities of fresh water are in Bahrain, Sudan, Djibouti, Tunisia, Algeria, Morocco, Jordan, Syria, and the United Arab Emirates, will have serious impacts on food production and increase the risk of malnutrition, in addition, food prices have become linked to fuel prices, which in turn has doubled the cost of a loaf of bread in most parts of the world.

These changes will lead to increased temperatures, lower rainfall, and recurrence of drought cycles ,a change in the wind pattern, an increase in the rate of evapotranspiration, untimely rainfall, lower temperatures, and precipitation, and a rise in sea levels, which will negatively affect agricultural production, food, and water security, and cause environmental stresses for plants, and this is defined as the effect of any climatic factor on living organisms, which is the effect of environmental, physical and chemical factors on plants, and stress factors (heat, drought, salinity, wind, and radiation).

A new report issued by prominent climate experts at the United Nations predicted that global warming would rise by 1.5 degrees Celsius after about ten years (nearly 2030) compared to the pre-industrial era, which means that the world is threatened by "unprecedented" natural disasters, in addition to an increase in climate change and CO_2 gas levels, and the availability of moisture can suit the growth of weeds, pests, viruses, bacteria, and insects, which leads to damage to the yield of cultivated crops, the latest report on climate change in the Arab region, expected to raise temperatures in the region from 1.2 degrees Celsius to 1.9 °C by the period 2046- 2065 and 1.5 - 2.3°C by 2081-2100 in a moderate scenario, and 1.7 - 2.6 and 3.2°C - 4.8°C in the worst case scenario, according to climate models' forecasts as follows:

1. An increase in winter temperature 1% leads to a 12% loss in agricultural productivity across the Arab region and warming accompanied by an increase in hot day and nights with heat waves, caused warmer temperatures and changes in weather patterns that lead to more severe droughts, water scarcity, severe fires, rising sea levels, floods, catastrophic storms, and reduced biodiversity.
2. The most heat conditions increase energy demand for cooling and may negatively impact freshwater, agricultural productivity, health, coastal areas, biodiversity, and infrastructure.
3. Clear changes in the distribution of rainfall in different regions and an increase in torrents (floods) during rainy periods especially the autumn months on the Red Sea Mountains.
4. Increasing atmospheric humidity in the interior regions accompanied by an increase in the surface of huge water reservoirs behind dams, such as the Merowe Dam, and a rise in humidity measured in northern Sudan.
5. Agriculture, forestry, fisheries, energy and tourism sectors that are vulnerable to climate change are increasingly negatively affected, disrupting harvests, depleting natural resources, eroding livelihoods, stimulating infectious diseases, nutritional deficits,
6. Environmentally fragile areas, such as oases and rangeland, are exposed to a significant deterioration in their environmental conditions.
7. Water shortages in the Arab region contribute to a reduction in the gross domestic product over time the differences across the region in national wealth and the country's ability to respond to climatic and weather changes may lead to various efforts towards adaptation, such as improving regional drought monitoring, investing in water conservation and efficiency, and shifting to crop more tolerant to heat.

Nino phenomenon

A natural weather phenomenon known as El Niño is caused by hot currents, in the Pacific Ocean, heading towards the east coasts of South America as a result of the heating caused by these currents at the bottom of the Pacific Ocean, together with others, they form an integrated system, leading to a large change in water temperatures and thus the occurrence of El Nino, potentially raising the temperature to a planet that is already getting hotter due to climate change.

The El Niño Southern Oscillation, as it is properly called, is known to have three different phases (hot, cold, or neutral). The hot phase, El Niño occurs on average every 2-7 years, and episodes usually last from 9 to 12 months. It is a naturally occurring climate pattern associated with warming ocean surface temperatures in the central and eastern tropical regions of the Pacific Ocean, but it occurs in the context of climate change caused by human activities, spread across The Ocean pushes large amounts of heat into the atmosphere.

World Meteorological Organization (WMO) report (2023)

- The annual mean global near-surface temperature for each year between 2023 and 2027 is predicted to be between 1.1°C and 1.8°C higher than the 1850-1900 average. This is used as a baseline because it was before the emission of greenhouse gases from human and industrial activities.
- There is a 98% chance of at least one in the next five years beating the temperature record set in 2016, when there was an exceptionally strong El Niño.
- The chance of the five-year mean for 2023-2027 being higher than the last five years is also 98%.

- Arctic warming is disproportionately high. Compared to the 1991-2020 average, the temperature anomaly is predicted to be more than three times as large as the global mean anomaly when averaged over the next five northern hemisphere extended winters.
- Predicted precipitation patterns for the May to September 2023-2027 average, compared to the 1991-2020 average, suggest increased rainfall in the Sahel, northern Europe, Alaska and northern Siberia, and reduced rainfall for this season over the Amazon and parts of Australia
    - that there is a 90% probability of the emergence of clear effects of the "El Niño" phenomenon, starting from the second half of the year 2023, which will affect the weather in different regions of the world during the next few years, starting from next winter, according to an official statement issued by the organization during the first week of July 2023, the return of the "El Niño" phenomenon will greatly increase the possibility of breaking temperature records and causing more severe heat waves in many regions of the world .
    - Seasonal. 2023 and 2024 are the hottest in temperatures, and setting a new global temperature record next year is certainly reasonable, this depends on the magnitude of the El Nino phenomenon. The big El Nino at the end of this year gives a great chance that we will have a new record in global temperature in 2024, this natural phenomenon is the strongest fluctuation in the climate system anywhere on Earth. Experts indicated that the phenomenon is likely to make 2024 the hottest year in the world, they fear that this will help push the world beyond the stage of a temperature increase of 1.5 degrees Celsius,
    - Reports showed that the highest temperature in July 2023, and based on the significant increase in temperatures, we expect:

Environmental factors affecting date palm cultivation and date production

Intensive date palm cultivation extends between two latitudes 10 and 35 degrees north of the equator, and the ecological date palm belt extends in the dry areas (Arid Zones) and semi-arid areas (Semi-Arid Zones), in the areas extending from the Andes River in Pakistan to the Canary Islands in the ocean.

In the Northern Hemisphere, date palm cultivation limits are at 39degrees north latitude in the Kyzyl Arafat region at the edge of the Turkmenistan desert, where there are date palm commercial farms while north of this line they not fruiting and cultivated as landscaping. In Spain, date palm trees are cultivated to a limited extent and they fruit in Alicante, Valence, Marcie, Andalusia, Malaga, and Almeria, states until Elche province at latitude 38.17 degrees, in Italy, it is cultivated in Venice and Boodeghera region also Riviera at latitude 45.24 and, 44 degrees north respectively, however, as an ornamental tree it is not fruitful also 4000date palm trees cultivated in Boodeghera area (Rome).

In the southern hemisphere, cultivation extends south of the equator at 20 degrees south latitude, mixed with the Doum palm, until 18 degrees north latitude, and its cultivation is not at 10 degrees latitude, where the oil palm appears. (Oil palm)}, and palm trees are observed in Mogadishu at 2 degrees latitude and in Tabora in Tanzania at 5 degrees south latitude.

The date palm is a desert fruiting tree, but it requires a rain-free atmosphere starting from the pollination season and ending with the harvesting season to obtain fruits with good qualities, it can be exposed to the stress of increased water (humidity, rain, and floods), Climatic factors have an important role in influencing the growth of the palm and the production of dates in quantity and quality.

Date palm cultivation is successful and gives good production in areas where the weather throughout the period of fruit growth, from flowering to Fruit ripening is high in temperature, low in humidity, and devoid of rain, this is provided by the region located between latitudes (16-27) degrees north of the equator, which is known as the ecological date palm belt, in climatic conditions other than that, date palm may not bear fruit or produce a crop.

Economically, date palm trees flower in areas where the temperature in the shade reaches 18°C, which is called the degree of flowering initiation bear fruit in areas where the temperature in the shade is 25°C. The climatic requirements of the area suitable for date palm cultivation and date production are characterized by the following specifications:

1. Long hot summers and moderate winters free of frost
2. Lack of rain, dew, and relative humidity in the late summer and early fall months, especially during the last stages of fruit ripening Rutab and Tamer.
3. Lack of strong and dry winds laden with dust during the growth and development of fruits, especially the two stages (green stage - Al-Jamari / coloring stage - Al-Khalal).

Date palm cultivation is affected by various environmental factors (temperature, humidity, rain, soil and water salinity, wind, light, and sunlight), each of these environmental factors has a minimum, an optimum, and a maximum range so the Physiological and Metabolic processes, growth and development reach their maximum levels when the environmental factor reaches the optimum level, and the rate of operations is affected by an increase or decrease in the intensity or level of the environmental factor from the optimum level.

The date palm is one of the most adapted trees to harsh climatic conditions. It also requires minimal water requirements and has the ability to withstand drought, and high temperatures and adapt to climate changes. The date palm maintains the environmental balance and combats desert encroachment because of its ability to adapt to climate change.

Environmentally important of date palm

The date palm tree is a source of shade and protection from the desert winds, a factor in the environmental, economic, and social balance for the inhabitants of deserts (FAO ,1994) and the main factor in adapting the population to the appropriate conditions and sustaining their lives, if it were not for the date palm tree, most of the oases spread throughout the Arabian Peninsula would not have existed, and the Arabs would stopped traveling.

Indeed, the spread of the human race in the dry and arid regions of the world would have been limited had it not been for the date palm

- ### Preserving biodiversity

Date Palm farms are considered a refuge for many wild species that are important for the environmental balance, play a positive role in the richness of biodiversity, and create an environment suitable for the life of many animals, reptiles, and birds.

- **Reducing dust and pollution**

One date palm tree traps an average of 60g/m^2 of dust suspended in the air which is equal to 40-80% (Ibrahim, etal. 2001), and the total amount of metals absorbed by leaves ranges between 22-91%, also absorbs 70% of toxic air-polluting gases such as CO_2 and SO_2, and trap more than 90% of lead compounds emitted from car exhausts (Al-Ani ,*et al.*2010).

- **Carbon dioxide Absorption**

Plants use carbon dioxide (CO_2) during photosynthesis to make glucose. It takes six molecules of CO_2 to make every molecule of glucose, and this basic building block is then used for energy and to make the structure of the plant itself. This biochemical reaction is the same for all plants, but the faster a plant grows, the more carbon dioxide it will use up per second. By that measure, bamboo might be the best at sucking up CO_2. However, fast-growing plants tend not to live long and when a plant dies, all the carbon in the plant is broken down by insects, fungi and microbes and released as CO_2 again.

Sharif *et al* (2011) indicated that according to the photosynthesis equation, 1.46 tons of carbon dioxide + 1.2 tons of water produce 1 ton of sugar + 0.53 tons of oxygen gas + 0.62 tons of water. This means that the amount of water used in the reaction is 0.58 tons.

The amount of carbon dioxide gas absorbed from the atmosphere through the photosynthesis process depends on the size and area of the plant's green parts, as known, the date palm is distinguished by the length of its leaves (fronds), which ranges between 3-5 meters, in addition to its long biological lifespan of six years. The frond contains approximately 100-250 pinnae (leaflet /Khusa) representing between 60-80% of the terminal length of the frond, the pinnae (leaflet) are arranged in four levels around the leaf axis, this arrangement facilitates light exposure and lack of shading. The leaflet length ranges between 20-75 cm and its width is 2.5-3 cm.accordingly, its absorption of carbon dioxide is very large, in addition, carbon constitutes 50% of the composition of dry wood compared to water, which constitutes 75% of the volume of the living plant, while in the date palm, according to studies, water constitutes 25% and carbon 60%, this means that the wood during its formation carries out the process of storing carbon

Since the date palm is one of the large and massive trees, distinguished by the size of its vegetative system and the expansion and spread of its root system, the density of the date palm wood is estimated between 200-900 kg/m^3, and because its lifespan approximately 100 years, the tree during its life absorbs large amounts of $C0_2$ from the atmosphere, in addition to the amount of carbon, Which is extracted and stored in the trunk and roots. If we assume that a palm tree is 15 meters tall and its trunk is 0.5 meters in diameter, the mass of wood in it could be 1472 kg,

since water represents 25% of the tree, its quantity in it will be 1472 x 25/100 = 368 kg, the solid part of the palm tree is = 1472-368 = 1104 kg, and thus the amount of carbon = 60/100 x 1104 = 662 kg during its growth period and its lifespan of 100 years, assuming that the amount of carbon dioxide absorbed = 366/100 x 662 = 3492 kg, meaning that one date palm tree can absorb 3 tons of carbon from the atmosphere ,if this number is multiplied by the number of trees, even if we assume one million trees is able to seize 1.8 million tons of carbon dioxide gas, and this can reduce its amount in the atmosphere by 100 thousand tons according to the photosynthesis equation (Sharif, 2008,2011) .

The date palm is considered an important source of food security in light of the expected climate changes. If the current climate changes with a rise in temperature at a rate of 1-2°C, it will have an impact on the continuity of plant production, while if the temperature rises at a rate of 4-5°C, it will lead to major losses in the agricultural system except for date palm plantations that can adapt.

Effect of fluctuation in temperature Season 2021/2022

The date palm tolerates temperature fluctuations to a large extent, as the maximum temperatures it tolerates reach more than 50 °C, and the lowest temperatures reach -2 °C but the best date palm production areas are those in which maximum temperature ranges from 35-38 °C, and the minimum is 3-14 °C. We will mention examples about temperature fluctuation in / Season 2023

Arab Republic of Egypt / Aswan Governorate

The effect of temperature fluctuation can be indicated by noting the difference between the 2021 and 2022 seasons, as it is noted that the 2022 season is later than the 2021 season due to the lack of the necessary heat accumulation and low temperatures, as shown in table no (2) :

Table No. 2: effect of temperature fluctuation on agriculture practices

Agriculture practices	Season 2021		Season 2022	
	start	end	start	end
pollination	15/2	13/6	22/2	20/4
Thinning and bunch lowering	19/4	5/7	5/5	4/6
Bagging	28/6	17/7	17/7	2/9
Mejhool harvesting	7/8	15/9	16/9	20/10
Barhi harvesting	23/7	6/8	29/7	16/8

1. All agricultural practices were delayed by an average of one month compared to the previous season due to the lack of necessary heat accumulation and low temperatures.
2. The heat accumulation for the 2021 production season reached 3172 thermal units, while in 2022 the thermal accumulation reached 2820.5 thermal units
3. Early pollination in December and January, accompanied by the fall of fruit set later.
4. There was a large difference between the temperatures of night and day. where temperatures were recorded for two consecutive days in the month of April, and the difference was shown below and this cause heavy fruit dropping occurred in date palm farms in Aswan Governorate,

Date	Temperature		Note
	Low	High	
6/4/2023	8	42	Heavy drop in flowers and setting fruits due to the difference in day and night temperatures
7/4/2023	8	43	

Bahariya Oasis area/Giza

The heat accumulation reached 4202.76 BTUs for the 2021 season (while in 2022 the heat accumulation reached 3684.21 BTUs), the heat accumulation in selected months in the two seasons as in the below table.

Month	Heat accumulation	
	2021	2022
February	81.2	0
May	566.99	439.58
August	815.61	722.61
Yearly total	4202.76	3684.21

The differences between the two seasons are as in the table No (3).

Table No.3: difference between the two seasons in some fruit development

Situation description	Season 2021	Season 2022
Spadix appearance percentage	97%	69%
Pollination time	17/2	22/3
Fruit setting percentage	98%	86%
fruit dropping percentage	56%	71%
Coloring	12/7	23/7

New Valley Region

The extreme difference between the night and day temperatures during September 2022, led to a delay in the ripening of Sway cultivar , and due to low temperature and morning dew, Calyx Rot End appeared near the perianth as dark ring, especially in Rutab stage, the beginning of Tamar stage,

This disease spreads in Iraq, the USA, Morocco, Saudi Arabia, Bahrain, and the Sultanate of Oman. Ants and some other insects may play an important role in transmitting the spores of these fungi to the fruits, in addition to high humidity. It affects the fruits in Rutab stages, and the infection rarely appears on Khalal stage, the disease caused by(Aspergillus niger and Aspergillus phoenicis)

Heat accumulation in New Valley Region

The Table No. 4 show the difference between day and night temperatures in September and the total heat accumulation for the month for the seasons 2021 and 2022.

Table No. 4: Difference between day and night temperatures in September and total heat accumulation for the two seasons.

Date	Heat accumulation	
	Season 2021	Season 2022
25/9	16.7	8.7
26/9	17.9	7.6
27/9	16.6	7.7
28/9	16.6	7.3
29/9	14.6	3.1
30/9	15.0	9.1
Total heat accumulation	344.9	405.70

The effect on the ripening rate in different regions as follows

Region	Ripening %
Alkharjah	90
Aldaekhelah	60
Farafra	50
Bahariya Oasis	25

Effect of low temperature and frost on date palm

We explain some of the effects of low temperatures and freezing on spadix formation, flower growth, fruit setting, and ripening

Effect on spadix appearance

1. The temperature in the late autumn and winter has a direct effect on the growth and development of the Spadix and the subsequent bloom of the inflorescences, in the warm winter and early summer there is early flowering and early ripening of the fruits, in contrast to the season in which the winter is cold and the summer is late.
2. The flowering degree 18 ° C it is the basis for calculating heat accumulation
3. The average temperature at which flowering begins and spadix appears in the axils of the leaves at the head of the date palm must not be less than 18 degrees Celsius.
4. There must be Heat accumulation not less than 400 thermal units or degrees Celsius approximately 17 days. , Ruther and Crawford (1946).
5. Temperature is related to the success and speed of pollen grain germination and arrival to the egg and the success pollination and fertilization process.

6. The minimum temperature for the pollination process to occur is 8°C, the maximum is 40°C, and the optimum temperature for completing the pollination and fertilization process is 25-30°C

7. The fruit setting continues as the temperature rises to 35°C, outside these limits, the pollination process fails, therefore, in the case of low temperatures, the spadix is covered with paper bags after pollination. Directly, studies have shown an increase in the percentage of fruit set compared to uncovered, especially in seasons when low temperatures, rain falls, and winds blow during the pollination process. The paper bags can be removed 20-30 days after the procedure is performed.

8. The density of the leave (fronds) affects the return of thermal radiation to the soil again, as the leave act as a reflective surface for thermal radiation at night, which reduces the chances of frost damage and low temperatures in desert areas.

Effect on fruit repining

The temperature in winter and the heat that occurs after the flowers open and the subsequent stages have an effect on fruit ripening time. The total heat units have an effect on fruit growth and ripening, and this affects the timing of the different agricultural practices as well as marketing.

During the period of flower opening (February/March/April). Until the fruits ripen in (August/September/October), the average temperature, depending on the cultivars and their ripening time, must be between 21°C for the early and 29°C for the very late as shown in Table No. (5).

Table No.5: Average temperature according to the ripening dates of cultivars

Cultivars	Average temperature
Early ripening	21°C
Moderate ripening	24°C
Late ripening	27°C
Very late ripening	29°C

The effect of high temperatures on date palm

1. Date palm cultivars differ in the tolerance degree to high-temperature stress and it was noted that the temperature reaching more than 68 degrees Celsius leads to the death of trees and that the vegetative offshoots are more tolerant of the high temperature than the tissue offshoot

2. High temperature accompanied by high relative humidity during the early stages of fruit growth and development and the ripening stage causes skin loss and skin separates from the flesh of the fruit.

Loss Skin

It is the occurrence of slight swelling in the fruit, the separation of the fruit's skin or outer wall (the fruit's skin is called the Exocarp or Epicarp includes exodermis) from the fleshy part, forming a separate cover of 50%. This is clearly observed in the tamer stage, where the percentage of peeling in one cultivar does not exceed 10%, except for Khalas, Barhi, Jabri, and Sultana, where the percentage exceeds 20%.The cultivars differ in the appearance of this characteristic, which is considered one of the low and unacceptable characteristics that cause deterioration in their quality and marketing value.

Some cultivars are characterized by the presence of a space between the fruit flesh and the seed and the low thickness of the flesh part, while this space disappears in other cultivars such as (Mejhoul/ Khastawi/ Deglet Nour/ Maktoum/Bream). This phenomenon occurs in cultivars grown in coastal areas and near the coasts, where the separation of the skin from the flesh is observed where multiple causes, including high temperature and air humidity together. It is spread in all areas of date palm cultivation and in sensitive cultivars, especially Khalas, Jish Rabie, Hatami, Abu Maan, and Barhi. Sari, Safri, and Abu Al-Athouk, loss of skin is considered an undesirable characteristic of fruits that reduces their marketing value, makes them susceptible to rotting and the appearance of sugar crystals, and reduces their ability to be stored and It is one of the most important problems facing soft dates in the Kingdom of Saudi Arabia, and causes a high loss of the crop, ranging between 25% - 50% of production, as its classification changes from first class to second class.

Extremely high temperatures combined with drought and a decrease in humidity cause a rapid loss of fruit moisture and shortening of the Rutab stage, the fruits turn directly to Tamer and dry without going through the Rutab stage, as happens in the areas of northern Sudan and southern Egypt, where the fruits are dry and very hard.

Sudden climatic conditions change and high temperatures (Iraq)

1. Strong, dry, hot winds that coincide with the growth and development of fruits, irregular irrigation, and shortage of water during this stage, as well as the change in relative humidity and the severity of drought lead to the shrinking of the fruits, then drying and drop early before ripening.

2. In small fruiting offshoots, exposure to direct sunlight and the proximity of the fruits to the soil surface, in particular, places them under high thermal

stress from the top, which is the heat of the sun, and the bottom, from the soil temperature, especially sandy ones, which causes wilting and (drying) in khalal stage and when the fruits are completely discolored.

3. Direct exposure to the sun's rays, especially when the temperature rises to 50 °C, and the solar radiation in June and July increases to more than 10 in some dry areas causes solar injury or sunburn, sun blight on the fruits, as well as sun blight on the fruit stalk, which causes drying of the bunch stalk due to direct exposure to the scorching sun rays, is observed in sensitive cultivars and in the bunches facing the sun.

1-2 **Low green color**
3-5 **Moderate Yellow color**
6-7 **High Brown color**
8-10 **Very high Red color**
11 and More **Extreme Violet color**

Sand and dust storms

The effect of dust storms on pollination

1. Dust storms cause accumulation of dust on the stigmas, which cause stigma drying, pollination process failure and reduce fruit set percentage
2. Wind helps to transport many insects, such as the Dust mites , Parlitoria date scale insect, and Date butterfly Almond moth

MothCadra (*Ephestia*) cautella walker from one area to another, or from one orchard to another

3. Physiological disorder (White End)

It is a hardening (dryness) of the fruit part close to the fruit cap (perianth) in the form of a light-colored ring that expands in width depending on the severity of the disorder. This hardening or drying occurs due to the cessation of cell growth in this area during the Rutab stage and continues until the Tamer stage. This disorder does not occur as a result of pathogenic causes (Fungi, bacteria, viruses) and not insects, but rather a physiological phenomenon (physiological disorder) caused by weather conditions in the region, especially temperature, dry winds, and the sensitivity of the cultivar, and it is directly proportional with the age of the date palm tree.

The infection appears on many Iraqi cultivars especially Hallway, which is one of the economic cultivars whose cultivation is widespread in Basra Governorate where most of this cultivar production was exported packed in cardboard or wooden boxes to the United States of America, but the fruits are affected annually by this disorder at a rate ranging between 25-30 %, and in some years the percentage may reach 40-60%. The infection rate varies between the fruits of a single bunch, ranging between 6-20% in the outer spikelet, and 1-9% in the inner of the bunch. The infection rate in orchards near rivers and irrigation sources also ranges between 8-13% and in far orchards 20-70%, this causes a decrease in the economic value of infected dates, as the price of a ton of uninfected dates is seven times the price of a ton of infected, this disorder has been observed in many Arab countries and on different cultivars in (Morocco, Libya, Egypt, and the United States of America, where it is called white tail or white nose.

The incidence has been observed in the Naghal, which is one of the early Omani cultivars and is widespread in the United Arab Emirates, and in the Shishi is widespread in the Kingdom of Saudi Arabia and the United Arab Emirates where it is called (Abu Tuwaiq), as the end of the fruit sometimes dries up near the perianth in the form of a collar, and in the Medjool grown in Medina and Jordan, as well as in the Egyptian cultivar Saidi, however, fruits affected by this disorder have a special market and consumers want them in all Arab Gulf countries.

Etiology

Shortage of irrigation water, and drought during the kimri (green stage), led to an increase in the incidence of this disorder by a greater percentage than when fruits were exposed to a lack of irrigation water, and drought in the khalal (colored stage) and Rutab stage. (Furr and Armstrong,1960) .

The long period of drought and hot climatic conditions increase the incidence of this disorder.

Blowing of hot, dry northern winds during fruit changing from Rutab to Tamer stage



Effect of dust and sand on date palm fruits

1. Fruits collide and friction with the leaves(fronds) causing black spots on the fruits

2. Sand sticks to the fruits in the Rutab and Tamer stages as a result of sand storms, affecting fruit quality which is consumption and reducing their marketing value.

3. The wind causes the broken of the Fruit stalk or bunch holder, and this occurs as a result of the breaking of the internal vascular bundles of the fruit stalk in the early stages of fruit growth, which results in the form of a notch or smooth cut in the tissues of the lower part of the frond and the bunch stalk as if it were cut with a sharp knife or a complete cut of the frond and stalk, (Cross cut), this causes the fruits to wilt and dry out and turn into shrivel fruits.

The effect of humidity and rains

The date palm can be exposed to water stress (humidity, rain, and floods), and high humidity or rainfall causes fruit damage that affects marketing value, and rain effect depends on (the quantity of rain /rain time and period).

Rain causes severe damage when it falls at pollination time as it may cause the removal of pollen grains from the stigmas of female flowers and the explosion of the pollen tube.

Autumn rain accompanied by high humidity and warmth before pollination causes the infection with.

Inflorescence Rot

Some countries, it is called inflorescence rot, this disease affects the flower inflorescences of male and female trees, and it is one of the most important and dangerous fungal diseases that affect date palm trees in the world. The loss resulting from infection is about 2-15%, and in some countries, infections may reach about 50% in years of epidemic disease, and its impact on males may be greater than on females as a result of the shortage of agricultural practice services for male trees.

The disease is spreading in Morocco, Algeria, Tunisia, Egypt, Libya, Iraq, Palestine, the Arab Gulf countries, and Iran, it is spreading in the coastal areas with high humidity, and the disease severity varies from one country to another and from one region to another in one country, depending on the prevailing environmental conditions such as temperature and humidity. The disease is caused by the following fungi:


Mauginiella scaettae, *Fusarium moniliforme* and *Thielaviopsis paradoxa*. The fungus M. scaettae is considered the main cause of this disease, but we sometimes infections caused by the fungi T. paradoxa and F. moniliforme, knowing that the second fungus is more common than the third fungus in such cases. The *M. scaettae* fungus lives as a mycelium (the vegetative body of the fungus) between the leaf bases and the fibrous tissue in the head of the date palm tree for a long period that may reach five years.

The spores of this disease spread in the head of the infected tree and from one tree to another on the same farm by wind, insects, and humans. Infections are renewed next year on the healthy date palm trees, where the fungus remains between the leaf bases and the fibers at the head of the tree, the cycle of the disease is repeated, and rain, high humidity, and low temperatures are encouraged on the occurrence and spread of the disease.

Symptoms of infection.

1. Severe infection results in young spadix not opening, drying up, and dying, so no fruits are obtained, and male spadix cannot be used for pollination.
2. Brown spots and a white powder are observed on the spikelet, which are spores of the fungus that cause this disease.
3. When the spadix cracks transparent yellow spots in contrast to the brown spots observed on the outside of the spathe, and brown spots on the inside of the spathe are noticed in the area where the cover comes into contact with the infected flower spikes.

Side spot decay

It is caused by the fungus *Altenaria*. It causes economic losses when infects fruits during ripening, as it attacks the wounded fruits at the khalal stage, and the Rutab stage, appears as small black spots then expand to form a large oval or circular spot in shape, dark in color.

Date Palm fruit rot

It is caused by the fungus Botryodiplodia sp, which spreads in date palm areas with high humidity due to its proximity to the coasts or due to rainfall.

Symptoms of the disease are notches and suffocation in the fruit and soft rot that quickly turns to dry with the appearance of the infection site in a dark brown color, like dust mite infection

Black nose disorder

The blackening of the fruit end, and the infection appears at the end of the green stage (Kimiri) and the beginning of the colored stage (Khalal). It is a physiological phenomenon caused by:

1. High relative humidity around the fruits,
2. Accumulation of early morning dew on the fruits
3. Short-term rainfall during the Rutab and Tamer stages



4. Increased irrigation water in summer causes cracking of the fruit's skin, especially in the area near the perianth, with transverse cracks followed by dryness, death of the layer under the cracked skin, and darkening of its color.

It is widespread in Iraq, Egypt, Morocco, Algeria, Tunisia, Mauritania, Libya, and the United States of America, affecting the fruits, distorting their appearance, and reducing their quality and marketing value. The annual loss in yield ranges between 5-50% , the incidence of this disorder in the Sayer cultivar is 7% in the Basra, and it increases to 85% with river water rise and increased irrigation while in California, the infection rate is 5% in the Deglet Noor rising to 50% with high humidity, and the most sensitive Egyptian cultivar Hayani.

Fruit explosion and rot

In young fruiting date palms due to high humidity around the fruits and heavy irrigation, or soil waterlogging, with severe thinning and fruits dropping, water absorption occurs without being matched by water released from the fruits through the process of evapotranspiration, and an imbalance in the water balance occurs with increased turgor pressure. , where the fruits swell as a result of filling with water, also, the increased potassium concentration due to the many additives, causes the fruit to explode and emerge the juices and the associated white color is fungal rot .

High relative humidity in the surrounding air of the fruit

When rain falls at the end of the khalal stage and the beginning of the Rutab stage, cracking of the fruit's skin and flesh occurs (splitting)

Cause reduces the loss of moisture in the fruits and leads to a physiological defect in the development of the fruits due to the difficulty of getting rid of the excess moisture inside the fruit, which leads to a prolonged Rutab stage and delays the natural ripening of the fruits, which causes fruit dropping, as well as the appearance of physiological disorders is the case in some date palm cultivars in the United Arab Emirates and the Sultanate of Oman, this notice when the Anbara cultivar is cultivated in coastal areas, and also un scheduling of irrigation leads to fruits cracking and rotting.


Rainfall at the last stage of the Rutab and Tamar stage in the 2022 season (Sultanate of Oman/UAE/Al-AHSA/Pakistan) It causes fruit dropping, fermentation, and souring.

- ***Effect of water immersion and flood***

Lack of aeration in the soil leads to suffocation, a decrease in the plant's ability to absorb water, and a loss of water balance between the absorption carried out by the roots and the transpiration carried out by the leaves.

There are several factors that affect the percentage of damage caused by insufficient ventilation of the roots in the soil, including (type of plant, Soil type, temperature, period of immersion of roots in water, type of microorganisms in the soil).

- ***Effect on newly planted offshoots***

The young date palm trees and newly planted offshoots aged 5 years, cannot tolerate having its head (Apical meristem) submerged in water, when exposed to water submersion for 120 days and at a height of two meters, all the offshoots die.

- ***Effect on Fruiting trees***

The date palm is distinguished from most other plants and trees, except for aquatic plants, by its tolerance to being submerged in water for long periods. In the swamps of Punjab in India, the trunks remained submerged in water for six years without dying, also, in Iraq, it was observed the trees continued to produce even though their trunks were submerged in water for

10 years on the banks of the Euphrates River. In Egypt the tree continued to grow for decades, submerged in water to a height of 1.5-3 meters on the banks of the Nile, without being affected.

The symptoms observed

- Increased dryness of the fronds and small fruits that tend to blacken.
- Wilting of the bunches tips in the Khadrawi and Hallway cultivars.
- Rot under the fruit cap (perianth)) in Sayer cultivar before ripening and the fruits dropping

Drought effect (water stress)

The shortage of sufficient irrigation water for the date palm tree exposes it to water stress, (drought) and causes:


1. Delayed flowering, fruit dropping, low fruit quality, and small size.
2. Slow growth process, weak trees, and drying of a high percentage of leaves (fronds) .
3. Newly planted offshoots in the permanent field dry up or die.

4. *Drought and less irrigation water cause heavy fruit drop*

The exposure of offshoots and fruiting trees to drought with high temperatures for a period of two weeks or more leads to fruit dropping at the abscission zone from the slightest movement or vibration of the tree branches. One of the reasons for this occurrence is that the fruit set faces high temperatures accompanied by severe drought and low air humidity.

Effect of salinity

Salinity is one of the challenges facing agricultural production, especially in arid, semi-arid and desert areas. An increase in the concentration of salts in water or soil affects negatively the growth and productivity of crops, and the successive irrigation process causes the salt washing out under the root area, and the salts accumulate deep in the soil, which requires washing away the accumulated salts, as their accumulation leads to a severe lack of nutrient absorption needed for the plant in particular. Potassium, magnesium and calcium, resulting in poor growth and decreased plant productivity in quantity and quality.

The rise in the ground water level considered an additional source of salts as a result of its movement upward and reaching the root growth area in order to increase its content of dissolved salts. The salts accumulated in the root vessels are transferred to the stem and leaves, and the accumulated salts in the leaves can be drawn to the stem. The most important elements remaining in the leaves are Ca, B, Mn, and Silicon.

Effect of salinity on leaves (fronds)

1. The appropriate salinity concentrations for offshoot planting are 2000-2500 ppm, taking into account offshoots or seedlings source, vegetative or tissue culture.
2. The date palm tolerates high salinity of 10-18 ds/m, but in high-salinity soils, has few fronds and bunches.
3. The date palm tree shows symptoms of yellowing (Chlorosis) on the leaf (frond) base, drying leaves tips, and leaves dwarfing and bending due to incomplete growth, which is called “madness” disease in Algeria, and in the desert of Tunisia, date palm trees growing in salty soils are called “AboSafa.”

Effect on productivity

There is a direct relationship between increased soil salinity, irrigation water salinity, and date palm productivity. The date palm tolerates high salinity and can tolerate a salinity of 3-4%, but its production decreases if the salinity is 1%, and fruiting is regular if the salinity becomes 0.6%while crop amount decreases to 50%

when the soil salinity is 18ds/m (14400 ppm) and the irrigation water salinity is 12ds/m (9600 ppm).

Effect of tornedo on date palm in Oman 2021

Cyclones Shaheen consecutive tropical cyclones that impacted Iran, Oman, and the United Arab Emirates, caused the destruction of a number of cities and the bulldozing of many date palms and other fruit trees in Oman.

Impact of El Nino phenomenon on the date palm season 2023

1. Early ripening of fruits more than the previous season in order to provide the heat accumulation necessary for ripening
2. High temperature exceeding 50 degrees Celsius and increased solar radiation, especially ultraviolet radiation during the daylight hours from 9 a.m. to 3 p.m., cause the fruits facing sunlight to suffer from blight or sunstroke.
3. Fruit wilting and Dryness.

Impact of climate changes on the date palm Pests

The effects of climate change on pests will lead to:

- Changes in the geographical distribution of insects and increase in wintering insect population.
- Change in host plant resistance.
- changes in the behaviour of insects and their generations, and the damage percentage caused by each generation will differ. It is possible that the second and third generations of most fruit pests, such as lesser date moth and greater date, will be more harmful than the first generation, which is considered to be the main generation that causes 70% of the damage and does not care about other generations.
- Decreased effectiveness of biological control and changes in the activity and density of natural enemies.
- Increased risk of invasive pest species and the spread of insect-borne diseases.
- Heavy rainfall causes washing of the insects from the plant and decreased survival during winter while low rainfall increase plant sensitivity (plant more susceptible to insect attack.

How do we confront climate change?

Adaptation is defined as a set of practices and technologies that can be applied to reduce the negative impacts of climate change on agriculture. The most important of these practices are:

1. Adopting farming systems friendly to the environment.
2. Adopting technologies and applying developing agricultural practices.
3. Combating desertification and rehabilitating degraded lands.
4. Determine the optimal fertilizer equation, fertilization rates, and appropriate timings.
5. Maintaining soil moisture, by following appropriate cultivation systems (Zero tillage cultivation), and improving crop residue management.
6. Using unconventional water as a source of irrigation water as a substitute for freshwater.
7. Rational management of available water resources and dissemination of water harvesting technologies and modern irrigation methods.

How date palm resist climate changes?

The date palm is distinguished by its adaptation to desert environments and tolerance to harsh environments, especially high temperatures, drought, salinity, and lack of ground humidity.

For the date palm to grow and produce well and express its genetic potential, it must not be exposed to stressful conditions, and it is anatomical and morphological structure helps with this,

Features of roots

1. Roots of date palms are adventitious, and the trees have the ability to form adventitious roots along the trunk, with the superior ability to form new roots and replace damaged roots within three months for uprooted offshoots.
2. The absence of root hairs due to the inability to form them, as well as the roots, are always close to soil moisture, and absorption occurs through the absorbing roots.
3. The roots have exceptional ability to exclude the harmful ions ($Na+$, $Cl-$) and highly control absorption of these ions from the saline soil solution and irrigation water, and also tolerate water logging for a longer period, because of air passages, extending from the roots through the trunk, to the leaves, stomata which facilitate its respiration.
4. The root system spreads horizontally and vertically in the soil until it reaches wet areas, and the depth of the roots depends on the groundwater level and the limestone layer, the absorption rate is 95% of water up to a depth of 180 cm. The roots go deep into the soil at an angle and in a shape resembling tent ropes, thus anchoring the palm trunk firmly to the ground.
5. The presence of air passages in the cortex helps survive in wet and waterlogged soil, as well as in marshes and swamps, the passages are connected to their counterparts in the trunk and extend to the leaves to connect to the stomata, where the process of respiration through the stomata

Features of leaves

1. The age of date palm leaf (frond /Safaa) is six years after the leaf activity stops, losing chlorophyll pigment and drying up, but they don't drop down due to the absence of an abscission zone. It should be cut by man.
2. The leaflets are thick and surrounded by a waxy layer, and the leaflets are folded on their longitudinal axis in the shape of a boat.
3. The leaf (frond) axis is covered with a waxy layer, and the leaflets (pinnae) at the leaf base o are transformed into long, green, spines, with little water loss through evapotranspiration, as the stomata are small and sunken, and their number on the leaf upper surface is less than the lower surface.

Features of trunk

1. The trunk of the date palm is huge, and cylindrical despite the absence of cambium as it is a monocot, this is due to the growth of the apical apex and enlargement of leaf bases. The apical dominance is

clear in the date palm, and the stem does not branch except in rare cases for many reasons, including those related to the cultivar, as in the Tabarzal cultivar, or for other reasons, cutting off the apical meristem means the death of the tree, and the trunk is flexible, strong, and durable covered with leaf bases, which represent the main part of the trunk.

2. The length of the trunks ranges between 20 - 30 m, and the annual longitudinal growth rate ranges between 30 - 90 cm depending on the cultivar, environmental conditions and agricultural practices.
3. The vascular bundles in the trunk remain active throughout the tree life, and the bundle branches into two, one of which heads to the frond or bunch, and the other forms one of the original trunk bundles.

Features of apical Meristem

The apical meristem has relative stability in the temperature due to:

- The apical meristem is enclosed with leaf bases and fibers which protect it from temperature fluctuations.
- The sap flow rising from the roots to the shoot apex (water and nutrients) affects the temperature of the apical meristem and water moderates the temperature to be close to the temperature of the water in the soil surrounding the roots, as is known, as known that water in the soil is not affected by changes in climate factors above the soil surface.
- The regularity of the fronds at the head (top) of the date palm tree and the appropriate cultivation distances are of great importance in reducing the loss of heat gained from the soil at night through heat dissipation or through radiation, these factors keep the apical meristem temperature without significant change and helps to resist fluctuations in temperature.

Establishing new date palm farms

Concepts have developed among many farmers and

investors in establishing new date palm cultivation, and investment in the field of date palm farms and orchards is not limited to date production only but has gone beyond that to goals and objectives according to the investor's, awareness, capabilities, and interests among those goals:

1. Cultivation of distinguished and economical cultivars with high economic value.
2. Producing high-quality dates suitable for direct consumption and marketing in different packages that attract the consumer.
3. Benefiting from date palm by-products, which some farmers call (waste), most of them ignore their value and importance.

1. Study the environmental requirements of the cultivars and their suitability to the region's environment.

Heat accumulation

The basis for calculating heat accumulation is the degree to which flowering begins (18°C), which represents the average temperature at which flowering begins and the appearance of spadix in the leaf armpit at the head of the date palm. Some cultivars begin flowering at a temperature lower or higher than (18°C), but the degree at which it begins, flowering must not be less than (18°C) and there must be a heat accumulation (400) degrees Celsius or thermal units, meaning approximately (16) days

Heat accumulation in the region

The period is calculated from the beginning of the month in which the average temperature rises above 18°C until the month in which it drops below 18°C.

Heat accumulation for the cultivars

The period is calculated from the month in which flowering takes place until the Tamer stage and fruit harvesting, in days it varies from one cultivar to another, between 120-240 days.

Heat accumulation for each growth and development stage of the Fruit.

The temperature that occurs after the spadix opening and the subsequent stages have an effect on the ripening date, and the total heat units have an effect on the growth and ripening of the fruits, and this affects the timing of the agricultural practices and marketing. The heat units required for date palm fruits were calculated during the different stages of fruit growth and ripening in different regions of Iraq.

Al-Jassani (2007) indicated that the heat units required for date palm fruits during the various stages of fruit maturity from the first stage until the Tamer stage in the regions of Iraq between 2196-1906 °C, the number of weeks for the fruit growth stage according to cultivars is between 19-25 weeks, which is equivalent to 133-175 days, as follows:

Growth sage	**Length of stage (week)**	**Length of stage (day)**	**Heat units °C**
Hababouk	4-5	28-35	195-209
Kimri	6-8	42-56	845-900
Khalal	4-5	28-35	374-383
Rutab	3-4	21-28	242-352
Tamer	2-3	14-21	250-352
Total	19-25	133-175	1906-2196

Heat accumulation according to ripening stage of the cultivars

The following table shows the heat accumulation of the varieties according to the maturity date

Total heat units °C	**Notes**
Less than 1550	All cultivated cultivars not ripening
1750- 2250	All early cultivars ripening
2250-2750	Early and medium cultivars ripening
2750-3250	All cultivated cultivars ripening
More than 3250	All cultivated cultivars ripening with good quality

2. Establishing specialized farms suitable for the region’s environment.

The farms diversified according to the purpose of their establishment and the method of investing:

- ■ Date palm farms for producing offshoots
- ■ Establishing specialized farms for male trees, irrigated with triple-treated wastewater.

Tertiary treated wastewater is considered one of the (non-traditional) water resources that can be used in cosmetic agriculture as well as in growing crops, and trees as a sustainable source of water, it can used in irrigation male farms established to Produce pollen grains and sell them to farmers in a way that ensures their quantity availability and preservation of vitality, through implementing a comprehensive monitoring program for water, soil, and inflorescences from lands irrigated with treated wastewater and comparing them to those irrigated with natural water.

- ***Establishing a farm for cultivars edible in Khalal stage***

The fruit is physiologically mature, hard ripe and the color changes completely from green to greenish yellow, yellow, pink, red or scarlet depending on the cultivars. The stage is characterized by:

1. Long of this stage 1s 4 to 5 weeks depending on cultivars, with a low average relative weekly increase in fruit weight (3 to 4 %).
2. At the end of this stage, date fruit reaches its maximum weight and size, but sugar concentration (sucrose), total sugar and active acidity have a rapid increase associated with a decrease in water content (around 50-85 % moisture content).
3. It is to be noted that date fruit accumulate most of their sugar, both the sucrose type and the reducing sugar type, as sucrose during the Khalal stage
4. At this stage color of the seed changes at the end from white to brown.

5. Some cultivars such as Brahi, Hallway, Hayni and Zaghloul are consumed in this stage, as they are very sweet, juicy and fibrous but not sour.
6. However, Khalal dates must be eaten immediately after harvesting as they will keep for only a few days without cold storage (7°C for one week or 0-1 °C for longer periods) due to their high sugar and water content which cause fermentation during hot weather. If supply and demand are in equilibrium, the Khalal season will last for a couple of weeks.
7. Cultivars harvested and marketed at Khalal stage present the following advantages: minimum infestation, possibility of cutting the whole bunch, easy handling and packing, high yield and consequently high income.

3. Diversity of cultivars

Stay away from monoculture by focusing on one or two commercial cultivars on one farm.

Cultivars' composition must be changed to suit climate changes, early, medium, and late cultivars must be cultivated in the new farm.

Fresh or soft dates that contain humidity of 35-25%, which require 2000 heat units, while the semi-soft or semi-dry dates contain 15-25% moisture and need 2000-3000 heat units and the dry dates contain less than 15% humidity but required more than 3000 heat units.

Classifications of cultivars according to a tolerance of low temperature, high humidity, and rainfall.

Tolerant to	Resistance cultivars	Moderate	Sensitive
Cold and low temperature	Zahdi,Hayani ,Ashersi ,Sayer ,Saagi , Khistawi	Barhi, Deglet Noor, dayri ,Maktoum ,Mehjoul , Khdarwi	Hillay , Braim , Khalas ,Sukari , Ghars, firsy
Relative humidity	Khniazi, Khasaab , Shahel . Umalsela	---------------	Lulu , Khalas ,Naghal , Mejhoul, Deglet Noor
Rain fall	Dayri , Khasaab ,Farad , Hillay, Sayer , Thawry , Khdarwi , Khistawi	Naghal, Shishi , Barhi, Zahdi , Hillely	Hayani , Gharis , Jish-Rabee , Deglet Noor

4. Diversification of consumption

There is a strong relationship between date consumption and the ripening stage and at any stage, they are suitable for human consumption. Dates are divided into three categories regard to their consumption, which are:

- ***Dates consumed during the season***

They are consumed fresh in the summer during the Rutab stage, and a small portion is consumed in the (Khalal) stage, where the fruits of some cultivars are harvested at this stage, the fruits of which are sweet in taste and not astringent. They are characterized by being devoid of or containing small amounts of astringent tannins, such as (Zaghloul, and Barhi, Braim, Samany ,Khinazi) and the consumption rate in the Khalal and Rutab stages is estimated at 48%.

- ***Dates are consumed after fruit harvesting , so consumption is:***

- ***Loose dates***

Dates packed individually and naturally without any mechanical pressure.

- ***Pressed dates***

The fruits are pressed in layers using mechanical pressure.

- ***Filled dates***

Whole pitted dates stuffed with nuts (walnuts, almonds, pistachios)

- ***Cooled or frozen Rutab***
- ***Cooking Khalal.***
- ***low-quality dates***

Dates are low quality and their fruits are not harvested and left on trees or on the ground, and most of them are from seed trees with low quality fruits.

5. Calculate the fruit's physiological age

Number of days from pollination until harvest, and is calculated in days from full bloom to harvest, it is for some cultivars (Deglet Nour reached 208 days in California, for Al-Zahdi, 170 days, for Al-Sayer, 130 days, and for Al-Khastawi, 150 days in the central regions of Iraq.

6. Implement Good Agriculture Practices (GAP)

Using the most appropriate agricultural practices to achieve the principle of optimal exploitation of land and water resources, improving the agricultural environment, and taking advantage of the cultivated area in an economical and environmentally friendly, as dates can be produced with different specifications and shapes if good management and proper agricultural practices are followed with date palm trees, especially post-harvest treatments, and the tree is exploited in the correct way.

- *Drop in temperature after pollination*

The pollinated inflorescence must covered with paper bags:

- This will raise the temperature inside paper bags by 3-6 °C, Which helps increase the germination rate of pollen grains and fertilization process,
- Increased relative humidity around bagged flowers, the flowers' stigmas will be suitable for a longer period of time to receive pollen grains than other flowers exposed to the air.
- Prevent pollen grain losses in case of rainfall and strong wind and success pollination .

- *The main challenge in all Arid regions is drought and water crises*

Management of water properly to conserve water, efficiently use, and maintain soil productivity. Therefore, irrigation must be scheduled according to the date palm tree's growth stages, and fruit growth and development stages.

Date palm tree growth stages and water inputs:

Growth Stage	Age of tree (year)	% of total volume
Vegetative stage	1 to 5	33%
Intermediate stage	5 to 10	66%
Production stage	10 and more	100%

Irrigation scheduling according to the stages of growth and development fruits

Stages of reducing irrigation	Stages of increasing irrigation
pollination	After fruit harvesting
Rutab stage	Flowering(spadix appearance)
Tamar Stage	Fruit setting
Harvesting	Green stage
Winter months	Color stage

- *Fertilization*

- Focus on potassium fertilizers, especially (potassium sulfate), to accelerate ripening
- Stay away from calcium , fertilizers which increase hardness, such as Cal boron(%18 Ca %6B), which used to increase fruit set
- and reduce fruit dropping, but delay ripening.
- With the increase in temperature, fertilizing with all types must be stopped except liquid fertilizers that are added to irrigation water, and focus on potassium fertilizers.

• Bagging and thinning

In the case of expected rain and high humidity

- Bagging using graphite paper bags Brown A2 to cover the fruit t is placed on the bunch in the form of a funnel with an open bottom.
- Ventilating the tree head by removing a number of fronds and preventing crowding and entanglement.
- Thinning remove spikelet from bunch core and reducing number of spikelet on the bunch.
- Early harvesting and artificial ripening techniques are used like poly carbonate chambers

• Bunch lowering

To avoid sun scaled

- Pull the bunch from the top of the tree to be under the fronds in a way that blocks the sun's rays.
- Bagging the bunch as soon as possible.

Fruit drying

- Giving abundant irrigation during the period of high temperature and until the fruits reach the Rutab stage.
- Irrigation should be done early morning and late evening, and avoid irrigation in mid of the day.
- Establishment of weather stations and linking with irrigation system so that irrigation programming is linked to weather conditions and drought.
- Maintaining moisture in the head by keeping a large number of fronds and not performing the late thinning process.

• Pesticides Spraying

In high temperatures, it is preferable not to spray chemical pesticides because this causes the fruits to burn. Biocides or plant extracts can be used.

• Fruit Touch

Avoid fruits touching for any reason, especially when the temperature is high in the afternoon because this causes a break of fruit skin, damages the stomata, and causes water imbalance and wilting of the fruits.

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Global Climate Change and Feed the Future Impact assessment for sustainability of global small scale agriculture.

A better future for farmers and livelihoods

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Agriculture today faces new challenges. Rising food prices and ever-changing agriculture, effect the security of livelihood and are stimulants to bio-fuel issues. Since 2005 the introduction of a bio / clean source of energy such as ethanol began to take shape in the world of agriculture philosophy. There are many issues having to do with food vs. fuels and the ultimate bio-fuel sector domain, where limited land for energy opposed to the purpose of food security has changed the goals of sustainability especially for the case of small scale farmer communities. This has increased the possibilities for successful small farms and has stretched just a little, the food security bubble waiting to burst. The tangible approach to the point of research where applicability is but a doorway to be applied back to the institutions that are collaborators is a good means to the solution of climate change. The infrastructure of any movement is the solution to the major problems as well as how to deal with data collected for the benefit of small farming communities represented as the key solution for long term expectation of delivery.

INTRODUCTION

To what matters most to human beings; is it the lasting survival of the human race? The well-being of our climate and earth is a major topic that deserves far more attention than the efforts of the United Nation's COP system, action is the key to such efforts. Numerous debates have gone without impact, bringing into existence by literatures written in human ethics in Agriculture. The impact of climate change on food security, the focus on livelihood and higher food prices are moving agriculture back to the center of global concerns (Wilson, 2009). As former United Nations Secretary-General, Kofi Annan said at the Conference on Climate Change in Bali, in December 2007, "It is of the utmost importance to incorporate the dimension of food security when dealing with the challenges of climate change". If we do not act immediately, climate change will increase the number of hungry in the world. That is a momentous challenge for world food security". With the ongoing debate of food vs. fuel, I believe they come hand in hand, where food cannot be produced without a reasonable way of creating energy from the waste. With the moral discussion behind this concept, it is safe to say in my opinion that the one true fault in man is having no heart for other men. With greed as a stimulus this becomes a grave situation without remorse to anyone who stands in their way.

The ongoing debate remains, while man struggles to agree on one simple aspect of what life stands for. Carbon Dioxide, also known as CO_2 and overall belonging greenhouse gases, will be the doom of human kind and all species on the planet, for its side effects on earth as excess heat is trapped in the lower atmospheres. Throughout history, we have always made mistakes in all things, a trial and error approach, we must say that we have reached the point where mistakes no longer make a difference in the variables that bind reality (Ackerman *et al*., 2009). Regarding Agriculture, plant species being unable to fully and efficiently carry out their survival cycles that involve temperatures being specific or ranged. The fluctuating levels of climate change have harmful ramifications towards plants in general, but it is not that fact that is terrifying, rather that the time frame in which the changes are being observed. (Frank *et al*., 2009).

The backbone of the United States of America and global players, land is what ultimately makes all the wheels spin harmonically. The manner in which land is used will determine the outcomes of that use. It has been well agreed upon throughout the experts in agriculture that any process has its limiting residues that cannot be recycled due to cost or prospect. So we come to the idea that transcends between the guidelines of agro-ecological principles increasingly being recognized as potential guidelines, for designing achieving a more sustainable agriculture (JSA, 2006).

As Thompson (2012) mentions; market drivers of bio-fuels indeed skew consumption of agricultural grains, a non-unique issue with bio-fuels that is a determinant of how false information of ethical bases of biofuel is understood. The poorest people are those that truly feel the effects of food security affected by the production of bio-fuels and changes in agriculture technology/practices. An adequate agricultural ethics for biofuels or food will require commitment by both private and public sector developers to ensure that potentially positive attributes of biofuel development are fully realized (Thompson, 2012).

RATIONALE, OPTIONS AND SIGNIFICANCE

In the 'Smithsonian' an article by Michael Pollan, argues that the later generations of the Mayan people having remarkably grown corn for almost 9000 years survived on this one grass as a main supply of food. The need of energy helped revolutionize the colonizing of the western world (Hepburn *et al*., 2014). After the settlements, the need to make more came as a problem, hence the search led to uses of spreading ammonium nitrate on farmland as fertilizers came to become one of the worlds greatest inventions, but also a strong player in the climate change problem.

German Jewish chemist named Fritz Haber – the inventor of the nitrogen fixing process. This chemist discovered synthesis of synthetic nitrogen that was very essential due to the populations increase. Haber's rise to fame due to working for the German government; the down side on the other hand of his intervention are causes related to fossil fuels hence global warming as a larger panoramic view. Pollan's point in his article is that he wants to get to a more natural agricultural system due to the prices of fossil fuels. Moving to a diversified and sustainable agriculture was his solution to reduce and eventually stopping dependency on synthetic nitrogen, giving up monocultures of corn (Godard, 2009).

The increasing demand for food has created a greater push for larger and faster production thus creating larger and more specialized way of producing food. Today, agricultural practices are responsible for 40% of the phosphorus and 60% of the nitrogen emissions (Richards, D., 2009). New technologies within modern livestock agriculture, have also driven the growth in farm size. The enabling technologies are mechanical, biological, and chemical (ERS.USDA, 2014). With all of these technologies combined farmers and ranchers are able to produce more food in a shorter amount of time for less money ultimately lowering the cost of food in supermarkets and generating enough food to feed the growing world population. Though the use of these facilitating technologies is rapidly deteriorating our ecosystem, which sustains our food source: Land. The shift to large-scale farming has led to improved productivity, production and much more livestock. Productivity improvements lead to lower wholesale and retail prices for meat and dairy products, while freeing land, labor, and capital resources for expanded commodity production (ERS.USDA, 2014). These enhancements and benefits do not come without a price; larger farms make it increasingly harder for smaller farmers to compete in the market, ultimately driving them out of business. Ethically this is an example of the major issues we have recognized ever since issues relating to agriculture land efficiency have surfaced. With fewer contributors to the

market price is no longer driven by competition but set by the major producers. Creating ever more challenges for the solution of small farm communities. Though patterns of fragmentation and concentration of land-ownership occur in different ecological situations, they share the same cause – an almost complete reliance on the real estate market to determine the highest and best use of the land (Burch, 1975). This is another aspect that is part of the main trunk holding up the global climate change case.

With the world population estimated to soon reach 9 billion people, a number of subjects concerning our resources arise, the biggest being how will we feed the masses and will we have the land needed to produce enough food? Many aspects are considered when facing agriculture issues, specifically ethically using land and water. Factory farming has become a major contributor to the mass production of the current food supply and land use. It has come to the point where it is doing more harm than good? Organic and sustainable agriculture has become increasingly popular over the last years mostly due to a rise in concern about how and where our food is being produced. This might just be the solution to the paradox of growing more than we need on limited land, Blatz (1991). More food production on less land with less human effort, but some of our methods deteriorate the resources to such an extent', in correction perhaps many or most of applied methods cause negative fallouts. Available space and resources needed to feed the world's population through organic agriculture.

In contrast to the agriculture solution, adopting agriculture practices that also involve how aspects of accomplishing the goals can be viewed in many ways; One of these points is the health and nutrition associated with conventional agriculture and hunter gatherer techniques. Diamond (1975) makes a non arguable point, we realize that truly the harder the work related to farming the better or healthier we are rather than making things just easier entirely. This harder work is seen today in developing countries, expressing the vulnerability of climate change but not taking the toll on the benefit but the complete opposite. If it wasn't for modern agriculture we would not have reached our technological capabilities and advancements today, in the sense that we could have approached and mechanized the subject in a better way that is good for the environment, us in general and especially the small farmer agriculture communities. An obligatory sense that with climate change and movement of population, we had no choice but to adopt this wrong manner of growing foods, the casual agent. I can say that anyone


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can see Diamonds (1975) concerns and views as we have become in sense lazier as time passed. Obesity is an example of this! The separation of social classes is a part of this branch we have created as farmers and their customers, drawn apart even more (Diamond, 1975). It is these aspects that diamond explores that give rise to how climate change came to be and its impacts back then and today.

DISCUSSIONS

With sustainable agriculture the food is produced and consumed locally, not shipped thousands of miles away; this lessons the impact of damage to the environment generated through transportation pollution. Also, with foods that are produced locally the product is fresher and involves a longer shelf life, therefore containing more nutrients (GCF, 2011). Sustainable small-scale farming not only creates a higher quality food but it helps support the local economy as well, this can be easily envisioned globally.

The farms provide jobs for members of the local community resulting in a boost in the economy (SARE, 2011). A study by the University of Minnesota Extension Service revealed that small farms with gross income of $100,000 made almost 95% of total expenditures within their local communities. Large farms with gross incomes greater than $900,000 spent less than 20% locally (GCF, 2011). This shows a clear positive impact of organic small community farming, laying the steps that small landholders should take to mitigate and adapt the climate change impact, which still places a thought of inspiration; scarcity of water is directly linked with usable land and how that land is used. Perhaps the solution to food and security is dependent on water availability and quality, while the replenishing of the natural water cycle through detoxifying rivers and ocean reservoirs (Olivier, 2009)

CONCLUSION

The roles played by the accumulation of the former suggestions that would impact the levels and limitations of greenhouse gasses will indeed play an important role in the sequestration of carbon (Anthoff *et al.*, 2009). Although time is of utmost importance in coordinance with this whole issue, the mere belief of success in a plan of that sort is possible in all ways, we can look at our bright history.

As consumers become more aware of where and how their food is produced, the demand for better quality food will continue to increase. The manner in which we obtain food will ultimately change as pressure is put on leaders of the world. Sustainable agriculture is able to provide the better and safer quality product teamed with commercial farming in order to produce enough food to feed the growing population. The use of land and water are the two factors that ought to be investigated further. Ultimately it will take a balanced effort from both sides in order to meet this demand. Feeding 9 billion people with increasingly less space will still drive the need for large-scale commercial farming. It is extremely important for the health standards to be monitored in order to make sure the consumers have access to healthy lands for the production of healthy foods (David et al., 2009).

It is in the mission statement of FAO, together with the other United Nations agencies based in Rome the Consultative Group on International Agricultural Research (CGIAR) – a "High-Level Conference on World Food Security and the Challenges of Climate Change and Bioenergy", which will be the focal point since its inauguration to deal with this climate change vs. adaptability debate. Rather than the United Nations being the single drive to the solutions we need, small community government funded groups will ultimately facilitate to exchange views with several small communities belonging to member nations on the impact of climate change on agriculture and food security in many regions. One aspect to be stressed in order to achieve a more round level of understanding is the need for further study on impact and challenges at regional levels. It is worth stressing that the importance of the date palm in the fight against hunger and poverty, when it comes to the fuel or food paradox. The value of its production and development extends beyond any one region. The date palm is an integral part of the sustenance and aerobiological diversity of the desert regions (Zaid, 2019) allowing to expand the boundaries set by modern environmentally destructive techniques.

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Emirates Environmental Group's Urban Afforestation Project

Accelerates Climate Action to Net Zero

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Abstract

Emirates Environmental Group (EEG) is a professional working group established in 1991 in the United Arab Emirates. It is devoted to protecting the environment through the means of education, action programmes and community involvement. EEG is actively encouraged and supported by concerned local and federal government agencies. It is the 1st environmental non-governmental organisation (NGO) in the world to be ISO 14001 certified and the only organisation of its kind in the UAE with accredited status to the United Nations Convention to Combat Desertification (UNCCD) and the UN Environment Programme (UNEP).

EEG is a member of the UN Global Compact, Global Urban Development (GUD), and the Global Investors for Sustainable Alliance (GISD). It is also a member of the One Planet Network under the Sustainable Food System (SFS) programme, its Multi-Stakeholder Advisory Committee (MAC), and the Global Partnership on Marine Litter (GPML).

EEG, as an NGO, has played a major part in driving sustainable actions within the UAE and the GCC countries. Through its action-oriented community projects, campaigns, lectures, and discussions,

EEG has established itself as a pioneer in the country. Today, the organisation continues to set examples and best practices that are followed by various entities and has also significantly contributed to reshaping sustainable practices in the country.

Introduction

Over the last one and a half centuries, human beings discovered the value of oil and began its use to power various machines. As its extraction and utilisation efficiency increased, the use of oil and gas further continued and increased and continues to date. The burning of oil to fuel is linked to the emission of various greenhouse gases (GHG), including carbon dioxide (CO_2).

The pivotal truth is that in 1856, Eunice Foote demonstrated the heat-trapping properties of the GHGs (1). She even speculated on the possibility of rising global temperatures as a result of the GHGs. While, as a female scientist, her discovery and theory went unnoticed and unrecognised by the then scientific community, Irish physicist John Tyndall, who is credited with having explained the effect of GHGs in Earth's atmosphere, published a series of studies on the same in 1859 (2). Despite their conclusive discovery, the world continued to release carbon into the atmosphere, which has led to the global crisis we know today.

Currently, a 2021 analysis conducted by the Mauna Lao Observatory in Hawaii shows the atmospheric CO_2 level exceeds 417 parts per million (ppm), compared to the 278 ppm present in pre-industrial levels from records taken from ice core measurements. This is a 50% increase compared to the 1800s (3).

In the 21st century, the continuous unregulated emission of carbon into the atmosphere from the use of fossil fuels has culminated in the climate crisis that is known today. To rectify the same, the world governments came together at the United Nations to adopt the Kyoto Protocol in 1992, which was ratified in 2005 (5). This protocol operationalises the United Nations Framework Convention on Climate Change (UNFCCC). Furthermore, in 2015, the world once again joined hands to sign the Paris Agreement to keep the average global temperature below 2 °C above the pre-industrial level, with the ideal goal of keeping it below 1.5 °C to reduce and control the effects of climate change.

Now, in 2023, the world has started to witness the impact of climate change. Heat waves, forest fires, strengthening tropical storms, flash floods, droughts, rapid glacier ice caps melting, coral bleaching, biodiversity loss, and much more are witnessed in all corners of the globe. To rectify this, numerous actions are being implemented worldwide by various entities, including the United Arab Emirates (UAE).

EEG's actions in the UAE

Since its inception in 1991, EEG has initiated the environmental sustainability movement in the country that mobilised the mass. Since its inception, EEG has had a massive impact on millions of people in the country and beyond.

EEG has 8 primary objectives:

- To increase the level of public awareness of all local, regional and global environmental issues.
- To assist the concerned authorities, where possible, in implementing environmental programmes and projects.
- To promote positive environmental action by individuals through active participation in specific projects, campaigns, and activities.
- To compile a database on various environmental issues and make it available to the public and institutions.
- To mobilise the support of experts on various environmental issues from the public and private sectors.
- To propagate community waste reduction and recycling schemes, both as a means of protecting the environment and as a flagship for improving the community's environmental awareness.
- To foster the exchange of information, experience, and practices, including our areas of expertise.
- To liaise with various target groups within the community to spread environmental messages and encourage volunteerism to preserve and protect the environment.

As the strongest environmental non-government entity in the UAE and one of the strongest in the region, these objectives are effectively implemented through 4 key focus areas.

1. Educational Programmes
2. Waste management & Recycling
3. Community Engagement & Outreach
4. Corporate awareness & engagement

EEG's Urban Afforestation Programme

One of the main aims of EEG is to mobilise the community and find unique ways of ensuring environmental protection and preservation. The Emirates Environmental Group supports the preservation of all-natural habitats and the restoration of destroyed and damaged habitats. By being involved in resource conservation, recycling, and tree planting, EEG strives to make a real difference on the ground by encouraging all to be actively involved and to contribute effectively.

All of EEG's programmes and projects are designed and implemented with a focus on the preservation of natural resources and local habitats. The aim is to work towards a future where the next generation will be able to be safe and healthy in an environment that is robust and beautiful. The recycling projects of the Emirates Environmental Group concentrate on Aluminium Cans, Plastic, E-waste (inclusive of electronic waste, mobile phones & Toner Cartridges), paper (including cardboard), glass and the latest edition; Tins to stop these materials from ending up in landfills and oceans.

However, recycling alone will not correct all the damage that has been done and continues to be done to the environment, so EEG combined its recycling projects with the tree planting programme to ensure that the approach to environmental challenges is done in a more holistic manner.

The Emirates Environmental Group supports and actively works towards the achievement of the 17 Sustainable Development Goals set by the United Nations in 2015 in all its programmes, for this particular programme, the focus is on Goal #11 (Sustainable Cities & Communities), #13 (climate action), #15 (Life on Land) and Goal #17 (Partnerships to Achieve Goals).

On 8th November 2006, with inspiration from the late Professor Wangari Mathai, the United Nations Environment Programme (UNEP) launched its "**Plant for the Planet – The Billion Tree Campaign**". Under this campaign, the UN encouraged entities all over the world, from both government and non-government organisations, to plant indigenous trees in their respective locales to cumulatively plant one billion trees worldwide by 2010.

In line with this, EEG, as an organisation accredited to UNCCD and UNEP, launched its "Million Tree Project" in 2007. With EEG's active engagement with the community, it received pledges from various entities in the UAE to support and plant trees under the "**Million Tree Project**". EEG oversaw and facilitated the pledging and planting of more than one million trees in the UAE and the neighbouring countries by the end of 2007.

The trees planted included Acacia Arabica, Acacia Tortilis, Azadirachta Indica, Parkinsonia Aculeata, Phoenix Dactylifera, Prosopis Cineraraia, Silvadora Presia, Tecomella Undulate, Ziziphus Spina Christi, Acacia Ehrenbergia, Acacia Farnesiana, Caelotropis, Cassia Acutiolia, Leptadenia Pyrothecia, and Pitchecelobium Inga Dolce. This marked the culmination of the official affiliation with UNEP for the tree planting project, which went above and beyond in fulfilling its responsibility for this global campaign.

With the success of this project, EEG decided to roll it out as an on-going annual programme under the title of "For Our Emirates We Plant". Over the years, more organisations, corporations, academic institutions, and families joined hands in preserving and protecting the natural habitat of the UAE through this unique urban afforestation endeavour. By 2010, EEG had managed to exceed the target and had planted **more than 2 million** indigenous and well-adapted trees within the UAE.

In another effective step to increase participation and the visibility of this programme and to meet its objectives, EEG took the bold step of connecting its waste management and recycling programme with the tree planting, Special targets were put in place for each category (families, corporations and academia) for the collection of the different recyclable materials, and those achieving the set targets were given the opportunity to plant saplings of native trees in different public places in the UAE on a historic day.

The 1st annual tree planting event was held on the date of **09.09.09**. Thereafter, the event is held every December on the date corresponding to the last digits of the year. As an example, in 2012, the planting activity was held on **12.12.12**...etc.


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In the year 2022, campaign was carried out at a beautiful Bee Reserve in Al Minaie – (Skheibar area), South of Ras Al Khaimah, under the patronage and presence of H.H. Engr. Sheikh Salem Bin Sultan Bin Saqr Al-Qasimi, member of the Executive Council of the Government of RAK and Chairman of the Department of Civil Aviation in Ras Al Khaimah.

Projects Feeding into "For Our Emirates We Plant" Programme

To feed into this urban afforestation programme, 2 main projects were rolled out.

1. ***Recycling Projects:***

- The "Neighbourhood Recycling Project"

The "Neighbourhood Recycling Project" began in 2010 to give EEG student members an opportunity to involve their neighbours in starting their own recycling initiatives under the guidance of EEG. After the successful completion of one decade of this project, EEG in 2020, opened this project for non-student members as well. Through this project, students are required to collect one or all of the following recyclable materials: paper, plastic, mobile phones, aluminium cans, and toner cartridges, involving 20 neighbouring families.

The activity spans over a two-week period during the months of June to September. The students who reach the target of collecting the specific recyclable item are gifted a sapling of an indigenous tree to plant in their name in the month of December.

- One Root, One Communi-Tree

One Root, One Communi-Tree is a project that was 1st rolled out in 2010. In 2020, EEG expanded the project and rolled it out in two phases, with the first phase taking place in the first half of the year (January to May) and the second phase taking place in the second half of the year (July to November). This project is open to all sectors of society, including academic institutions, families, government entities and the private sector. The participants are required to submit a certain quantity of a recyclable material/s within the span of 2 weeks to achieve the target and secure the sapling.

- Paper Walk

Paper Walk is a project that links EEG's recycling programmes with the Earth Hour Challenge and afforestation campaign. Earth Hour is an event that is held globally, encouraging individuals, communities, and businesses to turn off non-essential electric lights for one hour, from 8:30 to 9:30 p.m. on a specific day towards the end of March, as a symbol of commitment to the planet. On the day of the event, participants are required to submit a small quantity of waste-paper and, in turn, be eligible to plant trees in December.

- Green Call

EEG launched a month-long project called "Green Call" in April 2016 with the original intention of engaging EEG student members during their spring break and, at the same time, boosting mobile phone collection to reach the set target for 2016. In 2017, and with the positive response received from the student community, EEG decided to open the programme up to all sectors of society, with a higher target put in place. In 2018, this programme was officially linked with the "For Our Emirates We Plant" Programme, rewarding participants to plant saplings of native trees in return for their achievements.

- Recycle. Reforest. Repeat

This project was initiated as a one-month campaign to collect paper waste in 2016 on the 17th of June (the world day to combat desertification) in an attempt to strengthen EEG's partnership with the UNCCD and to serve as an advocate for the messages and targets that the UNCCD stands for and promotes. The day serves as a unique reminder for everyone that land degradation neutrality is achievable through problem-solving, strong community involvement, and cooperation at all levels. The entities that reach the target recyclable waste threshold become eligible to plant saplings of indigenous trees in the following December.

- Adopt a Tree

EEG introduced this new project in 2018 for companies, the academia and individuals that were not able to participate in the Waste Management programmes but were nevertheless keen to plant trees. The entities are given the opportunity to adopt a tree and plant in a public area of the UAE.

Tree Planting in Numbers

Since the inception of the urban afforestation programme in 2007, EEG has planted native trees in all the Seven Emirates. The locations of tree planting are decided by various municipalities and government agencies in the UAE. Emirates Environmental Group liaises with the government bodies in each Emirate to ensure that the trees planted by EEG are well maintained and taken care of.

The UAE's geography makes it difficult for various trees to grow without proper care. The climate of the county is semi-arid, with hot summers. The majority of the land comprises vast sandy deserts, dunes, a few oases, rocky mountains in the northern emirates, accompanying valleys, mashes, salt plains, and a heathy mangrove ecosystem in the coastal areas. Thus, when planting trees in these ecosystems, various steps have to be taken into consideration.

These include:

1. Fresh water for irrigation with an accompanying drip system
2. Sweet soil for providing nutrients to the trees
3. Natural fertilisers
4. Well-placed and deep planting hole.
5. Garden mesh in certain areas to protect young saplings

Upon receiving the above measures from the relevant municipalities, EEG starts the process of planting the saplings. These additional steps have allowed over 99% of EEG's trees to mature and grow. In the rare case where we find that an afforestation site has been somehow neglected, we ensure that all the indigenous trees that wilted are replanted after getting assurance that the trees would be properly maintained.

The Afforestation Reach

Since the inception of the campaign in 2007, EEG has planted 2,115,712 trees in the UAE. An area of 3 m^2 is left as a gap between each tree that is planted. The gap ensures that the tree has sufficient area to grow and will not hinder the growth of the neighbouring trees. Thus, taking into consideration the 2,155,712 trees planted and the area of 3 m^2 per tree covered as a green space, the following conclusion can be reached:

Conversion → $3\ m^2 = 0.000003\ km^2$

Area Covered → $0.000003\ km^2 * 2{,}115{,}712$

→ $6.347136\ km^2$

→ $6.3\ km^2$

Thus, assuming the precision of 3 square metres between each tree, EEG has afforested a total of 6.3 square kilometres of land area.

EEG's Urban Afforestation Benefits

By planting 2,115,712 trees over an area of 6.3 km^2, EEG has effectively contributed to various environmental goals, including governmental targets and national goals.

2. Carbon Emission

EEG has planted various indigenous trees in the country which are drought-tolerant including Ghaf, Sidra, Samar and Acacia. These are distributed and planted in the reserves and conservation parks and according to their natural habitat.

Averaging the sequestration capacity of the trees planted, upon reaching maturity, EEG has calculated the emission sequestration. By planting 2,115,712 trees, EEG has effectively contributed to sequestering **12,475 MT of CO_2e** from the atmosphere.

1. Natural Barrier

As the UAE is a vast desert environment, the soil in the majority of the country is not fertile or stable. Thus, planting indigenous trees helps to stabilise the soil and also acts as a natural barrier against dust and sandstorms, which can become a major cause of concern in urban environments and on highways. EEG is a member of the United Nations Convention to Combat Desertification (UNCCD). Therefore, these green spaces are a key part of tackling climate change and combating desertification, which is a prominent issue in the region.

2. Increase in Biodiversity

Since 2015, EEG has been planting indigenous trees in the Al Minaie Region of Ras Al Khaimah, which is a mountainous region with valleys and fresh water supplies. This is a strategically located place where this urban afforestation programme has had a positive impact on the whole area. One of the critical reasons is to increase the biodiversity in the area, with particular focus on the bee population. EEG has worked strategically to provide the right habitat for the local bees to thrive thus turning the place eventually into a Bee Reserve. This has contributed to the national strategy of increasing the bee population in the country and improve food security.

Since 2018, the number of hives on the farm has increased from 200 in 2018 to 2,268 in 2023, a 1,034% increase in the number of hives. A healthy hive can have up to 50,000 worker bees. Which means that if all the hives are healthy, 103 million bees will be active in the peak season. On the other hand, the number of trees planted by EEG on the farm increased from 1,000 in 2018 to 12,966 in 2022, an 1,196.6% increase.

The trees have not only increased the bee population but also acted as a micro-habitat for various other insects, arachnids, reptiles and birds. In some areas of the tree planting, certain species of gazelles have also been observed. The trees provide shade and help cool the area and they also provide nutritious food when the trees are mature enough to flower and bear fruits in three to five years.

3. National Afforestation Goals

The UAE is one of the leading countries in the region and beyond, with strong environmental laws and regulations. To reach the target goals of 2030. The UAE government has rolled out numerous goals and agendas. One of the goals is the Dubai 2040 Urban Plan. H.H. Sheikh Mohammed bin Rashid Al Maktoum, Prime Minister, Vice President and Ruler of Dubai, has announced that 60% of the Emirate of Dubai will be dedicated and covered with green spaces as nature reserves.

Considering that Dubai has an estimated area of 4,114 km^2, EEG has already assisted the emirate in reaching the 2040 urban plan and will continue to do so in the future.

4. Green Recreational Areas

Urban afforestation efforts have been an important part of EEG's planting drive, in addition to afforestation in conservation areas and natural reserves. Some of these areas have been transformed and are now open to the public to use and enjoy. As an example, EEG has planted thousands of native trees in Al Qudra Area. This locality, along with the Al Qudra lakes, is one of the most popular picnic locations for tourists, residents, and various clubs. Transforming otherwise barren land into a productive one with a beautiful and thriving natural habitat for the local species to thrive and also attract some of the migratory birds to settle is a pivotal part of its urban afforestation drives, boosting social and economic prosperity in the country.

Conclusion

In conclusion, as with afforestation programmes all across the globe, EEG's efforts in the country have made a significant improvement in tackling environmental issues. EEG's unique approach to involving all sectors of the society and members of the community, linking its waste management and recycling projects to afforestation, and involving the relevant authorities to maintain the trees has been a pivotal part of its success.

Planting 2,115,712 trees since 2007 over an area of 6.3 km^2 has helped sequester 12,475 MT of CO_2e from the atmosphere. These trees act as natural carbon sinks, improve the micro-climate, increase biodiversity, cool down the area and help combat desertification. The afforestation programme has overall been beneficial to the environment, to the society and the economy of the UAE. The afforestation programme also helps accelerate and assist the UAE government in achieving its sustainability and climate goals.

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Enhancing Climate Change Adaptation in the Arab Region's Food and Agricultural Sectors:

Exploring the Role of Systems of Innovation

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Abstract:

Climate change poses significant challenges to agricultural systems worldwide, necessitating the development and implementation of innovative strategies for adaptation. This paper examines the crucial role of innovation in fostering agricultural adaptation to climate change. It explores the various dimensions of innovation, including technological advancements, institutional reforms, and knowledge management, and their impact on enhancing the resilience and sustainability of agricultural systems. By reviewing relevant literature and case studies, this paper highlights the potential of innovation to address climate change impacts on agriculture, promote food security, and improve livelihoods. Furthermore, it identifies key barriers and opportunities for innovation adoption in the agricultural sector and provides recommendations for policymakers, researchers, and practitioners to foster innovation and support agricultural adaptation efforts in the Arab Region.

Introduction:

The future of agriculture in the Arab Region is being forged by a multitude of forces, with climate change emerging as a pivotal factor. The dynamic nature of the climate necessitates a proactive response from the agricultural sector, demanding the adaptation of practices to accommodate the ever-changing climatic conditions (Wehrey, F., *et al*. 2003). However, climate change represents merely one among several major forces that will shape the trajectory of agriculture. Population growth, rising incomes, and transformations in human capital, knowledge, and infrastructure exert equally significant influence. Consequently, the agricultural sector must navigate a complex landscape of interconnected factors to ensure the sustainability and resilience of food production. Climate change poses substantial challenges to agriculture, including shifts in temperature and precipitation patterns, an increased occurrence of extreme weather events, altered dynamics of pests and diseases, and water scarcity (IPCC, 2022). These impacts can have far-reaching consequences for crop yields, livestock productivity, and overall agricultural systems. To mitigate these effects, farmers must embrace adaptation strategies that enhance the resilience of agricultural systems. These strategies may encompass practices such as crop diversification, improved water management, conservation agriculture, agroforestry, and the adoption of climate-resilient crop varieties. (FAO, 2022). In addition to climate change adaptation, the reduction of greenhouse gas (GHG) emissions must be prioritized within the agricultural sector. Agriculture is a significant contributor to GHG emissions, primarily through methane release from livestock and rice cultivation, as well as nitrous oxide emissions from fertilizer use. Implementing mitigation measures, such as improved nutrient management, agroecology, sustainable intensification, and the integration of renewable energy in agricultural operations, can contribute to climate change mitigation and foster a more sustainable food system (IPCC, 2021). Population growth and increasing income levels exert profound influences on agricultural dynamics. As populations expand and incomes rise, the demand for food, including diversified diets and higher-value agricultural products, escalates. Consequently, agricultural production systems, market dynamics, and value chains undergo transformation to meet evolving demands. Accompanying these changes is the need to invest in human capital, knowledge, and infrastructure within the agricultural sector. Education, training, and capacity-building for farmers are essential to enable the adoption of innovative practices. Access to information, research, and extension services is crucial for disseminating knowledge and best practices. Additionally, investments in agricultural infrastructure, such as irrigation systems, storage facilities, and transportation networks, can enhance productivity and improve market access for farmers (IFPRI, 2021).

The future of agriculture hinges on technological and institutional innovations. Technological advancements, such as precision farming technologies, remote sensing, automation, and digital agriculture tools, empower farmers with data-driven decision-making capabilities. Institutional innovations encompass policies, regulations, and governance mechanisms that support sustainable agricultural practices, stimulate research and development, and facilitate market access for farmers (FAO, 2020). Navigating the complex landscape of climate change, population dynamics, income changes, human capital, knowledge, infrastructure, and innovations is paramount for the agricultural sector to thrive in the future. This article aims to explore the multifaceted interactions between these forces and examine their implications for the evolution of agriculture in the Arab Region. By elucidating the challenges and opportunities presented, this study seeks to contribute to the development of strategies and policies that can foster a sustainable and resilient agricultural system.

2. Dimensions of Innovation in Agricultural Adaptation

2.1 Technological Innovations

Technological innovations play a crucial role in enhancing food and agricultural adaptation in the Arab region. In the face of climate change and the need for sustainable agricultural practices, advancements in technology offer opportunities to improve productivity, resource efficiency, and resilience. This section explores several dimensions of technological innovations that are driving transformative changes in the region's food and agricultural systems.

Precision agriculture (PA) harnesses advanced technologies such as remote sensing, Geographic Information Systems (GIS), and Global Positioning Systems (GPS) to enable farmers to monitor and manage their fields with precision. This facilitates precise irrigation, targeted application of inputs such as fertilizers and pesticides, and real-time data collection for informed decision-making. By optimizing agricultural practices, PA enhances resource efficiency, reduces environmental impacts, and improves crop yields (Al-Saidi & Elagib, 2017).

Climate-smart technologies are being developed and adopted to address specific challenges in the Arab region, such as water scarcity and soil salinity. Drip irrigation systems, hydroponics, and aeroponics are examples of technologies that optimize water use and improve crop production in water-limited regions. Protected cultivation systems, including greenhouses and shade nets, provide controlled environments that protect crops from extreme weather events and pests, ensuring more reliable yields and enhancing the resilience of agricultural systems (ICARDA, 2019; FAO, 2018).

Biotechnology and genetic engineering also contribute to technological innovations in the Arab region. Efforts are focused on developing genetically modified (GM) crops that are adapted to local conditions, such as drought-tolerant or salt-tolerant varieties. These GM crops can help farmers overcome challenges related to water scarcity and soil salinity, improving their ability to produce food in arid and challenging environments (World Bank, 2021).

Technological innovations also extend to the agri-food supply chain. Blockchain technology is being used to enhance traceability and transparency, ensuring food safety and quality. Sensor-based monitoring systems enable real-time quality control, reducing post-harvest losses. Additionally, e-commerce platforms facilitate direct farm-to-consumer sales, improving market access for farmers and promoting local food systems (FAO, 2018).

These technological innovations offer significant potential to enhance food and agricultural adaptation in the Arab region. However, their successful adoption and implementation require supportive policies, adequate infrastructure, access to finance, and capacity-building initiatives. Collaboration between governments, research institutions, private sector entities, and farmers is crucial to foster an enabling environment for technological innovations. By embracing technological advancements, the Arab region can enhance its food and agricultural systems, ensuring sustainable and resilient food production in the face of evolving challenges.

2.2 Institutional Innovations

In addition to technological innovations, institutional innovations play a crucial role in promoting food and agricultural adaptation in the Arab region. Institutional innovations refer to changes in the policies, regulations, governance structures, and social systems that support and facilitate the adoption of new practices and technologies. This section explores several dimensions of institutional innovations that are driving transformative changes in the region's food and agricultural systems.

One dimension of institutional innovation is the development of policy and regulatory frameworks. Governments in the Arab region can establish supportive policies that incentivize the adoption of climate-smart agricultural practices. These policies may include subsidies for water-efficient irrigation systems, support for the implementation of sustainable farming methods, and regulations that encourage the use of environmentally friendly inputs. By creating an enabling policy environment, institutional innovations can drive the widespread adoption of sustainable practices (ACSAD, 2021).

Policy and regulatory frameworks represent one dimension of institutional innovation. Governments in the Arab region can establish supportive policies that incentivize the adoption of climate-smart agricultural practices. For example, governments can provide subsidies for water-efficient irrigation systems, support for the implementation of sustainable farming methods, and regulations that encourage the use of environmentally friendly inputs. By creating an enabling policy environment, institutional innovations can drive the widespread adoption of sustainable practices (FAO, 2022).

Capacity building and knowledge exchange represent another dimension of institutional innovation. By enhancing the capacity of farmers, extension services, and other stakeholders in the agricultural sector, institutional innovations enable the adoption of climate-resilient farming practices. Capacity building programs can provide training and information on efficient water management, soil conservation techniques, sustainable pest and disease management, and climate-smart farming methods. Knowledge exchange platforms, such as farmer field schools, networks, and demonstration farms, facilitate the sharing of experiences and best practices among farmers, researchers, and policymakers (ICARDA, 2021).

Financial mechanisms and investment support are also important dimensions of institutional innovation. Governments and financial institutions can establish funds or programs that provide farmers with access to affordable credit, insurance schemes, and grants for implementing climate-smart technologies and practices. These financial mechanisms reduce the risks associated with adopting new innovations and encourage farmers to invest in sustainable agricultural practices (World Bank, 2020).

Stakeholder engagement and collaboration are key elements of institutional innovation. By fostering collaboration among farmers, researchers, policymakers, private sector entities, and civil society organizations, institutional innovations ensure that agricultural policies and practices are context-specific, inclusive, and aligned with the needs and priorities of local communities. Multi-stakeholder platforms facilitate dialogue, knowledge sharing, and joint decision-making, leading to more effective and sustainable agricultural adaptation strategies (FAO, 2022).

Institutional innovation can also address challenges related to market access and value chain development. By establishing market linkages, developing quality standards and certifications, and promoting fair trade practices, institutional innovations enable farmers to access markets for their climate-resilient agricultural products. This incentivizes farmers to adopt sustainable practices and produce high-quality agricultural products (ICARDA, 2021).

Effective governance and policy coordination are critical dimensions of institutional innovation. Establishing inter-ministerial committees or dedicated agencies responsible for coordinating climate change adaptation efforts in the agricultural sector ensures coherent and integrated approaches. By strengthening governance structures and policy coordination mechanisms, institutional innovations promote effective and coordinated actions across different sectors and levels of government (World Bank, 2020).

2.3 Knowledge Management Innovations

Knowledge management innovations play a critical role in enhancing food and agricultural adaptation in the Arab region. In the face of evolving challenges and the need for sustainable agricultural practices, effective knowledge management is essential for disseminating information, sharing best practices, and facilitating learning among stakeholders. This section explores several dimensions of knowledge management innovations that are driving transformative changes in the region's food and agricultural systems (Al-Sharafi & Abdel-Dayem, 2021).

One dimension of knowledge management innovation is the development and use of digital platforms and information systems. These platforms facilitate the collection, organization, and dissemination of agricultural knowledge and information. Online databases, web portals, and mobile applications provide farmers, researchers, and extension services with access to up-to-date information on climate-resilient farming practices, pest and disease management, market trends, and other relevant topics. By making knowledge easily accessible, digital platforms empower stakeholders to make informed decisions and adopt sustainable agricultural practices (Anupindi & Sivakumar, 2019), (Nikolova, 2020).

Another dimension is the establishment of knowledge-sharing networks and communities of practice. These networks bring together farmers, researchers, policymakers, and other stakeholders to exchange experiences, share best practices, and collectively address challenges. Knowledge-sharing networks can operate at various scales, from local communities to regional or national levels. Through regular meetings, workshops, and virtual platforms, these networks foster collaboration, promote learning, and facilitate the co-creation of knowledge that is tailored to the specific needs and contexts of the Arab region (Kiss & Heijman, 2014).

Institutionalizing knowledge management practices within agricultural organizations and extension services is another important dimension of innovation. This involves developing mechanisms for capturing, documenting, and sharing tacit knowledge and experiences among staff members. By creating knowledge repositories, implementing mentoring programs, and promoting knowledge-sharing practices, agricultural organizations can ensure the continuity and transfer of valuable knowledge. This institutionalization of knowledge management practices enables the effective utilization of existing expertise and the integration of new knowledge into agricultural practices (Kumar & Sundaram, 2018).

Collaborative research and development (R&D) initiatives represent another dimension of knowledge management innovation. By promoting partnerships between research institutions, universities, and agricultural stakeholders, collaborative R&D initiatives foster the generation of scientific knowledge and its translation into practical solutions. These initiatives encourage interdisciplinary cooperation, combining expertise in agriculture, climate science, engineering, and social sciences. By involving stakeholders in the research process, these initiatives ensure that knowledge generated is relevant, applicable, and localized to the needs of the Arab region (Al-Sharafi & Abdel-Dayem, 2021).

Enhancing farmer-to-farmer knowledge sharing is yet another dimension of knowledge management innovation. Farmers possess valuable experiential knowledge gained through years of working in specific agro-ecological contexts. Farmer-to-farmer knowledge sharing platforms, field schools, and demonstration farms provide opportunities for farmers to learn from each other, exchange traditional practices, and adapt innovative techniques. This bottom-up approach to knowledge sharing recognizes the importance of local knowledge systems and promotes the integration of indigenous and traditional knowledge into modern agricultural practices (Kiss & Heijman, 2014).

Effective knowledge management also requires investing in capacity building programs. These programs aim to enhance the skills and capabilities of farmers, extension workers, and agricultural researchers in knowledge creation, dissemination, and utilization. Training programs can focus on information and communication technologies, data analysis, research methodologies, and participatory approaches to knowledge sharing. By building human capacity, knowledge management innovations strengthen the foundation for sustainable agricultural development in the Arab region.

3. The Impact of Innovation on Agricultural Adaptation

3.1 Resilience Enhancement

Innovation plays a crucial role in enhancing the resilience of food and agricultural systems in the Arab region. By fostering the development and adoption of innovative practices, technologies, and approaches, agricultural systems can better withstand and recover from shocks and stresses. This section explores the impact of innovation on food and agricultural adaptation in the Arab region, with a specific focus on resilience enhancement.

One key area where innovation drives resilience enhancement is in climate-resilient farming practices. Climate-smart agricultural techniques such as conservation agriculture, agroforestry, and precision farming enable farmers to adapt to changing climate conditions. These practices enhance soil health, conserve water resources, reduce greenhouse gas emissions, and improve crop productivity (Smith *et al*., 2022). By adopting these innovative practices, farmers can mitigate the impacts of climate change and build resilient agricultural systems.

Water management innovations also play a significant role in enhancing resilience. Water scarcity is a major challenge in the Arab region, making innovative water management practices critical for agricultural adaptation. Technologies such as drip irrigation, precision irrigation systems, and wastewater reuse systems help optimize water use, minimize water losses, and increase the efficiency of irrigation (Jones *et al*., 2021). These innovations improve water availability for agricultural production while reducing the strain on limited water resources. Through adopting water management innovations, farmers can enhance the resilience of their farming systems to droughts and water scarcity.

Crop diversification and genetic innovations contribute to resilience enhancement in the Arab region. Diversifying cropping systems by introducing climate-resilient and drought-tolerant crop varieties reduces the vulnerability of agricultural production to climate variability. Genetic innovations, such as the development of stress-tolerant and disease-resistant crop varieties through biotechnology and breeding programs, enhance the resilience of crops to pests, diseases, and adverse environmental conditions (Brown *et al*., 2023). These innovations provide farmers with more options and flexibility in adapting to changing circumstances.

The use of digital technologies and data analytics has transformative effects on agricultural adaptation and resilience in the Arab region. Remote sensing, satellite imagery, and geographic information systems (GIS) enable real-time monitoring and early warning systems for weather, pests, and diseases. In combination with data analytics, these technologies provide valuable insights for decision-making, resource allocation, and risk management in agricultural systems (Wang *et al*., 2023). As a consequence of harnessing the power of digital technologies, farmers and policymakers can make informed decisions and respond effectively to challenges, improving the resilience of the agricultural sector.

Financial innovations also play a crucial role in enhancing resilience. Innovative insurance schemes, such as index-based insurance, help farmers manage risks associated with climate variability and extreme weather events (Kurukulasuriya *et al*., 2022). Access to affordable credit and microfinance programs enables farmers to invest in climate-resilient technologies and practices. Via providing financial safety nets and risk-sharing mechanisms, these innovations enhance the capacity of farmers to recover from shocks and maintain agricultural productivity.

Knowledge and capacity building are essential for resilience enhancement. Capacity building programs provide farmers, extension workers, and policymakers with the knowledge and skills needed to adopt innovative practices, technologies, and approaches. Farmer field schools, training programs, and knowledge-sharing networks create opportunities for experiential learning, peer-to-peer exchange, and the dissemination of best practices (Gupta *et al*., 2023). as a result of building human capital and promoting knowledge transfer, these innovations enhance the adaptive capacity of individuals and communities, fostering resilience in the face of challenges.

3.2 Sustainability Promotion

Innovation plays a significant role in promoting sustainability in food and agricultural systems in the Arab region. By embracing innovative approaches, the region can address various environmental, social, and economic challenges while striving for long-term sustainability. Here are some key points highlighting the role of innovation in promoting sustainability in food and agricultural systems in the Arab region:

Resource Efficiency:

Innovations in agricultural practices, technologies, and systems can enhance resource efficiency, such as water and energy use, in food production. For example, precision irrigation techniques, advanced water management systems, and renewable energy solutions can reduce resource wastage and minimize the environmental impact of agriculture (Abid *et al*., 2019).

Climate Change Adaptation:

Innovation can help farmers and agricultural systems adapt to the challenges posed by climate change. This includes the development and adoption of climate-resilient crop varieties, precision farming technologies, and climate-smart practices that optimize resource use, enhance productivity, and mitigate climate-related risks (Kaur *et al*., 2021).

Sustainable Intensification:

Innovation can support sustainable intensification, which aims to increase agricultural productivity while minimizing negative environmental impacts. This can be achieved through the adoption of sustainable farming practices, integrated pest management systems, and improved soil management techniques that optimize nutrient use and reduce reliance on chemical inputs (Smith *et al*., 2020).

Agroecology and Organic Farming:

Innovation in agroecological and organic farming practices can promote sustainable agriculture in the Arab region. These practices focus on enhancing biodiversity, reducing soil degradation, and minimizing the use of synthetic inputs, thereby ensuring the long-term health and productivity of agricultural systems (Foley *et al*., 2011).

Digital Technologies and Data Analytics:

The use of digital technologies, such as remote sensing, Internet of Things (IoT) devices, and data analytics, enables farmers to make data-driven decisions, optimize resource allocation, and improve productivity. These technologies also facilitate better monitoring and management of agricultural systems, leading to more sustainable and efficient farming practices (Rasheed *et al*., 2022).

Circular Economy and Waste Reduction:

Innovation can contribute to the development of circular economy models in the Arab region's food and agricultural sectors. This involves minimizing waste, promoting recycling and reuse, and creating value from by-products and agricultural residues. By adopting innovative waste reduction and management strategies, the region can achieve more sustainable and resource-efficient food systems.

Market Linkages and Value Addition:

Innovation can help establish better market linkages, promote value addition, and support the development of sustainable agri-food value chains in the Arab region. This includes the adoption of e-commerce platforms, traceability systems, and innovative processing and packaging techniques that enhance product quality, reduce post-harvest losses, and increase market access for farmers.

4. Barriers and Opportunities for Innovation Adoption

4.1 Barriers to Innovation Adoption

The adoption of innovation in food and agricultural adaptation in the Arab region faces numerous barriers:

Limited Access to Finance:

Limited access to finance is a pervasive barrier in the Arab region's food and agricultural sector. Many farmers and agricultural enterprises struggle to secure affordable credit and investment capital necessary for implementing innovative practices. This barrier is particularly challenging for small-scale farmers and rural communities who lack collateral or formal financial documentation. The lack of financial resources hampers their ability to invest in new technologies, equipment, and infrastructure required for adopting innovative solutions. Addressing this barrier requires the development of innovative financing mechanisms, such as microfinance programs and public-private partnerships, to ensure that adequate financial resources are available to support innovation adoption in the sector (OECD, 2021).

Lack of Technical Knowledge and Information:

The limited technical knowledge and information available to farmers and agricultural stakeholders hinder innovation adoption. Insufficient awareness about innovative practices, emerging technologies, and their potential benefits creates a significant gap in knowledge. Farmers often lack access to training programs, extension services, and relevant research findings that can guide them in adopting new approaches. Bridging this knowledge gap requires strengthening agricultural extension services, promoting knowledge-sharing platforms, and providing capacity-building programs to enhance farmers' understanding of innovative solutions. Collaboration between research institutions, universities, and farmers' associations can also play a vital role in disseminating knowledge and best practices (FAO, 2020).

Inadequate Infrastructure:

Inadequate infrastructure poses a considerable barrier to innovation adoption in the food and agricultural sector. Insufficient transportation networks, storage facilities, and processing centers limit farmers' ability to adopt innovative practices and technologies. The lack of proper infrastructure affects the efficient distribution of agricultural products, leading to post-harvest losses and reduced profitability. Addressing this barrier requires strategic investments in rural infrastructure, including the development of modern storage facilities, irrigation systems, and transportation networks. Public-private partnerships can play a crucial role in mobilizing resources and expertise to improve infrastructure in rural areas (World Bank, 2021).

Limited Research and Development (R&D) Support:

Limited research and development (R&D) support is a significant challenge in the Arab region's food and agricultural sector. Insufficient financial investment in agricultural research, inadequate collaboration between research institutions and farmers, and a shortage of skilled researchers and scientists contribute to this barrier. Strengthening R&D support requires increased funding allocation to agricultural research, fostering collaboration between researchers and farmers, and promoting knowledge transfer and technology dissemination. Enhancing the capacity of research institutions and supporting interdisciplinary research can also drive innovation in the sector (AOAD, 2020).

Policy and Regulatory Constraints:

Policy and regulatory constraints act as barriers to innovation adoption in the food and agricultural sector. Complex bureaucratic procedures, unclear regulations, and a lack of supportive policies discourage farmers and agribusinesses from adopting innovative practices. Ambiguous intellectual property rights frameworks, trade barriers, and cumbersome approval processes for new technologies impede the diffusion of innovative solutions. Addressing this barrier necessitates the development of clear and streamlined regulatory frameworks that facilitate innovation adoption. Governments should create supportive policy environments, including incentives, subsidies, and simplified approval processes, to encourage the adoption of innovative technologies and practices (ESCWA, 2020).


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Socio-cultural Factors:

Socio-cultural factors significantly influence the adoption of innovation in the agricultural sector. Traditional farming practices, entrenched beliefs, and resistance to change can create barriers to the adoption of new technologies and practices. Farmers may be hesitant to deviate from conventional methods that have been passed down through generations, even if innovative solutions offer potential benefits. Addressing this barrier requires targeted awareness campaigns, capacity-building programs, and farmer-to-farmer knowledge sharing. Engaging local communities, involving women and youth in decision-making processes, and promoting the cultural value of sustainable agricultural practices can help overcome socio-cultural barriers (IFAD, 2021).

Lack of Collaboration and Knowledge Exchange:

Limited collaboration and knowledge exchange among stakeholders in the agricultural sector hinder the adoption of innovation. Insufficient networking opportunities, weak farmer associations, and inadequate platforms for sharing experiences and best practices impede the diffusion of innovative ideas. Overcoming this barrier requires the establishment of collaborative platforms, such as innovation hubs, farmer field schools, and agricultural cooperatives, to facilitate knowledge exchange and learning. Strengthening partnerships between research institutions, private sector entities, and farmer organizations can promote collaboration and foster a culture of innovation (FAO, 2021).

Climate and Environmental Challenges:

The Arab region faces unique climate and environmental challenges that act as barriers to innovation adoption in agriculture. Water scarcity, drought, desertification, and soil degradation are prevalent in many areas. These challenges make it difficult to adopt certain innovative practices that may require abundant water resources, fertile soils, or specific climatic conditions. Addressing this barrier requires the development and adaptation of innovative technologies and practices tailored to the region's specific environmental conditions. Investing in climate-resilient agriculture, promoting sustainable water management, and implementing soil conservation measures are essential for overcoming climate and environmental challenges (ACSAD, 2021).

4.2 Opportunities for Innovation Adoption

Numerous opportunities exist to foster innovation adoption in the agricultural sector such as:

Sustainable Agriculture Practices:

The Arab region presents significant opportunities for adopting sustainable agriculture practices. By integrating innovative technologies and practices, such as precision farming, agroecology, and organic farming, farmers can improve resource efficiency, reduce environmental impacts, and enhance productivity. Sustainable agricultural practices offer opportunities to conserve water resources, mitigate soil degradation, improve biodiversity, and reduce the use of chemical inputs. These practices can contribute to long-term food security, resilience to climate change, and the preservation of natural resources (Smith *et al*., 2020).

Precision Agriculture and Smart Farming:

Precision agriculture and smart farming technologies offer tremendous opportunities for innovation adoption in the Arab region. These technologies utilize sensors, satellite imagery, and data analytics to optimize input usage, monitor crop health, and improve decision-making processes. By employing precision agriculture techniques, such as variable rate application of fertilizers and pesticides, farmers can enhance resource efficiency, minimize costs, and reduce environmental impacts (López-Lavado *et al*., 2021). Furthermore, smart farming solutions, including remote monitoring systems and automated irrigation, enable real-time data collection, analysis, and control, leading to improved productivity and sustainability (Liakos *et al*., 2018).

Vertical Farming and Controlled Environment Agriculture:

Given the region's limited arable land and water scarcity, vertical farming and controlled environment agriculture (CEA) present promising opportunities for innovation adoption. Vertical farming involves cultivating crops in vertically stacked layers or structures, utilizing artificial lighting and controlled environments (Fallovo *et al*., 2020). These approaches maximize land use efficiency, reduces water consumption, and enables year-round production. CEA technologies, including hydroponics and aeroponics, provide additional advantages by eliminating soil dependence and optimizing nutrient delivery. Vertical farming and CEA can contribute to food self-sufficiency, reduce import dependency, and provide opportunities for urban agriculture (Graamans *et al*., 2021).

Agri-Tech and Digital Solutions:

The rapid advancement of Agri-tech and digital solutions offers transformative opportunities for innovation adoption in the Arab region's food and agricultural sector. Mobile applications, Internet of Things (IoT) devices, and data analytics platforms can enhance farmers' access to information, market prices, and weather forecasts. These technologies facilitate efficient supply chain management, traceability, and market linkages, empowering farmers and improving market transparency (Rasheed *et al*., 2022). Additionally, blockchain technology can enhance trust and transparency by enabling secure and immutable record-keeping, which is crucial for food safety and traceability (Kamilaris *et al*., 2019).

Value-Added Processing and Food Innovation:

Investing in value-added processing and food innovation presents opportunities to enhance the Arab region's food value chain. By adopting innovative processing techniques and diversifying product offerings, farmers and agribusinesses can capture higher value in the market. This includes developing innovative food products, improving food packaging and preservation methods, and leveraging local ingredients and traditional knowledge to create unique and marketable food items. Value-added processing and food innovation contribute to economic diversification, job creation, and the development of a vibrant food industry (Yi *et al*., 2020).

Climate-Resilient Agriculture:

The Arab region's susceptibility to climate change necessitates the adoption of climate-resilient agricultural practices. This includes investing in drought-tolerant crop varieties, implementing efficient water management systems, and adopting climate-smart agricultural practices. Innovative approaches, such as agroforestry, conservation agriculture, and integrated pest management, can enhance the resilience of agricultural systems to climate-related risks (Abid *et al*., 2019) Climate-resilient agriculture not only mitigates the negative impacts of climate change but also enhances the productivity and sustainability of farming systems (Kaur *et al*., 2021).

Entrepreneurship and Agribusiness Startups:

The Arab region offers opportunities for entrepreneurship and the growth of agribusiness startups. With supportive policies, access to finance, and incubation programs, aspiring entrepreneurs can develop innovative solutions and business models in the food and agricultural sector. This includes areas such as agricultural technology development, e-commerce platforms for farm produce, value chain optimization, and sustainable food processing. Encouraging entrepreneurship and supporting agribusiness startups can drive job creation, economic growth, and technological innovation in the region (Sartorius *et al*., 2020).

Cross-Sector Collaboration and Partnerships:

Collaboration and partnerships between different stakeholders, including governments, research institutions, private sectors, and civil society, are crucial for fostering innovation adoption in the Arab region's food and agricultural sector. Public-private partnerships can facilitate knowledge transfer, technology dissemination, and investment in research and development (Birner *et al*., 2021). Collaboration between research institutions and farmers' organizations can bridge the gap between research and practice, ensuring that innovative solutions are tailored to local contexts. Furthermore, engaging local communities, women, and youth in decision-making processes can lead to more inclusive and sustainable innovation adoption (Ouma *et al*., 2020).

Conclusion

In conclusion, innovation plays a pivotal role in agricultural adaptation to climate change, as highlighted in the previous studies. By harnessing technological advancements, institutional reforms, and knowledge management approaches, innovation can enhance the resilience, sustainability, and productivity of agricultural systems in the Arab region. The opportunities for innovation adoption mentioned earlier, such as sustainable agriculture practices, precision agriculture, vertical farming, Agri-tech, and digital solutions, are key avenues to address climate change challenges. These innovative approaches can help mitigate risks, optimize resource usage, and improve agricultural productivity in the face of changing climatic conditions. However, to fully realize the potential of innovation, it is essential to address the barriers to its adoption and create an enabling environment. Policymakers, researchers, and practitioners have a crucial role to play in fostering innovation by implementing supportive policies, facilitating knowledge exchange, and promoting the widespread adoption of climate-smart agricultural practices. By embracing innovation, the agricultural sector in the Arab region can effectively navigate the challenges posed by climate change, ensure food security, and foster sustainable livelihoods for present and future generations.

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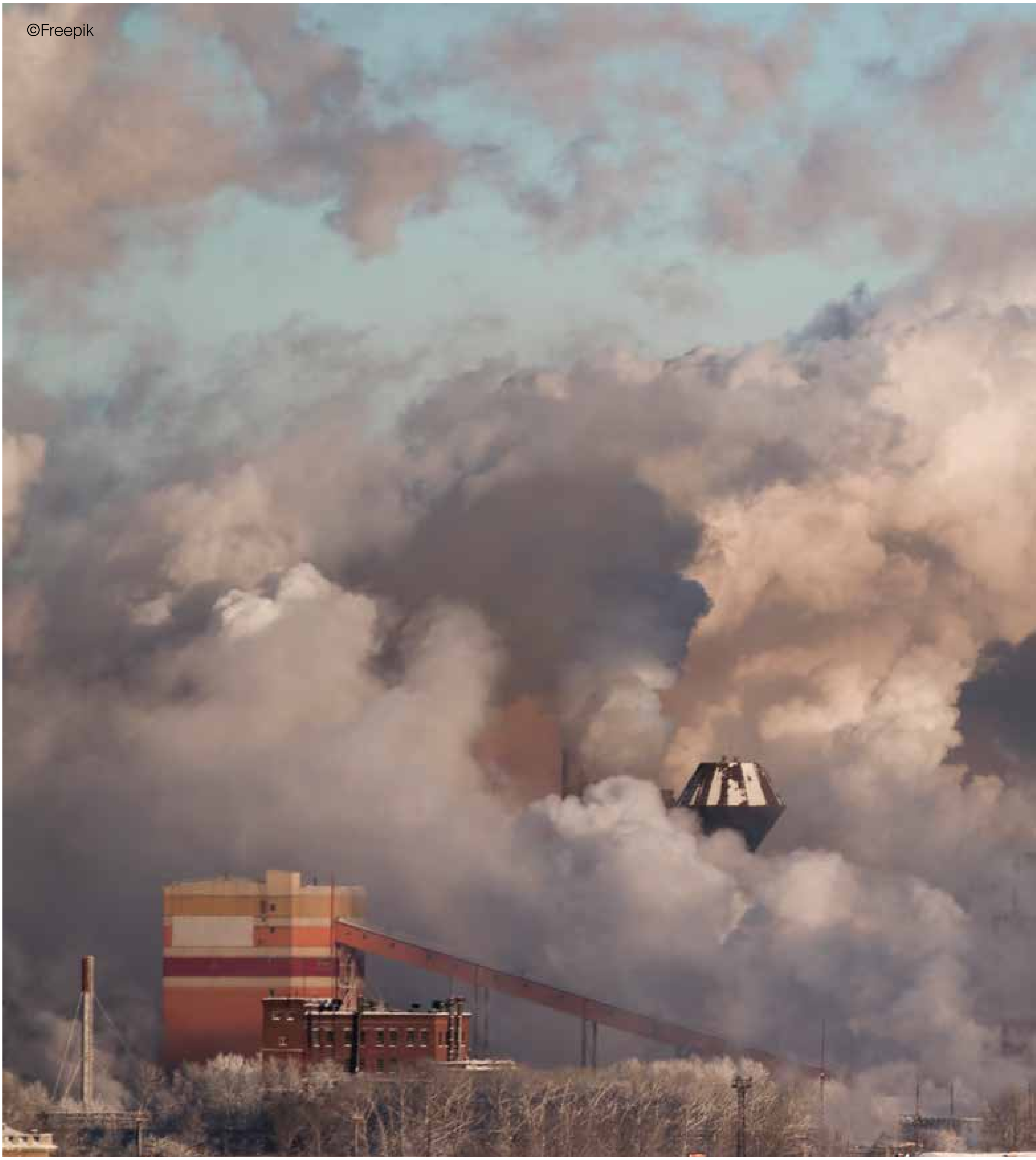

The role of innovation **in serving agricultural** adaptation to climate change

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Climate change is not a future concept; it is a stark reality that threatens every aspect of human life, including agriculture. The sector faces an array of challenges—extreme weather conditions, unpredictable rainfall, temperature fluctuations, and soil degradation—to name just a few. Given the gravity of the situation, innovations are indispensable for adapting agriculture to our changing climate. These innovations are not merely a way to sustain productivity but a pathway to ensure the survival of millions who rely on agriculture for livelihood and sustenance.

1. Background

Climate change poses an unprecedented threat to agricultural systems worldwide. With the escalation of extreme weather events, rising temperatures, and fluctuating precipitation patterns, traditional methods of farming are becoming increasingly untenable. The very ecosystems that agricultural communities have relied upon for centuries are now undergoing rapid changes, impacting both food security and socio-economic stability. As we move further into the 21st century, it is becoming imperative to identify innovative solutions to adapt agricultural practices to these new environmental challenges.

2. The Problem Statement

Before delving into the solutions, it's essential to grasp the magnitude of the problem. Climate change impacts manifest as increased frequency of droughts, storms, and floods, resulting in massive crop losses. Furthermore, warmer temperatures can alter the geographical range of many agricultural pests and diseases, making it even more challenging to protect crops. All these factors lead to a decline in crop yields, reduced farming seasons, and increased uncertainty in agricultural planning. Despite the wealth of scientific data highlighting the need for agricultural adaptation to climate change, there exists a significant gap in implementing scalable, practical, and sustainable solutions. The role of innovation in bridging this gap remains under-researched and under-utilized. Farmers, policymakers, and researchers need to understand how technological and process innovations can help agriculture adapt to changing climate conditions. This is essential not only for food security but also for the long-term sustainability of agricultural systems and rural economies.


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3. Technological Innovation

Technological innovation plays a pivotal role in adapting agriculture to the challenges posed by climate change. Given that agriculture accounts for nearly 10% of global greenhouse gas emissions and is extremely sensitive to weather and climate, it's clear that innovations are crucial not just for sustainability, but for the survival of the sector itself. Here, we dive deep into the technological solutions that are revolutionizing the way we farm in a changing climate.

3.1 *Precision Agriculture*

Precision agriculture aims to optimize field-level management with regard to crop farming. It employs a combination of satellite imaging, drones, and ground-based sensors to monitor variables like soil conditions, crop health, and weather conditions. This data-driven approach allows farmers to apply inputs like water, fertilizer, and pesticides only where and when they are needed, thereby minimizing waste and environmental impact.

▸ *How It Helps*

Efficiency: Automated tractors and drones can deliver the right amount of inputs at the right time, reducing waste and cost.

Resource Conservation: Precise irrigation and fertilization mean less water and fewer nutrients are needed, conserving valuable resources.

Adaptability: Real-time data allows farmers to make immediate decisions, adapting to sudden changes in weather or crop conditions.

3.2 *Biotechnology*

Genetic engineering and selective breeding are game-changers in the development of crops that can withstand the adverse effects of climate change. Techniques such as CRISPR gene editing have made it possible to develop crop varieties that are drought-resistant, pest-resistant, and more nutritious.

▸ *How It Helps*

Resilience: Crops can be engineered to withstand specific environmental stressors, making them more resilient to changing climate conditions.

Reduced Reliance on Chemicals: Pest-resistant and disease-resistant crops reduce the need for chemical pesticides and fertilizers, leading to more sustainable farming practices.

3.3 *Renewable Energy in Agriculture*

The transition from fossil fuels to renewable energy sources like solar and wind power is crucial for mitigating the carbon footprint of agricultural activities. Innovations like solar-powered irrigation systems and biogas digesters for animal waste management are increasingly being adopted.

▸ *How It Helps*

Carbon Footprint: Using renewable energy reduces greenhouse gas emissions associated with farming operations.

Sustainability: Renewable energy systems can be more sustainable in the long run, reducing operational costs for farmers.

3.4 *Artificial Intelligence and Big Data*

AI algorithms can process and analyze vast datasets to make accurate predictions about weather patterns, crop yields, and pest infestations. This technology enables farmers to make informed decisions quickly.

▸ *How It Helps*

Predictive Analysis: AI can predict climate-related risks and yield estimates, allowing farmers to take preventive actions.

Resource Allocation: By understanding which fields require more attention, farmers can allocate their resources more effectively, ensuring better yields.

3.5 *Robotics and Automation*

Automated machinery is becoming more prevalent in tasks like planting, harvesting, and sorting. Robots can operate around the clock and in varying weather conditions, providing a level of flexibility and efficiency that human labor cannot match.

▸ *How It Helps*

Labor Efficiency: Automation can reduce the need for manual labor, a significant concern given the declining workforce in agriculture.

Precision: Robots can perform tasks like weeding and harvesting with incredible accuracy, reducing waste and improving yield.

4. Sustainable Practices

While technological advances hold promise for revolutionizing agriculture in the face of climate change, sustainable farming practices provide a foundational approach that aligns with ecological principles. These practices aim to increase agricultural resilience, enhance biodiversity, and reduce environmental degradation, all critical factors for adapting to a changing climate. Here, we explore the innovative sustainable practices that are redefining agriculture.

4.1 *Agroforestry*

Agroforestry involves incorporating trees and shrubs into farmland, thereby enhancing biodiversity, improving soil quality, and reducing wind and water erosion. This practice has multiple benefits:

▸ *How It Helps*

Microclimate Regulation: Trees can provide shade and moderate the local microclimate, which can be particularly beneficial in the context of rising temperatures.

Carbon Sequestration: Trees capture and store carbon dioxide, helping to mitigate the impact of agriculture on climate change.

Biodiversity: The introduction of various tree species promotes a more diverse ecosystem, enhancing natural pest control and soil fertility.

4.2 *Cover Crops*

The use of cover crops—such as clover, rye, or barley—is a proven strategy for protecting and enriching soil. These crops are typically grown during off-seasons and offer a variety of benefits:

▸ *How It Helps*

Soil Health: Cover crops improve soil structure, increase organic matter, and enhance water retention capabilities.

Erosion Control: They protect the soil from water and wind erosion, which is increasingly important as climate change intensifies weather events.

Pest Management: Some cover crops can naturally repel pests or act as a habitat for beneficial insects.

4.3 *Conservation Agriculture*

Conservation agriculture focuses on minimizing soil disturbance, preserving soil structure, and maintaining soil cover. Methods include no-till farming, reduced tillage, and crop rotation.

▸ *How It Helps*

Water Efficiency: Improved soil structure allows for better water retention, a crucial feature in regions impacted by drought.

Soil Carbon: Reducing soil disturbance minimizes the release of stored carbon, contributing to climate change mitigation efforts.

Resilience: Crop rotation helps in pest and disease management, while also enhancing soil fertility and farm resilience.

4.4 *Regenerative Agriculture*

This practice goes beyond sustainability to actively improve the land and ecosystem. Regenerative agriculture involves a set of techniques that restore soil health, sequester carbon, and promote biodiversity.

▸ *How It Helps*

Soil Restoration: The focus is on rebuilding organic matter in the soil, which improves water retention and reduces the need for synthetic fertilizers.

Climate Resilience: Healthy soils are more resilient to climate stressors such as floods and droughts.

Carbon Storage: Regenerative agriculture is seen as a powerful tool for capturing atmospheric carbon dioxide in soil.

4.5 *Polyculture and Crop Diversification*

Polyculture involves growing multiple crops together in the same space, mimicking the diversity found in natural ecosystems.

▸ *How It Helps*

Resource Optimization: Different plants have different nutrient needs and growth patterns, which can lead to more efficient use of available resources.

Pest Management: A diverse crop portfolio reduces the spread of pests and diseases, decreasing reliance on chemical pesticides.

5. Policy Measures and Public-Private Partnerships

The challenge of adapting agriculture to climate change is not solely a matter of technological or even sustainable innovation; it is also a challenge of governance, collaboration, and strategic planning. Policies and partnerships between the public and private sectors play a pivotal role in fostering innovation and ensuring that new techniques and technologies are both effective and equitable. In this regard, let's delve into some key policy measures and the importance of public-private partnerships in driving agricultural adaptation to climate change.

5.1 *Subsidies and Incentives*

Government subsidies and incentives can be structured to promote the adoption of climate-resilient practices and technologies. For example, subsidies could be offered to farmers who invest in water-saving technologies or who shift to more sustainable, low-carbon practices.

▸ *How It Helps*

Accelerated Adoption: Financial incentives can significantly speed up the uptake of innovative and sustainable technologies.

Risk Mitigation: Subsidies can reduce the financial risk associated with adopting new farming practices, making farmers more willing to innovate.

5.2 *Regulations and Standards*

Governments can enforce regulations that mandate certain best practices, such as limiting water usage during droughts or prohibiting the use of certain harmful pesticides. Environmental standards can also be set for soil health and water quality.

▸ *How It Helps*

Consistency: Regulations ensure a minimum standard of practice, leveling the playing field and encouraging wider adoption.

Environmental Protection: Enforced standards can limit or prevent practices that contribute to environmental degradation and climate change.

5.3 *Research and Development Funding*

Public funding for research can be crucial in areas that may not be immediately profitable but are essential for long-term sustainability and climate resilience.

▸ *How It Helps*

Innovation: Funding drives research in sustainable practices, new technologies, and more resilient crop varieties.

Public Good: Government-funded research is often publicly available, benefiting smaller farmers who may not have access to proprietary technologies.

Public-Private Partnerships

5.4 *Shared R&D Efforts*

Collaborations between governments, research institutions, and private companies can combine public-sector orientation towards long-term sustainability with private-sector efficiency and innovation.

How It Helps

Pooling Resources: Joint efforts often result in more robust research and faster development of new technologies.

Scalability: Private companies can often scale up successful innovations more quickly than public-sector organizations.

5.5 *Extension Services and Knowledge Sharing*

Public-private partnerships can also extend to educational efforts, disseminating knowledge about best practices and new technologies through extension services.

▸ *How It Helps*

Education and Training: These partnerships can help ensure that farmers are adequately trained in the use of new technologies and practices, maximizing their benefits.

Localized Solutions: Collaboration with local organizations can tailor educational programs to the specific needs and challenges of a given community.

5.6 *Risk-Sharing Mechanisms*

Financial products like weather-indexed insurance can be developed in partnership with private financial institutions to mitigate the risks farmers face due to climate volatility.

▸ *How It Helps*

Financial Security: Such insurance products can provide farmers with a safety net, encouraging them to invest in more innovative and potentially riskier sustainable practices.

Incentives for Resilience: Insurance can be structured to offer lower premiums for adopting climate-resilient practices, thereby promoting sustainability.

6. Conclusion

The role of innovation in serving agricultural adaptation to climate change is paramount for addressing the pressing challenges facing our agricultural systems. Climate change has brought about extreme weather conditions, unpredictable precipitation patterns, and numerous other threats that jeopardize global food security and the livelihoods of millions of people dependent on agriculture.

Technological innovation offers powerful solutions to these challenges, with precision agriculture, biotechnology, renewable energy, artificial intelligence, and robotics providing tools to increase efficiency, reduce resource consumption, and enhance adaptability. These innovations not only bolster the resilience of agriculture but also contribute to mitigating its environmental impact.

Moreover, sustainable farming practices like agroforestry, cover cropping, conservation agriculture, regenerative agriculture, and crop diversification play a pivotal role in building resilient agricultural systems. These practices promote biodiversity, improve soil health, and reduce environmental degradation, aligning agriculture with ecological principles.

However, the transformation of agriculture to meet the demands of a changing climate also requires robust policy measures and effective public-private partnerships. Subsidies, incentives, regulations, and research and development funding can accelerate the adoption of innovative and sustainable technologies and practices. Public-private collaborations leverage the strengths of both sectors to drive research, development, and knowledge sharing, ensuring equitable access to the benefits of agricultural innovation.

Furthermore, risk-sharing mechanisms like weather-indexed insurance can provide financial security to farmers and incentivize the adoption of climate-resilient practices. These measures collectively form a comprehensive approach to address the multifaceted challenges of climate change in agriculture.

Innovation, sustainability, and collaboration are not just the keys to adapting agriculture to climate change; they are the keys to securing our future food supply, safeguarding livelihoods, and promoting the long-term well-being of our planet. As we move forward, it is essential that governments, private sectors, farmers, and researchers continue to work together to harness the full potential of innovation in serving agricultural adaptation to climate change.

Innovation and agricultural adaptation to climate change

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Abstract

Climate change poses a serious threat to agriculture and food security. Innovation can help farmers and other stakeholders adapt to the changing conditions and mitigate the negative impacts. However, innovation requires adequate policies, investments, and research to be effective and sustainable. This paper reviews some of the recent approaches and challenges of agricultural innovation for climate adaptation. There are some Arab countries that have used innovation and adaptation to the impact of climate change, such as:Jordan, which has developed a national action plan for adaptation to climate change and launched projects to increase water and energyefficiency 1.Morocco, which has adopted a national strategy for sustainable development and invested in renewable energy and climate agriculture projects 2.United Arab Emirates, which has established a Ministry of Climate Change and Environment and launched initiatives to reduce carbon emissions and increase adaptive capacity 3.

introduction

Climate change poses significant challenges to the agricultural sector, affecting food production, farmers' livelihoods and global food security. As temperatures rise, extreme weather events become more frequent, and rainfall patterns change, farmers must adapt their practices to ensure sustainable and resilient agricultural systems. In this document, we will explore the critical role that innovation plays in supporting agricultural adaptation to climate change.

1. Enhancing Resilience Through Innovative Agricultural Practices:

Innovation in agricultural practices is critical to building resilient agricultural systems that can withstand the impacts of climate change. This includes adopting climate-smart agricultural techniques such as conservation agriculture, precision agriculture, and agroforestry. These practices help conserve soil moisture, improve water and nutrient management, and reduce greenhouse gas emissions. By implementing innovative agricultural practices, farmers can enhance the resilience of their crops and improve their ability to adapt.

2. Developing Climate Resilient Crop Varieties:

Innovation in plant breeding and genetics plays a vital role in developing climate-resilient crop varieties. By using advanced breeding techniques, scientists can enhance the ability of crops to withstand various environmental stresses, such as drought, heat, and pests. These climate-resilient crops can withstand adverse conditions and continue to provide higher yields and better nutrition. Furthermore, the development of GMOs offers the possibility of introducing specific traits that increase the climate resilience of crops, such as disease resistance or increased water use efficiency.

3. Harnessing digital technologies for climate-smart agriculture:

Digital technologies have revolutionized agriculture by providing farmers with real-time data, remote sensing, and predictive analytics. These tools enable farmers to make informed decisions regarding crop management, irrigation and pest control, thus improving resource use and reducing environmental impact. In addition, digital technologies are facilitating early warning systems for extreme weather events, enabling farmers to take proactive measures to protect their crops. Integrating digital technologies into agricultural practices is crucial to enhancing agricultural adaptation to climate change.

4. Encouraging agricultural innovation and knowledge exchange:

Innovation in agriculture is not limited to scientific research and technological advancement. Farmers themselves are a valuable source of innovation, drawing on their local experiences and knowledge to develop adaptation strategies. Encouraging farmer innovation and knowledge-sharing platforms can promote the adoption of climate-smart practices and facilitate the exchange of best practices among farmers. This collaborative approach strengthens resilience and enhances the adaptive capacity of farming communities.

Conclusion:

Innovation plays a pivotal role in serving agricultural adaptation to climate change. By encouraging innovative agricultural practices, developing climate-resilient crop varieties, harnessing digital technologies, and encouraging agricultural innovation, we can build resilient agricultural systems capable of withstanding the challenges of a changing climate. It is essential that governments, research institutions and agricultural stakeholders collaborate to foster a culture of innovation in agriculture and ensure sustainable food production for future generations.

Introduction and Problem Statement

challenges of agricultural adaptation to climate change are:Some of the problems and challenges facing societies whose primary sources depend on agriculture by not using technology with the climate crisis are: Land degradation, biodiversity loss, pollution, drought and floods[1] Decreased productivity and yields, increased hunger and poverty[12] Weak ability to adapt to climate change and mitigate its effects[1] Negatively affected by the Corona virus pandemic, health measures, and the ban[2] Decreased demand for agricultural products and collapse of supply chains[23]Extreme weather events such as severe drought, floods, and pest infestations that can damage crops and livestock 1.Decreasing water availability due to increasing desertification and dwindling groundwater supplies 1.Changing crop suitability due to shifts in temperature, precipitation, and soil quality 23.Complex optimization decisions and general equilibrium dynamics that affect farmers' adaptation strategies 4.

These challenges require innovative solutions that can enhance the resilience and productivity of agriculture while reducing greenhouse gas emissions.

Some examples of innovative solutions for agricultural adaptation are:Smart farming solutions that use artificial intelligence, analytics, connected sensors, and other technologies to optimize crop and livestock management, increase yields, and reduce inputs 12.Drought-resistant crops that can withstand lower rainfall and higher temperatures 3.Smart irrigation systems that monitor soil moisture and weather conditions and adjust water delivery accordingly 1.Autonomous harvesting robots that can reduce labor costs and increase efficiency 1.Genetic editing that can improve crop traits such as disease resistance, nutrient content, and stress tolerance 1.Innovation can play a major role in serving agricultural adaptation to the climate change crisis in several ways, such as:- Developing crops and agricultural strains resistant to drought, heat and diseases**[13].Build smart irrigation systems that use water efficiently and improve water resources management**[12].Reduce food loss and waste across agricultural supply chains and increase storage and distribution efficiency, Enhancing coordination between sectors and raising awareness on issues of production based on adaptation to climate change and food security**[2].

Source: Conversation with Bing, 9/9/2023

- Addressing the issue of climate change in agricultural and food systems. https://www.fao.org/neareast/action-areas/climatechange/ar/.
- Agriculture in the era of drought... attempts to adapt to climate change. https://www.alarabiya.net/qafilah/2021/05/21/Agriculture-in-a-drought-attempts-to-adapt-to-climate-change.
- Adaptation to climate change The Integrated Management Program for the production of .... https://www.fao.org/agriculture/ippm/activities/climate-change-adaptation/ar/.There are many technological tools used in agriculture, such as:- Self-propelled machinery and heavy equipment such as crawler tractors, heavy ploughs, trenchers and chisel plows[1]Soil DNA testing and genetic engineering to improve nutritional content and resistance to pests and diseases[2]Digital agriculture, which uses digital technologies to pilot and scale up new services, tools and approaches to empower rural households.[3]

Climate change affects markets and trade in the agriculture sector in different ways, such as:

- Reducing productivity and yields and increasing costs and losses[12]
- Changing patterns of demand, consumption and prices[13]
- Exposure of global agricultural value chains to risks and disruptions[13]
- Changing competitive opportunities and comparative advantages of exporting and importing countries[3] Some ways to adapt to the impact of climate change on markets and trade in the agriculture sector are:
- Increase funding and investment in adaptation projects and programs
- Develop and implement appropriate policies, planning and institutions for adaptation[12]
- Promoting innovation, technology, research and development in the fields of sustainable agriculture[12]
- Improving access to agricultural and climate information and services for farmers[12]
- Enhancing cooperation and partnership between sectors, countries and concerned organizations[12]
- Some successful examples of ways to adapt to the impact of climate change on markets and trade in the agriculture sector are:
- Developing improved and water-saving irrigation systems in India and China[1]
- Implementing crop and livestock insurance programs in Kenya and Morocco[12]
- Promoting the use of renewable energy and energy efficiency in the agricultural sector in Tunisia and Jordan[12]
- Improving Soil Management and Biodiversity in Organic Agriculture in Colombia and Brazil[12]
- Encourage community participation and awareness of climate change adaptation issues in Bangladesh and Vietnam[13]

The importance of oases in facing climate change

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Introduction

Oases are islands of ground, lost in the middle of the desert, suitable for vegetation and human activities. Their sustainability depends mainly on water availability. In addition to their important economic, social, and ecological role, the oases serve as transit stops, passage and freight forwarders.

One of the important aspects of oases is that they have a very attractive and natural architectural and cultural heritage. They are spread in North Africa, in the South of the great Sahara, in the Near and Middle East region, in Asia, in America and Australia. There are several types of oases: those in warm areas (with or without palm date trees) and those in high altitude or continental zones with cold winters (Central Asia and China) and intermediate gradients.

Oases in dry zones count a population estimated at two billion people, about 28 % of the world population. They cover about 40 % of the globe among which 66 % in Africa. Hence, they occupy an important space of earth's surface, which offers a great agricultural potential.

Oases are nowadays threatened by climate change effects causing an increasing scarcity of water resources, a degradation of soil and water quality, a decrease of biodiversity, a decline of agricultural activities and migration of oases' communities. This situation is aggravated from an area to another due to an uncontrolled ongoing urbanization. The oases system weakened by climate change requires the application of the concept of sustainability through the integration of economic, environmental, and social dimensions.

To protect and develop this ancestral system, cradle of many cultures and civilizations, the "Sustainable Oases Initiative" is proposed to take concerted, shared, and appropriate actions so that oases of the world can continue to exist and fulfill their various environmental and civilizational roles.

Oases provide high-quality ecosystem services, with a rich and unique biodiversity, equitable social organization and diversified and differentiated production capacity. They serve as a habitat for a diversity of animal and plant species of great importance. Oases are complex and fragile systems that have been able to adapt to changing environmental conditions for centuries but are now facing threats mainly related to climate change and farming practices that do not respect their vulnerability, leading to soil erosion and salinization, loss of biodiversity and even desertification. All of the aforementioned factors make oases vital agroecosystems for humanity, which must be preserved, restored, and promoted as models for sustainable management and climate change adaptation.

1. A sharp reduction in water resources

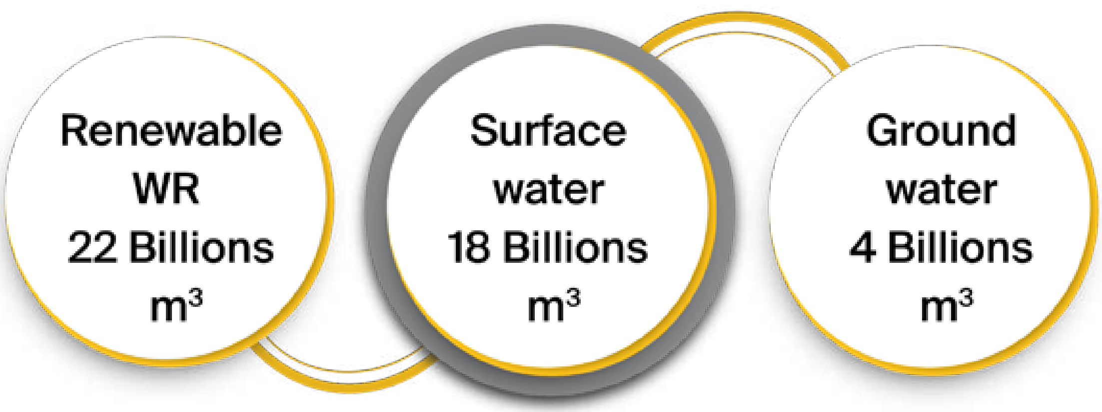
Rainfall in Morocco is highly variable between different regions, between seasons and from year to year. This variability requires a considerable effort to mobilize water resources in different regions to develop irrigation.

The average annual rainfall is around 200 mm per year, varying by minus 50 mm in some areas and may reach 1500 mm in very limited areas. The renewable potential of water is 22 billion m^3 per year, of which 3 billion m^3 is groundwater. This guarantees a level of 700 m^3/inhabitant/year.

The situation of water scarcity is becoming more striking in the southern Atlassic regions of Morocco, which lead to desert areas. To adapt to these conditions, the inhabitants of these areas have not lacked ingenuity to (i) create complex hydraulic structures in order to ensure the mobilization of water resources, (ii) maintain them properly so that they have been functional for centuries already and (iii) above all sustain a centuries-old organization to allow the sharing of water and the sustainability of the infrastructures achieved.

The climatic disorder that we are experiencing has not spared these areas, which are essentially marked by drying up of water resources with prone water on one hand and violent rainfall with devastating floods on the other.

It is in this sense that combined efforts should be made to build on the good practices developed in these areas that have allowed local populations to adapt to difficult climatic conditions. These are textbook cases for several other parts of the globe that are experiencing similar climate change. In addition, the adaptive capacity of these areas is further diminishing for multiple reasons that need to be addressed in order to allow these areas to continue, as in the past, to carry out their ecological, economic and social role.



2. Irrigation is an ancestral practice in Morocco

The Moroccan traditional irrigation is an ancient system of water management that has been used for centuries. It is based on the principles of conservation, efficiency, and sustainability. The system is designed to capture and store rainwater and to distribute it to crops and fields during dry times. The traditional irrigation system is made up of several components, including reservoirs, canals, dikes, and dams.

The reservoirs are used to store the water for later use, the canals are used to carry water from the reservoirs to the fields, the dikes are used to control the flow of water, and the dams are used to regulate the amount of water that is released. This system is still used today and is an important part of Moroccan culture.

Each structure built for irrigation, in an irrigated area, tells a story. It tells the story of a local population who knew how to coax the harsh conditions of nature, without disturbing its' stability, to ensure the required conditions of life and first and foremost food.

To illustrate this ingenuity, I content myself in this article with talking about two types of work, the most famous ones: the Khettaras and the Matfyas.

2.1 *Les Khéttaras*

The Khéttaras are composed of:

1. A gallery which ensures the drainage and catching of water
2. An adductor part, which transports the drained water to the irrigation perimeter.
3. An inactive head to carry water to the plots via channels feeding the sockets locally called "Mesraf"

The Khettaras are underground galleries that could reach several tens of kilometers connecting wells (manholes) of varying depths from a few tens of meters at the beginning of the Khettara to a few meters towards the end of it. The intervals between the wells are of a true logger between about 10 and 15 m. The water flows at the bottom of the gallery from one well to another until it comes out into the open air like a spring. When the flow rate is low, water is often collected in basins

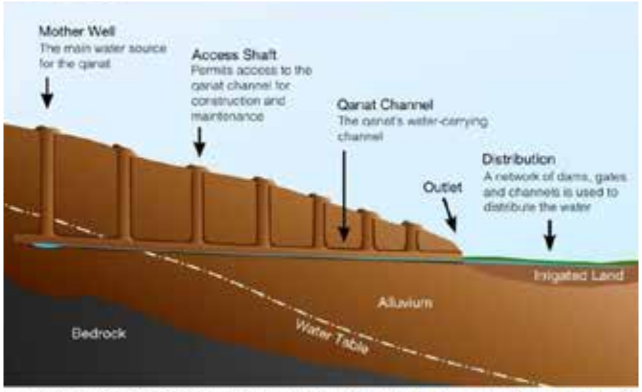


Figure 1: Diagram of standard Khéttara sections

to be distributed according to well-coded rules among the beneficiaries.

This ingenious technique was developed to mobilize groundwater resources and to continue the practice of agriculture in a context of great variability of surface water inputs in oasis areas. Such variability makes it impossible to sustain intensive agriculture in these areas.

The principle is to build a gallery, (i) draining groundwater for the upstream part located below the piezometric level of the water table, (ii) then conveying it in a canal for the part located above the piezometric line of the water table.

Depending on the nature of the land and the means available, different techniques are used for the construction of Khettaras.

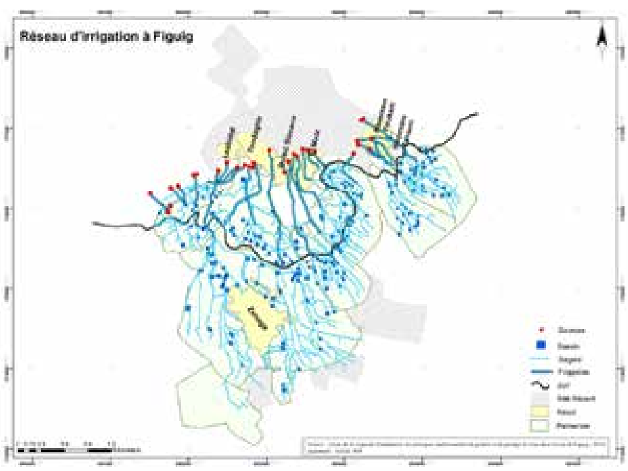


Figure 8: Diagram of the irrigation network of the Figuig oasis

Figure 2: External view of a Khéttara well

Figure 3: Externa viewl of sevral Khéttaras wells

Figure 4: Internal view of Khéttara with land lifting tool

Figure 5: Maintenance operations require more than one person working at a time

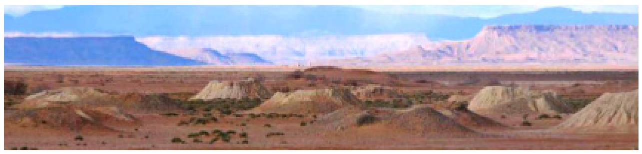


Figure 6: Striking landscape of a field of Khéttaras **defying the Atlas Mountains**

Figure 7: Entanglment of irrigation networks above and below the ground of the Figuig Oasis

2.2 *Les Matfyas*

The Matfya is a cistern of underground water, sometimes even dug into the rock to accumulate rainwater. It is often located in the surroundings of non-permanent water streams. This type of structure is found in areas where storms are the main water resource, which create ephemeral and transient flows.

It is a means of survival in certain areas of southwestern Morocco, ensuring a water supply for livestock, households, and public institutions. In the event of a surplus, they are used to provide supplementary irrigation for certain crops.

The average characteristics of this structure are as follows:

Inside:

- Various shapes: cylindrical, rectangular, oval horizontal or vertical.
- The side walls are sealed with clay plasters or lime and/or cement.
- The ceiling is not treated with a coating.

Outdoors:

- The roof is covered by a cement-based layer.
- The circular drawing hole is about 50 cm in diameter.
- The channel(s) to carry the water.
- The settling pond and a tree branch filter to retain impurities.

Figure 9: External view of traditional Matfya

Figure 10: Panoramic view of a series of Matfyas near the houses

- The impluvium, delimited by stones, collects rainwater to direct it towards the entrance of the Matfya. It must be as wide as possible.

For domestic use or livestock watering, Matfyas are often located near dwellings or even at the foot of them can collect rainwater from the roofs of houses. Each family shall endeavor to have one or more Matfyas, ensure that they are always closed and that the water usage is supervised by the custodian.

For the use of irrigation, Matfyas water is managed, as for agricultural land or rangeland. It can also be managed collectively.

Matfyas are also found near public places (mosques, souks, cemeteries, administrations, in fields, along paths and roads, etc.).

The ingenuity of these systems that have made it possible to resist throughout history, challenges us all to preserve them as well as a universal heritage and to study them in depth, in particular; technical, organizational, and socio-economic.

Conclusion

Although they are in sharp decline, these traditional water mobilization structures continue to serve in many localities in Morocco. They have a very important role in mobilizing small quantities of water and are in line with natural environments which are marked by a very pronounced scarcity of this essential resource.

In the absence of a more effective alternative, the construction of such structures continues to be resorted to, with improvements in the civil engineering of the various components of the structures to improve safety and to improve the forces exerted by the soil.

In addition, the maintenance of these traditional structures often requires expensive organization and work, which users are unable to carry out. This has doomed many of these structures, some of which have even become a tourist attraction.

As well as other practices, of paramount importance, increasingly pressing under the effects of climate change, deserve research and studies to bring about the necessary improvements in design and management. The use of science and technology in this sense is obviously the unavoidable means of adaptation in the face of unavoidable global warming.

The oases, islands of life in desert oceans, have developed ingenious practices to meet their needs with the existing minimum of natural resources. In fact, in the oases we say, "We have nothing, but we need nothing". In order to face the looming threats of global warming, it is crucial to look into how the oases survived and thrived in the midst of the driest deserts. In addition, the biological diversity in these areas is also an important resource for species that are more resilient and that have adapted to difficult climatic conditions.

In a context of global warming, oases ecosystems, which are certainly experiencing difficulties, are treasures of a heritage for all humanity, and require more interest. In oases, aside from problems, there are also solutions.

Agricultural terraces of the Atlas Mountains of Morocco:

A heritage serving community adaptation to climate change

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The majestic Atlas Mountains in Morocco demonstrate the signs of a brilliant and ingenious agricultural practices and civilization. This can be read on the slopes landscaping with countless agricultural terraces highlighting the aspect of “built” nature Most of these terraces are dated back hundreds or even thousands of years ago.

Multifunctionality is the major characteristic of these landscapes. They are historical places where options for the future are designed to serve quality of life including the social and cultural dimension and recently tourism and recreative activities. Man and women built them for this purpose, and again today they are attracting attention for the same reason. This is even more necessary for the human community which is looking for solutions to major current and future challenges. All we have to do is interpret their contemporary meanings.

Agricultural terraces are a geographic feature of mountainous areas landscapes around the world, which are transformed into areas that can be exploited for agricultural purposes and meet food needs. It should be noted that farmers in these slopy areas have designed similar technical and organizational solutions to cope with natural conditions, despite their different cultural, historical and geographical affiliations, as almost the same mechanism is found in many Mediterranean countries, Mexico, China, and others.

The steep areas in the Atlas Mountains have been shaped over centuries by human interventions that have been repeated and superimposed over time. Such intervention allowed the implementation of agricultural practices through a rational use of local resources in the mountainous areas.

Thus, agricultural terraces, made of drywalls using exclusively locally available materials, which were created to increase arable agricultural land, reduce soil erosion, as well as improving water management.

In fact, Changing the land geometry (height and slope) helps to control soil erosion by reducing runoff down the slope and by promoting water infiltration. This directly improves water availability for crops, and in the long run improves soil properties and quality.

In general, the construction of agricultural terraces determines an overall improvement in the agronomic properties of the soil, which can be summarized as the increase in (i) the useful soil depth proportion explorable by the roots, (ii) organic matter content (thanks to frequent fertilization) and (iii) water retention level.

Agricultural terraces are tightly related to human community evolution and the advancement of its productive practices. The agricultural terraces reflect well on such a relationship, as they were not natural elements, but created through the collective effort of those who, out of necessity, had to solve problems of life and secure the possibility of taking root in unfavorable environments.

The need to increase agriculture productivity in mountainous areas led to the birth of agricultural terraces which, through the creation of limited flat areas and the exploitation of favorable exposures, allowed the development and diversification of crop production which in turn tightened to some extent the link of many rural communities to their land.

Living and producing in these rugged areas requires integrated management of resources, means, and innovative exploitation of technology and knowledge, within a special institutional and regulatory framework. Following people's settlement and food needs increase they built more agricultural terraces to expand the cultivated land according to the number of families benefiting from them. Despite the small size of these areas and the difficult terrain, residents were able to achieve diversified agricultural production, including fruit trees and vegetables on irrigated terraces, as well as barley, seasonal crops, and other tolerant tree species. Such practices allowed better adaptation to drought on rainfed lands.

►►►

The agricultural terraces of the Atlas Mountains are a heritage in need of restoration,It was created by Moroccan mountain dwellers to cultivate the slopes, but neglection and climate change threatens its extinction. ▲

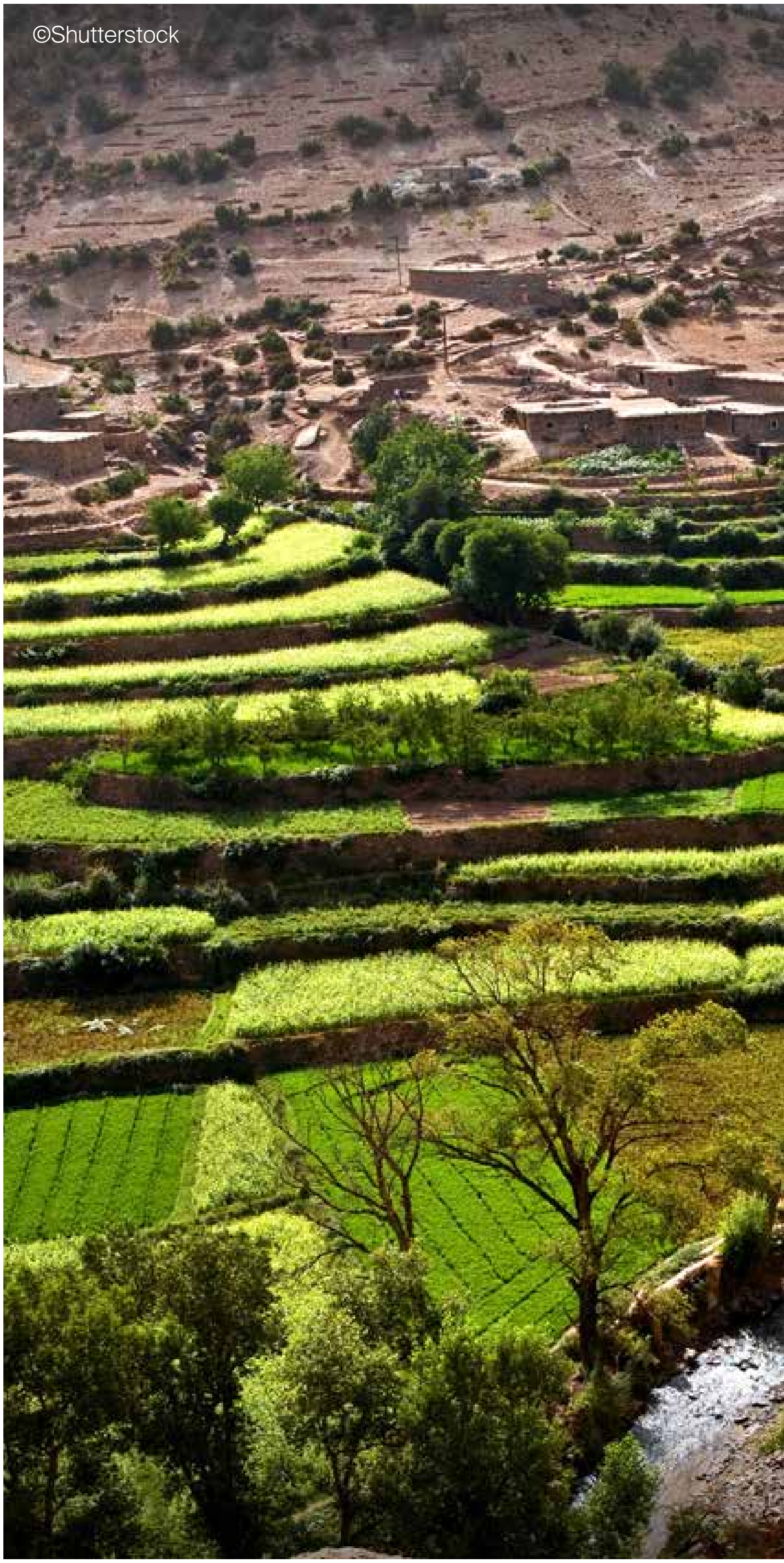
Most known agricultural terraces are located in the Anti-Atlas Mountains in the Souss region of central Morocco. Many elements show visible neglect of these terraces, particularly with the increasing frequency of droughts leading to a decline in crop yields and worsened by youngsters' migration towards other activities. Indeed, the income of the inhabitants in the villages of the Anti-Atlas depends on the exploitation of natural resources, agriculture, and livestock, in addition to the exploitation of argan fruit processing.

The Souss region is highly impacted by climate change, mainly by low and fluctuating rainfall, with heavy rainfall at times. Building agricultural terraces was one of the most effective options for sustainable farming with soil protection and good rainwater harvesting. Terraces-based framing systems played an important role in adapting to these changes. They are described by scholars as the pillars of the "scarcity economy" based on well-managed seed storage management and supplies and ingenious traditional irrigation and water management mechanisms. The terraces facilitate the penetration of excess water into the soil and reduce the speed of its flow down the slopes while reducing erosion and soil loss due to this flow.

Regarding climate change trends, these terraces require specific care and development to continue supporting population and ecosystems capacities to adapt and mitigate climate change and its consequences.

Drought impacted negatively the terraces and led to a decline in maintenance efforts. The abandonment of the exploitation of these terraces is mainly explained by the reduction of agricultural economic returns compared to other activities related to migration. All this generated notable deterioration of these agricultural terraces, worsened by climate extreme events such as the recent torrential rains. This has induced other negative impacts that affect the whole ecosystem components such as soil erosion increase, siltation of dams, and collapsing roads.

This calls for urgent measures to avoid the loss of this ecosystem and this agricultural heritage of the Anti-Atlas. The best way forward is recognizing the major role of such creations for the ecosystem equilibrium, for human living, and in improving climate change mitigation and adaptation capabilities. First by ensuring effective participation of the local population and encouraging and supporting farmers' investment to preserve and improve agricultural practices, second by including professionals and scientists in concrete proposals design and implementation regarding the future development of terraced-based farming systems. The heritage perspective is also a key issue, it is needed to revive collec-



tive memory and traditional reconstruction experiences for future generations. In addition, we are solicited to make a good combination of policy and technical interventions within an ingenious framework that values all stakeholders' -civil society, scientists, authorities, cooperatives...- contributions and responsibilities.

This forces us to think about the slow recovery activities of the abandoned historic landscape. This also requires taking into account innovative agro-climatic techniques and interventions in the development of local infrastructures and artifacts such as bridges, wells, canals, reservoirs, granaries... and many other artisanal creations based on local knowledge and having the common characteristic of using natural stone.

Faced with the magnificence of this authentic agricultural heritage and innovation, it seems necessary to create a dedicated "label" that attests to and values the role of agricultural terraces in the protection of soils from hydrogeological instability and loss of biodiversity and rich cultural heritage.

There is a large area of agricultural terraces in the Anti-Atlas Mountains of Morocco and more in others mountainous areas, unfortunately a large part of this heritage is in a state of abandonment that needs lot of work to be rehabilitated and maintained. We should keep in mind that these agricultural terraces are a key option to climate change adaptation and mitigation.

The question remains open to decision-makers in the conservation sector. What is the future of this historical heritage created by previous generations? Can we find new ways of life and activities that take advantage of these resources inherited from the past?

Here we can only have an open exchange between the different stakeholders of the terraced areas, including locals, dry stone artisans, researchers, farmers, activists and those working in the tourism sector. It is urgent to implement of a working group and a task force to show the way forward. As an opportunity to strengthen the solidarity cooperation network which has its roots in the terraced areas.

Climate change and food security challenges

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Food insecurity was already on the rise globally, due in large part to climate phenomena, as global warming affects weather patterns, causing heat waves, heavy rainfall, and droughts.

Ensuring food security in light of the impacts of climate change may be our greatest challenge of this century. More than 860 million people in the world now suffer from hunger

How could climate change affect agriculture and food security in the future?

Rising temperatures and carbon dioxide can be beneficial for crops up to a certain point. But rising temperatures also accelerate evaporation rates from plants and soil, and enough water must also be available for crops to grow.

For areas of the world already suffering from water shortages, the negative impacts of climate change on agricultural production are increasing through diminished water supplies, increased frequency of extreme events such as floods and severe storms, heat stress, and increased spread of pests and diseases.

These climate changes threaten the food security of the world's population. As temperatures rise and vary, agricultural crop yields decrease, as agricultural lands suffer from heat stress, drought, increased rates of salinity, the spread of pests, and decreased soil fertility.

The expected variation in temperatures will cause disruption to crop productivity. According to estimates by the Intergovernmental Panel on Climate Change, vegetables and fruits will lose 35% of their productivity, because they will not be able to withstand a rise in temperatures of 4 degrees Celsius by the end of the current century, and that between 30% and 60% of The area for growing beans, and between 20% and 40% of banana cultivation in Africa, will disappear, as the soil will no longer be suitable for agriculture due to weather fluctuations and drought.

Temperature changes also lead to the growth of various types of weeds that invade the land as well as disease in crops, which also reduces production. Scientists predict devastating effects of climate change, including extreme rains, prolonged droughts, high heat waves and floods that will inundate coastal farmlands, in addition to severe drought and the spread of diseases and weeds.

Heat waves are particularly disastrous to local crop production if they occur simultaneously with severe drought conditions. Successive heat waves in an area can cause crops that may have survived a single event to fail

How can agriculture adapt to climate change?

It is possible to reduce emissions and increase resilience, but doing so often requires major social, economic and technological change. There are some key strategies in this regard:

Use water more efficiently and effectively, coupled with developing policies to manage the demand side. Establishing more irrigation infrastructure facilities may not be a feasible solution if it becomes clear that water supplies will not be sufficient in the future to supply irrigation networks. Other options include improving water demand side management as well as using advanced water accounting systems and technologies to assess the amount of water available. These include soil moisture sensors and evapotranspiration measurements using satellites. These measures could facilitate the adoption of methods such as alternating wetting and drying systems for rice fields, which saves water and reduces methane emissions at the same time.

Switching to crops that consume less water. For example, rice farmers could switch to growing crops that require less water such as corn or legumes. This would also help reduce methane emissions, because rice is a major source of agri-food-related emissions. But it may not be easy for farmers who have been growing and consuming rice for thousands of years to switch to growing another crop that consumes less water and produces fewer emissions.

improve soil health. This is crucial. Increasing soil organic carbon helps improve water retention and allows plants to access water more easily, increasing their ability to cope with drought. They also provide more nutrients without the need for chemical fertilizers – a major source of emissions, allowing farmers to reduce carbon.

Among the solutions for adaptation and mitigation is the move towards practicing climate-smart agriculture, which is based on three goals:

- Increase agricultural productivity in a sustainable manner
- Improving farmers' income
- Building farmers' resilience to climate change and helping them find ways to adapt;

Reducing greenhouse gas emissions

A climate-smart agriculture approach can help farmers overcome these obstacles to sustain their livelihoods and help ensure a future without hunger.

Climate-smart agriculture is an approach that helps guide actions needed to transform and redirect agricultural systems to effectively support development and ensure food security in a changing climate.

Increasing soil organic carbon helps improve water retention and allows plants to access water more easily, increasing their ability to cope with drought. They also provide more nutrients without the need for chemical fertilizers – a major source of emissions. Farmers can recover carbon lost as a result of not tilling the soil and using cover crops, especially root crops

Favor rotation cycle instead of resting the fields. Solutions to environmental challenges derived from nature can provide about 37% of the necessary climate change mitigation capabilities.

However, convincing farmers to adopt these practices will take time, as well as increased awareness and training.

In places where plots of agricultural land are small and farmers cannot afford to fallow fields or even rotate with leguminous crops, improving soil health can be difficult.

Agriculture can also be adapted by adjusting planting calendar and crop diversity, and adopting organic agriculture to limit climate change. Agricultural rotations, green fertilization, and local seeds are all practices that work to increase soil fertility naturally and enhance its efficiency in water absorption, while participating to greenhouse gas emissions' reduction.

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Sustainable Alternative Soilless Growing Media and Substrates

from Date Palm Agricultural Residues: PalmPeat®

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Abstract

As global demand for soilless substrates is expected to increase, driven by climate change and transition of newer crops from soil to soilless production; the importance of exploring new sources of soilless growing media is becoming ever more critical in the view of future food production and food security. This article will shed the light on a new source of soilless media: PalmPeat® which is the world's first soilless growing media and substrates extracted from date palm agricultural residues. PalmPeat® provides a renewable and sustainable alternative to sphagnum peat moss, which has been facing increasing regulatory pressure on its extraction. PalmPeat® expands the range of peat-free soilless substrates. Resulting in more geographically dispersed economical supply, in suitable volumes and quality with minimal carbon footprint. Which fulfills the ever-increasing demand for soilless growing media by the horticulture industry, without threatening the sensitive sphagnum peatland ecosystem. PalmPeat® has been developed based on proprietary technology (UK patent pending). PalmPeat® has an excellent water-holding capacity and excellent airspace for better root aeration, root growth, and drainage. It has controlled pH and EC levels for the exchange of nutrients. Its spongy structure allows absorbing nutrients and slowly releasing them. It has excel-

lent wettability and decomposition rates slowly, hence can be reused in multiple growing cycles. PalmPeat® is free from weed seeds, pathogens, nematodes, and harmful micro-organisms. The analysis conducted on PalmPeat® indicate that the media matches the performance requirements of the soilless media industry which made it well received and accepted by the growing media industry, through a collaboration with leading soilless growing media suppliers in Europe and the United States.

Introduction

The growing media industry has been continuously challenged to source and process growing media in suitable volumes. Many of those challenges emerged from global geopolitical issues, increased regulatory pressures on peat moss extraction and use (which resulted in the depletion of natural habitats), unpredictable weather patterns (which affected harvests), as well as transportation costs and labour shortages.

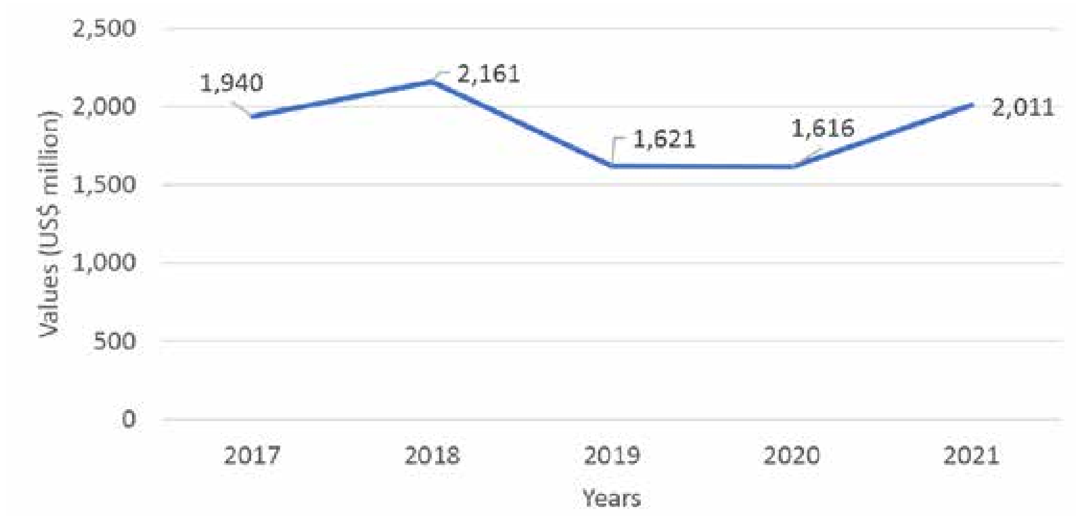

Figure 1: World imports of peat moss 2017 – 2021 CAGR 0.9% [1]

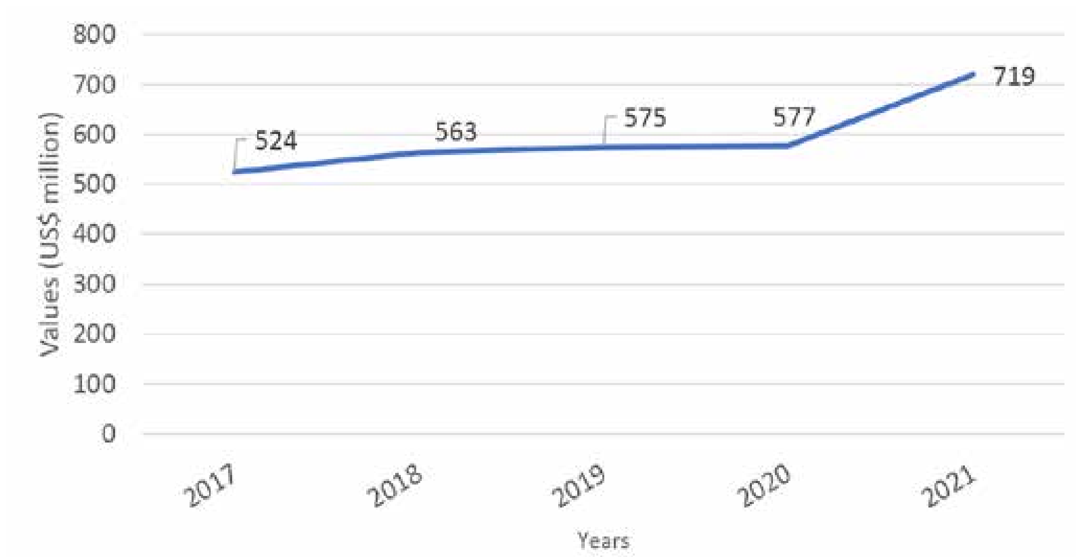

Figure 2: World imports of coconut coir pith 2017 – 2021 CAGR 8.2% [1]

The need for more non-peat materials has therefore led to the search for alternative soilless substrates, such as coconut coir pith and wood products. However, as global demand for soilless substrates is expected to increase, driven by climate change, the transition of newer crops from soil to soilless production, the increased crop production, the booming mushroom industry, and the increase in home gardening; the importance of exploring new sources of soilless growing media is becoming ever more critical in the view of future food production and food security. Figures 1 shows the global demand for peat moss which has reached US$ 2 billion in 2021, however due to the increasing pressure on extraction and trading of peat moss the growth rate was very low at CAGR 0.9% from 2017 – 2021. On contrary, the global market of coconut coir pith media was significantly smaller US$ 719 million, yet it was growing very fast at CAGR 8.2% during the same period as shown in Figure 2 [1].

Date palm is the main element of flora in the Middle East and North Africa with global harvested areas typically exceeding 1 million hectares. The estimated annual by-products of pruning of date palms globally are estimated as 5 million tons (air dry weight), which is often treated as agricultural waste [2].

Previous attempts to extract soilless growing media from date palm residues, have been limited to grinding the entire residues, which resulted in a grinded biomass of very diverse chemical, physical, and mechanical properties which is very difficult to control. This biomass was unsuitable for use as a soilless growing substrate unless it was mixed with other media and none of the previous attempts were able to develop media that can match the industry standards [3-9].

There is therefore a need for a novel soilless growing media which is capable of utilizing agricultural residues generated during pruning of date palms, that would have stable and controlled properties. Hence, the objective of this article is to illustrate the case study of developing soilless growing media from 100% date palm agricultural residues which has competitive properties that matches the industrial standards and based on a proprietary scalable technology.

Raw Material: Date Palm Agricultural Residues

Date palm (*Phoenix dactylifera* L.) residues of pruning were collected from a female Hayany cultivar from the governorate of Sharqiyah in Egypt. The residues were air dried with moisture content between 10– 15% as shown in Figure 3.

Figure 3: Date palm agricultural residues

PalmPeat® Technology

PalmPeat® has been developed based on proprietary technology (UK patent pending) for extracting lignin-rich media from palm agricultural residues. The media is characterized by a unique spongy cellular structure, with high cell rigidity and minimal fiber content, which is important to enhance the water-holding capacity as shown in Figure 4.

After development the novel PalmPeat® media have been extensively tested in key laboratories in the United States, France, Belgium, and the Netherlands.

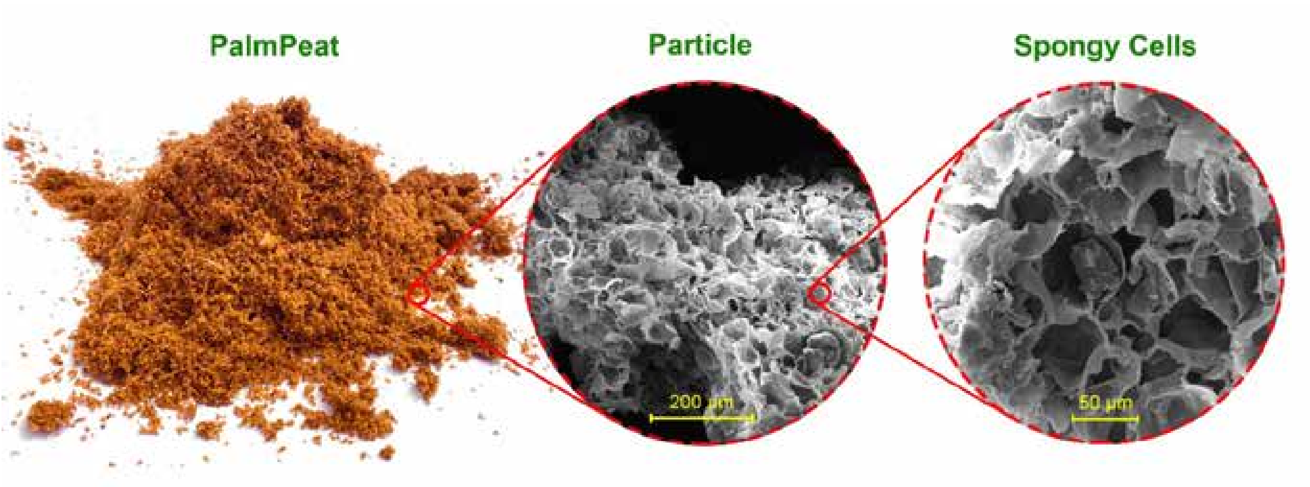

Figure 4: PalmPeat® is characterized by a unique spongy cellular structure.

Results

Table 1 lists a summary of the laboratory analysis conducted on PalmPeat®, and the results indicates that the media matches the performance requirements of the soilless media industry which made it well received and accepted by the growing media industry, through a collaboration with leading soilless growing media suppliers in Europe and the United States.

Table 1: Analysis results of PalmPeat® according to international soilless media standards

Physical Properties (Washed)		
Properties	**Values**	**Test Methods**
EC washed (ms/cm)	0.4	NF EN 13038
pH washed	5.6	NF EN 13037
Dry bulk density (kg/m^3)	107	NF EN 12580
Organic Content of dry matter (%)	91.6	NF EN 13039
Particle size (mm)	1 – 8	-
Fiber Content (%)	2 – 5	-
Expansion Ratio (l/kg)	12 – 15	-
WHC (ml/100gm)	600 - 700	-
Oxygen uptake (mmol O_2/kg o.m./h)	7	-

Macro/ Micronutrients (Unwashed)		
Nutrient Ions	**Values**	**Test Methods**
$N-NO_3$- (mg/l)	<0.050	NF EN ISO 11885
P (mg/l)	1.01	NF EN ISO 11732
SO42- (mg/l)	3.3	NF EN ISO 11885
Cl- (mg/l)	9.7	NF EN ISO 11885
$N-NH_4$+ (mg/l)	0.110	NF EN ISO 11732
K+ (mg/l)	89.26	NF EN ISO 11885
Mg_2+ (mg/l)	119.26	NF EN ISO 11885
Ca_2+ (mg/l)	183.31	NF ISO 9297
Na+ (mg/l)	78.71	NF EN ISO 11885

Metallic Trace Elements		
Elements	**Values**	**Test Methods**
Cadmium (mg / kg MS)	0.07	NF EN ISO 11885
Chrome (mg / kg MS)	4.88	NF EN ISO 11885
Copper (mg / kg MS)	5.25	NF EN ISO 11885
Mercury (mg / kg MS)	<0.011	NF EN ISO 12338
Nickel (mg / kg MS)	<0.27	NF EN ISO 11885
Lead (mg / kg MS)	<0.53	NF EN ISO 11885
Zinc (mg / kg MS)	13.6	NF EN ISO 11885
Chromium + Copper + Nickel + Zinc (mg / kg MS)	24.00	NF EN ISO 11885

Pathogens		
Organisms	**Values**	**Test Methods**
Escherichia coli (UFC/g MB)	<100	NF ISO 16649-2
Clostridium perfringens (UFC/g MB)	<100	NF EN ISO 7937
Enterococcus (/ g MB)	40	NF EN ISO 7899-1
Other microorganisms		
Listeria monocytogenes	Not detected	NF EN ISO 11290-1
Salmonella	Not detected	NF EN ISO 6579-1
Helminth eggs	Absence	FD X33-040
Biological Analysis	Not detected	DNA Multiscan
Nematodes	Not detected	Nematodes t.b.v. RHP
Pesticides	Not detected	LC-MSMS, GC-MSMS

Germination Testing

A germination test to check any phytotoxicity of PalmPeat® was conducted in France, which started on 16/5/2023 and ended 26/5/2023. The species used for germination was Ocimum basilicum, whereas the growing media used were per the experimental plan shown in Table 2.

Table 2: Experimental plan for conducting the germination test

Media	Composition			
	Blond Peat (%)	Black Peat (%)	PalmPeat® (%)	PGMix (Kg/m³)
M1 (Reference)	70	30	0	0.5
M2	35	15	50	0.5
M3	0	0	100	0.5

The experiment was conducted in 43 cm x30.5 cm sowing trays, using Photometer (HANNA HI83399-02), Multiparameter (HANNA HI5521-02). The sample dilution followed 1/5 EN method, the humidity target (GM) was 70 – 80%, using clear water, and artificial light at temperature 20°C. The number of seeds/tray was 50 and the number of replicates was 3 times. The trays were filled with 2-3 cm of growing media with the addition of 50 basilic seeds each. The seeds were covered with vermiculite and the trays were kept in a climate-controlled room made for multiplication.

The results indicated that all replicates met the 80% germination threshold (including the smaller sprouts) as shown in Figure 5.

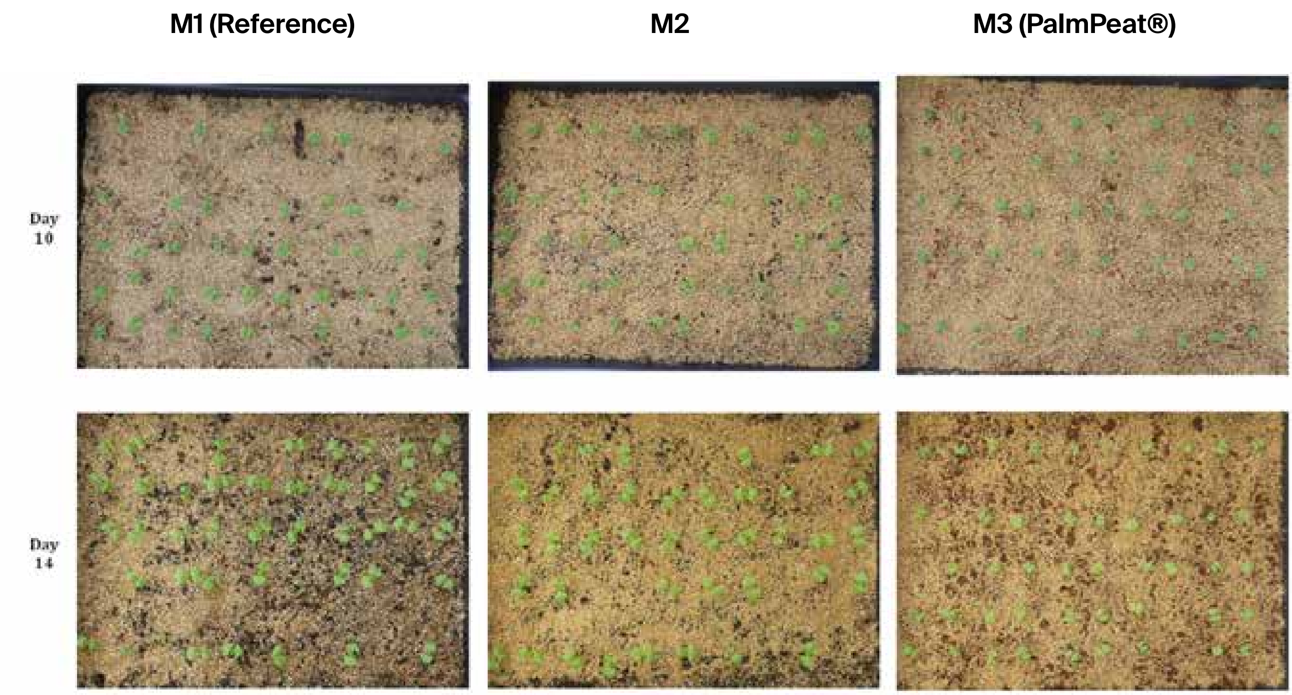

Figure 5: Germination experiment results after 10 and 14 days

Applications

PalmPeat® technology contributes to global food security by providing a sustainable peat-free soilless media, to fulfill the urgent and increasing demand for alternative media. PalmPeat® proprietary extraction technology could also be applied to agricultural residues of other palm species such as oil palm, and sugar palm. The unique features and characteristics of PalmPeat® make it an excellent sustainable growing media for a wide range of applications. Ranging from horticulture, floriculture, nurseries, gardening, landscaping, indoor farming, hydroponics, organic farming and lawns as shown in Figure 6.

Figure 6. Annuals, biennials, flowerpots, Chrysanthemums and perennials are major crops used in horticulture

PalmPeat® is very versatile and can be processed into various substrates, including particles with uniform texture, high water-holding capacity and high porosity, providing good drainage while retaining moisture and enabling healthier root growth. It can also be processed into chips that promotes aeration of substrates and allows easy repotting, which is ideal for growing orchids and for balancing air to water ratio for different applications. Or it can be processed into mulch with decorative appearance, that preserves humidity, limits rapid evaporation during summer, prevents erosion, and limits weeds growth as shown in Figure 7.

Palmpeat® can be wrapped in growbags in different sizes, which is ready to use and can be supplied with planting, dripping and drainage holes and can be reused in multiple growing cycles. It can also be compresses into blocks of various sizes, which are very easy to use and cost-effective in transportation, and can easily expand and transform into fluffy PalmPeat® by adding water. It can be pressed into discs which is ideal for starting seedlings and floriculture crops as shown in Figure 8.

Figure 7: PalmPeat® is very versatile and present in form of (a) particles, (b) chips, and (c) mulch

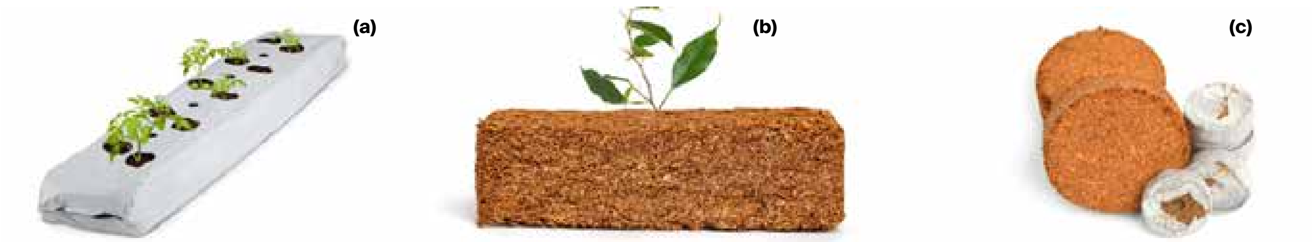

Figure 8: PalmPeat® ca be packaged in (a) growbags, (b) compressed bloacks, and (c) discs

Conclusion

PalmPeat® is peat-free media obtained from renewable bioresources which does not threaten the sensitive sphagnum peatland ecosystem. It is 100% biodegradable and compostable It is carbon dioxide neutral and consumes very low amounts of water and energy during extraction (sun-dried).

PalmPeat® is obtained from date palm, which is widely grown across the Middle East and North Africa, with very high populations in Saudi Arabia, Iran, UAE, Iraq, Egypt, Algeria, and Tunisia. This close proximity to major markets in MENA region and Europe minimizes the transportation carbon footprint, With estimated global availability that can reach up to 1 million tons/year (moisture ~20%).

PalmPeat® is obtained from palm agricultural residues and does not require extra investment in water, fertilizer, pesticide, or land. Those residues are often regarded as agricultural waste, with zero price in the field. Valorizing these residues provides an extra source of income for palm growers and generates thousands of decent jobs. In addition to, creating entire value chains within rural communities.

PalmPeat® has the excellent water-holding capacity and excellent airspace for better root aeration, root growth, and drainage. It has controlled pH and EC levels for the exchange of nutrients. Its spongy structure allows absorbing nutrients and slowly releasing them. It has excellent wettability and decomposition rate, hence can be reused in multiple growing cycles.

PalmPeat® is free from weed seeds, pathogens, nematodes, and harmful micro-organisms. The material has up to 90% organic matter, and it is safe during handling, use, and disposal. It has no traces of harmful pesticides or heavy metals.

PalmPeat® can be used in the same way as sphagnum peat moss and coconut coir pith. It doesn't require any special preparations or setup. It is available in compressed form as well as direct grow bags for easy use. It can also be easily mixed with other soilless media, fibers, or fertilizers.

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Sustainable climate smart technologies in agriculture:

Case study on introducing sprouting units following the living lab approach in Lebanon

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Abstract

Lebanon's food security crisis, exacerbated by climate change, underscores the urgent need to enhance agricultural resilience and adaptive capacity. To address this issue, the Environment and Sustainable Development Unit (ESDU) at the American University of Beirut, introduced the living lab (LL) concept in three Lebanese small ruminants sites: Akkar, Baalbek, and Hasbaya. The units integrated circular economy principles through the use of regenerative technologies incorporated in a barley sprouting unit. Results indicate that the LLs achieved self-sufficiency in water and energy, with a potential to produce 18,500Kg of sprout annually. This paper assesses the impact of the implemented labs based on the three sustainability pillars. Socially, LLs fostered capacity building and knowledge sharing, benefiting farmers and enhancing their adaptability to climate change. Cooperatives played a crucial role in facilitating access to knowledge and resources. However, monitoring and evaluation are key to ensure sustainability beyond the project's lifespan. Economically, preliminary analysis suggests that the optimized system can generate profits within a year, but initial capital and technical training pose challenges. Environmentally, the study showed that self-sufficiency in energy and water resources was achieved, contributing to year-round feed availability with minimal environmental impact.

However, further research and optimization is required to determine the optimal level of sprout supplementation in animal diets. Ultimately, the integrated system of sprouting units with animal operations is promising. The living lab approach serves as a compelling case study to encourage investments in climate-smart agriculture, offering a path towards a more resilient and sustainable agricultural future in Lebanon.

Introduction

Lebanon suffers from severe food insecurity, with the country being dependent on imports representing more than 80% of its consumption (Carnegie Middle East, 2023), and with more than 55% of the Lebanese population being trapped in poverty with the exacerbating socioeconomic situation (ESCWA, 2021). Climate change is worsening the ongoing catastrophic crisis. The Ministry of Environment estimated that climate change will cause a 14% fall in Lebanon's GDP by 2040, falling further to 32% by 2080, due to direct impacts (e.g. rising temperatures, increased scarcity of water resources) and indirect impacts (e.g. increased energy demand, rising rate of infectious diseases, decrease in agricultural output) (ESCWA, 2021). It is therefore crucial to build self-sufficiency by investing in agricultural resilience and adaptive capacity.

Small ruminant dairy production is an important sector within agriculture in Lebanon, especially in rural areas and among the most vulnerable communities. Although still in a primitive stage, it holds a great potential for growth given the high demand for local dairy products, the importance of this sector in enhancing rural livelihoods, and the availability of farming locations in Bekaa, North and South Lebanon. The country has, in fact, a high capacity of dairy production that can reach 160,000 metric tons per year. Nevertheless, the local supply satisfies only a third of the Lebanese market demand (BlomInvest Bank, 2016). Problems impeding local production for smallholder farmers include access to adequate funding, lack of technical skills, access to markets, lack of distribution channels, lack of locally produced good quality feed and competition from big industries. (AgEcon Search, 2022)

Based on the above, to ensure food security, maintaining agriculture as a job option and opportunity for the next generation of farmers is a must. Consequently, there is a need for new models of innovation to support and build resilience at all stages of the agro-food value chain,

A living lab (LL) is a concept utilizing stakeholder engagement processes to address complex societal problems. According to the European Network of living labs (ENoLL) it is as a user-centered, open innovation ecosystem using a systematic user co-creation approach while integrating research and innovation processes in real life communities and settings. In general, a living lab offers the opportunity to integrate sustainable research, design, and innovation over a longer time period. It is a platform for trans disciplinary exchange, development, and knowledge creation. (Food and Agriculture Organization of the United Nations, 2021).

With that being said, the Environment and Sustainable Development Unit and the American University of Beirut (ESDU), in partnership with the World Food Program (WFP), implemented the CLIMAT 2 Project "Climate and Livestock: Mainstreaming appropriate technologies" for the aim of addressing climate change with a special focus on the livestock sector. CLIMAT 2 aimed at strengthening the resilience and adaptive capacities of farmers and rural communities to decrease the negative impact of climate change on agricultural activities in areas with low levels of climate change resilience. The project focused on the small ruminants sector and implemented sustainable solutions based on the circular economy principles through the living lab concept.

In this paper, the impact of the installed LLs on the three pillars of sustainability will be assessed. Results are based on the monitoring and evaluation and impact assessment reports developed during and following up on the project implementation.

Materials and methods

Site selection

The project was implemented in three Lebanese sites; Akkar, Baalbek, and Hasbaya. The selection was made following the "CLEAR" study, commissioned by the World Food Programme (WFP) to the Issam Fares Institute at the American University of Beirut (AUB-IFI) in 2020. This study used several criteria but mainly focused on climate change susceptibility. It was, in fact, noted that the zones with the highest agricultural density, were also the most vulnerable to climate change and food insecurity. Overall, these three zones scored low on climate resilience capacity due to high poverty, low income-diversity, and the high sensitivity of crops to climate change. (Issam Fares Institute, 2020)

Selection of climate smart technologies for the living lab

The selection of the technologies to be piloted in each living lab were based on the circular agriculture concept. The latter consists of using agricultural biomass and food processing in a chosen food system as regenerative resources, hence resulting in closing the loop of nutrients and materials, reducing resource use and negative discharges, and valorizing the agro-food waste. The chosen technologies complement each other within the established "lab" and would be of direct benefit to the livestock farmers and their communities as they can demonstrate many solutions at once that the farmers can adopt depending on their critical needs.

Accordingly, the following technologies were installed in each unit, in the three sites, respectively:

- A 3000W Solar photovoltaic panels to power ventilation, lighting and irrigation within the unit
- A 8000L rainwater harvesting system to ensure the unit's water needs
- A sprouting barley unit consisting of metal support structures, trays and irrigation lines

Figure 1: Water harvesting units installed within the chosen sites

Figure 2: Solar panels installed within the Hasbaya Living Lab

The original installations targeted a maximum output of around 390Kg of sprouted barley per month. However, the optimized model has the capacity to produce 1560Kg on a monthly basis.

The hydroponic sprouting barley unit and rain harvesting technologies address the limited water resources in the project areas while leading to soil preservation due to minimal water runoff and decreased pollution from fertilizers. The solar energy supply serves to minimize the dependency on fossil fuel use and resulting emissions which directly alleviates climate change. Finally all organic waste is composted to complete the organic material cycle.

The Living Labs were housed under the custody of an active cooperative in each location. The farmers' within this cooperative are responsible for running the facility beyond the project's lifetime and following up on the optimization process through ongoing monitoring and evaluation in partnership with ESDU.

Capacity building and training

Capacity building modules were developed and delivered to 25 farmers in each location, for improving knowledge, skills and enhancing awareness on the following topics:

- Climate change and mitigation options
- Climate smart agriculture
- Circularity in agriculture
- Business development, Marketing, and social skills

In addition, 7 farmers in each location were selected to receive advanced training and serve as facilitators in further advancing awareness to fellow farmers. The specialized trainings included:

- Best practices in livestock management
- Intercropping for local forage production
- Circularity in livestock production
- Business development, marketing, and social skills
- Field visit and training on the implemented climate smart technologies in the local Living Lab

Data collection and monitoring

The project was completed in summer of 2022 and was followed by regular monitoring and evaluation visits for the following year. Data collected included verbal and written reports by the cooperatives hosting the living labs. The data collected covered technical, financial, and social aspects of the operation such as:

- Amount of sprout produced by the units
- Energy and water consumption of the units
- Technical problems and challenges
- Farmers access and use of the units
- Other information

The data was used for optimizing the systems' operations as needed, as well as for evaluating the overall sustainability of the installed units.

Figure 3: Sprouted fodder systems installed in the living labs

Figure 4: Sprout units within the living labs

Results

Social sustainability indicators

The capacity building and training activities were evaluated through pre – post questionnaires and showed a shift in the perception of farmers towards the practices that could be adapted and used under climate change.

The figures below represent the perception change of the farmers following the capacity building (Fig. 5) and advanced training activities (Fig. 6) (Impact assessment report by Dr. Katarina Diehl).

Figure 5-Topics perceived as most suitable for adaptation by the participants after the first training

Most of the farmers showed a level of commitment towards keeping the labs running beyond the scope of the project. However, two main problems were encountered. First, the low capacity of the lab due to budget constraint, resulted in insufficient feed yield. Consequently, the farmers were not able to fully integrate the sprout within their livestock. Then, considering the novelty of in vivo processes to the targeted beneficiaries, ongoing awareness raising on the manipulation and benefits of the implemented technologies were needed to persuade the farmers on the full adoption the models.

Environmental sustainability indicators

Following optimization, the LLs were self-sustained in terms of water and energy demands at the initial level of production of around 18,500Kg of sprout per year. Using renewable technologies diminished the generation of greenhouse gases emissions considering that the Lebanon's energy mix primarily relies on fossil fuels. Additionally, water harvesting has been proven to be an effective climate change mitigation especially in dry regions similar to the ones chosen within the CLEAR study. Below is a summary of needed and supplied resources:

Table 1: Quantity of water (L) and energy (Wh) needed and supplied to the living labs

	Quantity needed	**Quantity supplied**
Water (L)	13000	16000
Energy needs per hour (Wh)	1232	2200

In addition to water and energy consumption, the optimization process addressed other technical issues observed during operation. Most importantly, the best conditions for barley seed treatment, temperature and humidity control within the units were determined to limit mold growth considering that moldy sprout is not suitable for animal consumption.

On a different note, chlorine treatment of the seeds for mold control was also tested. The technique resulted in non-palatable sprout that was rejected by the animals.

Consequently, the optimized model achieved full control of mold growth and high sprout palatability through temperature and humidity control and without the use of chlorine.

Economic sustainability Indicators

The preliminary cost-benefit analysis of the optimized system indicated cost recovery and revenue generation within a year of installation of such units. Below is the summary analysis. It was assumed that 1560kg of sprout were produced on monthly basis and the market price was 0.7$/kg:

Table 2-Cost to benefit analysis of the CLIMAT 2 living lab

Total CAPEX	$ 8,726	USD
Monthly running cost	$ 321	USD
Monthly revenue	$ 1,092	USD
Monthly net profit	$ 771	USD
Net profit per year	$ 9,255	USD
Payback time in years	0.9	Years

As shown in table 2, for 1560kg to be produced an initial investment of 8726$ is needed. The expected net profit is about 9255$/year resulting in a payback period of 0.9 years or 11 months.

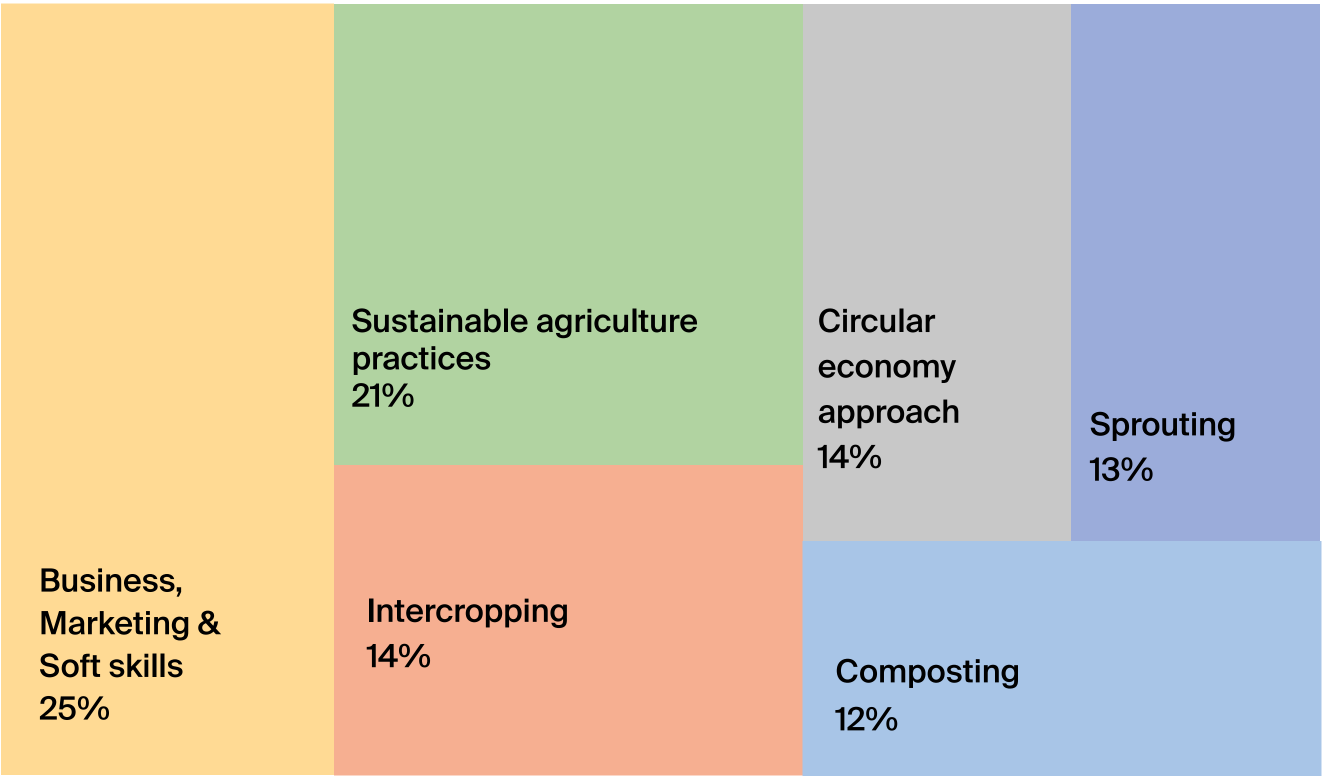

Figure 5: Topics perceived as most suitable for adaptation by the participants after the first training

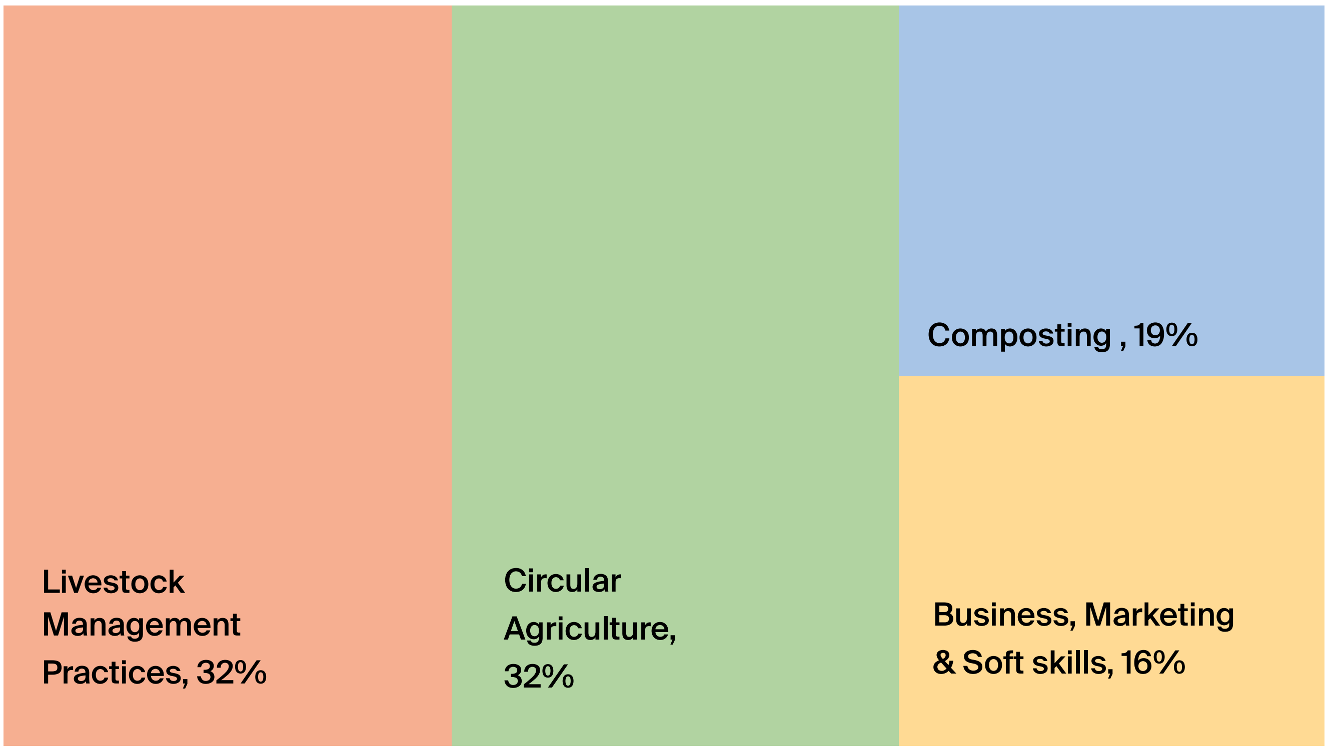

Figure 6: Topics perceived as most suitable for adaptation by the participants after the advanced training

Discussion

Social sustainability

The social pillar of sustainability addresses people's quality of life within their communities and the positive interactions within these societies. In Lebanon, cooperatives play an important role in organizing interactions within the farmers' communities (International Labor Organization, 2020). This study highlighted the importance of farmers' organizations and cooperatives in facilitating access to knowledge and services. The hosting organizations of the living labs played an important role in ensuring the proper functioning and fair access to the living labs to the beneficiary farmers.

Furthermore, tailoring the transmitted information to the beneficiaries' need is crucial to ensure impactful activities. In fact, the capacity building laid the basis for improving knowledge about climate change causes, effects and mitigation measures, sustainable agricultural practices, circular economy approaches and business development strategies. Additionally, the training topics were selected upon the needs and potentials to develop actions towards sustainability such as the adoption of the new technologies demonstrated in the living labs.

On the other hand, this study sheds light on an important challenge in rural development projects which relates to sustainability beyond the project lifetime (Hamadeh, 2006). The monitoring and evaluation visits beyond the project's lifetime were important factors in diagnosing adaptability gaps and ensuring the ongoing engagement of the hosting cooperatives and the farmers. This aspect was crucial for the ongoing running and optimization of the living lab units.

Overall, the living lab approach was positively received by the community eliciting high interest and engagement.

Environmental sustainability

The original installations of the three living lab units had a limited production capacity, however it was enough to serve as pilot for optimizing the conditions for operation at full capacity. The unit has the potential for self-sufficiency in meeting the energy and water needs which results in a year round feed source for animals with minimal environmental impact.

On the other hand, the conditions for optimal operation may not always be observed and accordingly it is expected that external energy and / or water inputs may be needed. Furthermore, sprouted barley is currently included as supplementary feed for small ruminants which does not fully replace the main concentrate or roughage components of their rations. Further studies are needed to optimize the level of sprout supplementation in a balanced ration for sustained animal health and production. This is particularly important in extensive and semi extensive systems where animal nutrition is greatly affected by the quantity and quality of available grazing resources, with high seasonal variation. The in vivo studies on animals are needed to complement the assessment of the environmental sustainability of the sprouted barley as feed alternative.

Economic sustainability

Based on this study, it is projected that the optimized system can generate net profit before the end of the first year of operation. However, an initial capital is still needed for the installation of the unit. This starting capital is often off-limits for small farmers. Similarly, technical training and skilled follow-up are needed for the unit operation. These factors could be challenging for adopting these technologies at a larger scale. However, the living lab approach, can be viewed as a convincing case study to encourage risk avoiders to invest in such ventures based on the real life experiment of the units under conditions similar to theirs. Micro financing options remain limited in Lebanon thus, preventing many SMEs and farmers from adopting new technologies and improving their operations (World Bank, 2023). As for the required skills development and trainings on new technologies such as in this case, here again there is lack of dedicated extension agents and training centers to that end (International Labor Organization, 2020). Academic research and development units such as the ESDU often collaborate with NGOs for filling this gap and address the highly needed capacity building in climate smart agriculture.

Finally, the full economic potential of the unit, can only be determined based on the integrated system of the sprouting units with the animals operation. This system's approach has the potential to be socially, environmentally and economically sustainable, pending additional testing with the animal component data included.

Conclusion

In conclusion, this study emphasizes the significant impact of the living lab approach on social, economic, and environmental sustainability. Socially, it highlights the role of cooperatives and capacity building in enhancing community life and knowledge access, while also addressing project sustainability challenges. From an environmental standpoint, living labs can achieve self-sufficiency in energy and water resources, with potential benefits for animal diets. Economically, the optimized system can generate profits but faces challenges like initial capital requirements and technical support, especially when scaled up. It ultimately serves as a compelling case study to encourage investments in similar ventures, especially in regions like Lebanon, where micro financing and training resources are limited, advocating for collaboration between academic units and NGOs to address these challenges and promote climate-smart agriculture.

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Artificial Intelligence in the Service of Climatic Agriculture

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I - Introduction

The use of artificial intelligence (AI) in recent years has revolutionized many industries and sectors, including the agricultural field which has witnessed a significant transformation in traditional farming practices and paving the way for more efficient and sustainable methods (Dharmaraj and C. Vijayanand, 2018; Liu, 2020; Ahhmed *et al*., 2022; Sharma *et al*., 2023). One area where AI has shown great promise is in agriculture, particularly in the mitigation of environmental change impacts on global sustainable food production or security. By using the power of AI, farmers are now able to make more informed decisions, optimize processes, and adapt to changing climatic conditions, ultimately leading to more productivity and sustainability.

AI has the potential to drive social innovation in the agricultural sector. By leveraging AI-powered agricultural technologies, small farm holdings can overcome unique challenges and optimize their operations. For instance, AI can provide personalized recommendations and guidance to farmers based on the specific needs and constraints of small farms, enabling them to make informed decisions regarding water management, crop selection, crop rotation, nutrition management, timely harvesting, type of crop to be grown, optimum planting, resource allocation, and pest attacks.

II - AI in Climatic Agriculture

This article explores the profound impact of AI in climatic agriculture and emphasizes its potential benefits and challenges in the following areas:

- Climate Change Adaptation
- Soil (Health, Monitoring, and Management)
- Crop Maturity Observation
- Weed Control and Smart Pesticide Spraying
- Precision / Smart Pesticide Spraying
- Breeding Seeds
- Field Harvesting
- Sustainability
- Supply Chain Management
- Solutions for Value Chain
- Smart Weather Data Management
- Crop Disease Detection and Management
- Irrigation and Water Management
- Risk Management
- Market Demand Analysis
- Farm Management
- Predictive Agricultural Yield/Produce
- Data Management
- Labor Management
- Livestock Management
- Food Preventing Loss / Food Safety Risk
- AI-Powered Precision Techniques and Climate Predictions

Climate Change Adaptation

Climate change is considered one of the significant challenges for agriculture, with changing weather patterns and extreme events affecting all types of activities in the farm including soil health and crop productivity. Predictive models and technological devices/systems combined with AI can help farmers adapt to any type of change by providing insights into how soil conditions may evolve in response to climate variability. This information allows farmers to adjust their farming practices.

Soil (Health, Monitoring, and Management)

Soil health and management play a critical role in agriculture, affecting crop growth, nutrient availability, and overall farm productivity. Soil health is considered to be one of the primary applications of AI in climatic agriculture. Previous traditional methods to assess soil quality mostly require several laboratory tests and it is expensive and time-consuming. The advantages for the farmers, when using AI, are numerous. It allows the farmers to collect soil data and monitor soil health or conditions in a short time, optimize nutrient management for healthy crop growth (nutrient levels, pH, and organic matter content), and improve crop yields. and use different sensors and data analysis techniques. These new technologies also provide recommendations on the optimal fertilizer application rates to the farmers to ensure that crops receive the necessary nutrients for healthy growth. AI-powered soil monitoring systems leverage advanced sensors and IoT (Internet of Things) technology to capture real-time monitoring and analysis of soil health parameters, ensure optimal soil conditions and improve water efficiency for plant growth, help farmers identify potential issues promptly and minimize all types of risk of crop failure, and increase production and profitability by enabling them to make better and intelligent decisions at every stage of the crop cultivation process, and result in more sustainable farming practices.

AI can also analyze soil data to detect the presence of diseases or pests. After monitoring soil conditions and correlating them with disease or pest infestations, systems powered by AI can provide early warnings, and this will help farmers take timely preventive measures. This approach helps reduce crop losses and minimize the need for chemical treatments.

In addition to real-time monitoring, AI can be used to develop predictive models for soil health. After analyzing the data collected from the farm, AI can identify patterns and correlations between soil parameters and crop performance. This information can be used to predict future soil conditions, optimize farming practices, and maximize yield.

Finally, traditional soil sampling and laboratory analysis can be time-consuming and costly. AI-powered technologies offer a more efficient alternative. Soil sensors equipped with AI algorithms can collect data on nutrient levels directly from the field, eliminating the need for manual sampling. This real-time data collection enables farmers to make immediate decisions regarding fertilizer application and nutrient management.

Crop Maturity Observation

Another area where AI proves invaluable is in crop maturity observation. Advanced algorithms, combined with image recognition technology, can accurately determine the maturity stage of crops. This data enables farmers to plan harvesting schedules more effectively, ensuring a higher crop yield and minimizing waste. Additionally, AI-powered cameras deployed in fields can monitor crop health, detecting early signs of diseases or infestations, allowing for timely intervention and preventing substantial losses.

Weed Control and Smart Pesticide Spraying

Traditional methods of weed control and spraying often involve the use of harmful chemicals that can have detrimental effects on the environment and human health. However, with the introduction of AI-powered robots, farmers now have access to more sustainable and precise solutions (Bak and Jakobsen, 2004; Bhagyalaxmi *et al*., 2016). AI-driven weed control and cultivation strategies can minimize the reliance on herbicides while ensuring the health and productivity of crops. Robotic weed control and precision spraying are two ground-breaking advancements in agriculture that have been made possible by AI technology.

Robotic weed control systems utilize computer vision and machine learning algorithms to identify and target specific weeds in agricultural fields. These robots are equipped with cameras and sensors that can distin-

guish between crops and unwanted vegetation. Once the weeds are detected, the robots can autonomously apply the necessary herbicides with precision, minimize the use of chemicals, reduce the risk of damaging crops, minimize labor costs, and increase crop productivity.

Precision / Smart Pesticide Spraying

AI takes into account plant health, weather conditions, and soil moisture levels to optimize the amount of pesticides or fertilizers needed. In this case, AI plays a crucial role in smart pesticide spraying, reducing the need for misuse of chemicals. Using AI algorithms and machine learning techniques helps farmers to optimize the amount and timing of spraying required for each specific area, targeting only the areas affected by pests, therefore minimizing waste, reducing environmental impact, and lowering costs.

Breeding Seeds

Plant breeding is an effective way for agriculture production and food security, whereas information tech-

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nologies are effective ways to promote plant variety improvement (Zhao *et al*., 2022). Breeding seeds that are resistant to climate change is an area where AI can have an impact. With AI, vast amounts of genetic data can be collected and analyzed, and desirable traits in plants can be identified to speed up the breeding process. This includes developing drought-tolerant or heat-resistant seeds that can withstand the effects of a changing environment. The ability to create resilient crops using AI has the potential to secure food production for future generations. Khan *et al*. (2022) prepared an extensive review on how applications of AI technology, utilized for current breeding practice, assist in solving the problem in high-throughput phenotyping and gene functional analysis, and how advances in AI technologies bring new opportunities for future breeding, to make enviro-typing data widely utilized in breeding.

It is well known that Agricultural work is difficult, and labor shortages are nothing new in the agricultural sector. Field harvesting is another area that benefits from AI technologies. Autonomous vehicles equipped with AI-driven algorithms can efficiently harvest crops, reducing the reliance on human labor and easing logistics. AI-powered machines, such as harvesting robots (Bendig *et al*.,2012; Bhagyalaxmi *et al*., 2016) can identify and harvest crops at the optimal time, minimizing losses due to delayed or premature harvesting.

Sustainability

Sustainability is a pressing concern in modern agriculture, with a focus on minimizing carbon emissions, conserving water resources, and mitigating the effects of climate change. AI plays a crucial role in achieving these sustainability goals (Linaza *et al*. 2021). By analyzing weather patterns, soil conditions, and crop characteristics, AI algorithms can provide actionable insights for farmers to apply the optimal number of inputs for each crop, optimize irrigation, reduce chemical and water usage, and adopt climate-smart agricultural practices.

Supply Chain Management

In developed and developing regions, supply chains of crops are vulnerable to several disturbances such as biotic, abiotic, and risk factors (Tzachor, 2022). One area where AI systems have made a significant impact in digital agriculture is supply chain management. Systems powered with AI can analyze huge amounts of data related to production, logistics, and distribution. Machine learning algorithms can optimize supply chain processes, ensuring timely delivery of agricultural produce and reducing wastage.

Solutions for Value Chain

AI enables integrated solutions for the agriculture value chain, bringing together various stakeholders such as farmers, suppliers, processors, and retailers. By integrating data from different sources, AI platforms can streamline processes, improve collaboration, and enhance transparency across the value chain. This integration improves the profitability for all stakeholders, increases efficiency, and leads to better decision-making. In a recent study, Ganeshkumar *et al*. (2021) stated that AI adoption in agricultural value chain could increase agriculture income, enhance competitiveness, and reduce cost. Most workers on value chain widely used AI for water resource management, yield prediction, energy efficiency, price/demand forecasting, optimaization of fertilizer/pesticide usage, crop planning, personalized advisement, and predicting consumer behavior.

Smart Weather Data Management

Management of weather data is an essential step toward implementing sustainability and precision in agriculture (Math *et al*. 2008; Djordjevic and Dankovic, 2019; Roukh *et al*., 2020; El Hashimi *et al*., 2023). In the past several years, researchers have been able to collect weather data with high spatial and temporal resolution. The study conducted by El Hashimi *et al*. (2023) represents an important input for numerous tasks, such as crop growth, development, yield, and irrigation scheduling, to name a few. The proposed smart weather data management system makes use of state-of-the-art statistical methods, machine learning, and deep learning models to derive actionable insights from these raw data. The system offers various services such as weather time series forecasts, visualization and analysis of meteorological data, and the use of machine learning to estimate important parameters needed daily for efficient irrigation. The platform, offered by the researchers, is designed to be service-oriented and incorporate other services to help farmers and policymakers.

Crop Disease Detection and Management

Crop diseases pose a significant threat to agricultural productivity and food security, and traditionally farmers had to manually inspect their fields, spending countless hours trying to identify signs of diseases or nutrient deficiencies in their crops. With the advent of AI-driven crop monitoring systems, farmers now have access to advanced technologies that can accurately analyze and predict the health of their crops. AI can analyze images of crops to detect early signs of diseases, nutrient deficiencies, or pest infestations (Soroker *et al*., 2013; Thulasi Priya *et al*., 2013; Bhagyalaxmi *et al*., 2016; Mahdavinejad *et al*., 2018; Farooq *et al*., 2019; Alaa *et al*., 2020; Ashry *et al*., 2020; Culman *et al*., 2020; Yasi and Rehman, 2021; Mohanta *et al*., 2020; Ahmed *et al*., 2022; Delalieux *et al*., 2023)

AI, combined with high-resolution satellite imagery, weather patterns, sensor networks (IOT or the Internet of Things), and drones equipped with multispectral cameras, enable farmers to monitor their fields in real-time with greater precision and detect diseases at an early stage, leading to improved yields and reduced environmental impact. AI can identify signs of diseases, such as discoloration or wilting, even before they become visible to the naked eye. In the past few years, several studies have been conducted on the subject:

1. Alla *et al*. (2020) proposed a novel method to monitor palm trees to detect three of the most common diseases and pests threatening date palm trees (leaf spot, blight spots, and red palm weevil). The diagnosis was carried out by capturing normal and thermal images of palm trees, and the image processing techniques were applied to the acquired images. This study gave satisfactory accuracy and reliability through aerial thermal imaging before visual symptoms of red palm weevil is observed on the palm canopy.

2. Ahmed *et al*. (2022) presented a survey of IoT in climatic smart agriculture and stated the IoT components, agricultural network architecture, and communication protocols that help farmers gain access to IoT and improve crop productivity. The study considered several IoT agricultural challenges and opportunities to better understand IoT when applied in smart farming. They expected that that IoT in smart agriculture and automation would soon replace traditional farming methods.

3. Delatieux *et al*. (2023) monitored date palm using a temporal Unmanned Aerial Vehicle (UAV) carrying RBG, multispectral, and thermal sensors. Maximum canopy temperatures and thermal spectral monitoring in this study showed the potential to detect the presence of the weevils.

4. Agrint Company created its IoTree highly sophisticated algorithms-based seismic sensor which meets the following criteria by detecting the borrowing activity of red palm weevil larvae inside the tree. I have evaluated the IoTree sensor's system on date palm trees in UAE. The sensor, installed on each palm tree, was capable of detecting very few larvae in a tree, capable of detecting larvae in their first week of life after hatching, the detection accuracy was 95% with a low level of false-positive alerts (<5%). The study was designed and tested under outdoor conditions at a temperature of up to 60 Celsius degrees and 100% humidity.

The above-stated technologies provided valuable information on crop growth patterns, the presence of diseases or pests, water stress or loss, reducing the reliance on chemicals, minimizing the environmental impact, and promoting sustainable farming practices.

Irrigation and Water Management

Water plays a major role in the climate system and in mediating the impacts of climate variability and change on all sectors of the economy (Bell *et al*., 2014). Water scarcity is a significant challenge in agriculture, particularly in the previous few decades and in regions with limited water resources. AI offers innovative solutions for water management in agriculture. By collecting data on soil moisture, weather conditions, and plant water requirements, AI algorithms can analyze the data and optimize irrigation schedules, minimizing water wastage and maximizing crop productivity (Bhagyalaxmi *et al*., 2016; Dela Cruz *et al*., 2017; González Perea *et al*., 2018; Talaviya *et al*., 2020). Furthermore, AI can enable the use of smart irrigation systems that adjust water delivery based on real-time conditions, ensuring efficient water utilization.

Risk Management

AI aids in risk management by predicting and mitigating the impacts of extreme weather events (Zechun and Sijian, 2023). By knowing the historical weather patterns and large-scale climate data, AI algorithms can analyze the patterns and forecast the likelihood of droughts, floods, or other extreme conditions, enabling farmers to implement adaptive measures in advance. Additionally, AI can facilitate hazard broadcasting, sending alerts and warnings to farmers and agricultural communities to help them prepare for or respond to potential crises efficiently.

Market Demand Analysis

Market demand analysis is an important aspect of agriculture where AI is involved. Farmers may utilize AI to address essential issues, including market demand analysis, pricing predictions, and determining when to plant and harvest crops (Javaid *et al*., 2023). After consumer purchasing patterns and market dynamics are analyzed, AI can provide farmers with valuable insights to guide their production decisions. This ensures that farmers can align their crop choices with market demands, minimizing waste, and maximizing profitability.

Farm Management

AI-based farm management systems have transformed the way farmers plan and manage their operations. These systems can analyze data from sensors, drones, and satellite imagery to provide real-time information about soil conditions, crop health, and weather patterns. With the help of these systems, farmers can make data-driven decisions regarding irrigation, fertilization, and planting schedules, optimizing yields and resource utilization.

Predictive Agricultural Yield/Produce

AI has revolutionized the processing of agricultural produce, leading to improved efficiency and quality. Predictive models, powered with AI, can estimate crop yields based on many parameters such as soil health, weather data, and other factors. By understanding the relationship between soil conditions and crop performance, farmers can make informed decisions about crop selection, planting density, and resource allocation. This predictive approach helps optimize yield and maximize profitability.

AI-powered sorting and grading systems can accurately classify fruits, vegetables, and grains based on their size, shape, color, and quality ((Javaid *et al*., 2023). This can assist farmers in sorting the fruit into stacks of varying readiness levels before sending them to market. This automation reduces manual labor, minimizes wastage, and ensures consistent product quality, thereby enhancing the competitiveness of agricultural products in the market.

Data Management

The proliferation of IoT devices and sensors in agriculture has resulted in huge amounts of data being collected, stored, and processed in a very short time on farms, and processing this massive quantity of data needs to use specific infrastructure that uses adapted IoT architectures (Debauche *et al*., 2022). AI plays a crucial role in managing and analyzing this data efficiently. AI-powered data management systems can aggregate, integrate, and analyze data from multiple sources, providing valuable insights for farmers. This data-driven approach enables precision agriculture, where farmers can tailor their interventions to specific areas of their farms, optimizing resource utilization and minimizing environmental impact.

Labor Management

Labor management is a critical aspect of agricultural operations, and AI can assist in optimizing labor utilization and reducing costs. AI-powered systems can analyze labor requirements based on crop cycles, weather conditions, and farm activities, enabling farmers to plan and allocate labor resources efficiently. Additionally, AI can automate repetitive tasks, such as harvesting and weeding, reducing the need for manual labor and increasing productivity. We need to keep in mind that the substitution of physical labor with sophisticated machinery and robots should generate demand for new labor competencies needed to manage increasingly capital-intensive agricultural production and related processes driven by the use of AI (Figiel, 2022).


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Livestock management

The IoT technology is expected to make a breakthrough in livestock management by connecting biological information of livestock and environmental information obtained by IoT sensors to farmers who are in remote locations from the farm via cloud (Iwasaki *et al*., 2019). Through the use of sensors and AI algorithms, farmers can monitor the health and behavior of their animals more effectively. This technology enables early detection of diseases, facilitates targeted treatments, and ensures optimal living conditions for livestock, ultimately resulting in better animal welfare and improved livestock productivity.

Food Preventing Loss / Food Safety Risk

Climate-induced changes in temperature, precipitation, rain patterns, and extreme weather events impact the yield, quality, and safety of food (Delcour *et al*., 2015; Karanth *et al*., 2023). With climate change, there have been increasing instances of observed changes in the safety of food, particularly from a microbiological standpoint, as well as its quality and yield. Therefore, there is a need for the implementation of advanced methods to predict the food safety implications of climate change (Semenza *et al*., 2012; Uyttendaele *et al*., 2015; Maggiore *et al*., 2019). AI and other such advanced technologies have, over the years, permeated many facets of the food chain, spanning both farm-to-fork production and food quality and safety testing and prediction (Njage *et al*., 2019; Taddeo *et al*., 2021; Misra el al., 2022). Karanth *et al*. (2023) provided a roundup of the latest research on the use of AI in the food industry, climate change, and its impact on the food industry, as well as the social, ethical, and legal limitations of the same. AI can play a crucial role in preventing food loss and promoting food recovery. After collecting data from the supply chain, including storage conditions, transportation routes, and expiry dates, AI algorithms can analyze the data and identify potential areas of food loss, and recommend preventive measures. In addition, AI can enable real-time monitoring of food quality and freshness, ensuring that only high-quality produce reaches the market.

AI-Powered Precision Techniques and Climate Predictions

AI technology enables accurate climate predictions by analyzing vast amounts of data collected from diverse sources and technical devices (Sensors, satellites, weather stations, IoT devices, unmanned aerial vehicle or UAV, image processing, and machine learning) (Ahmed *et al*., 2022). By utilizing machine learning algorithms, AI can identify patterns and correlations that humans may overlook. These predictions allow farmers to make informed decisions regarding crop selection, planting schedules, and resource allocation, mitigating the risks associated with extreme weather events.

The convergence of AI and Agricultural Technology has revolutionized the way farmers and agricultural businesses operate, unlocking a multitude of possibilities to increase productivity, efficiency, and sustainability in

the industry. AI-driven precision farming techniques offer immense advantages in climatic agriculture. Through the integration of AI, sensors, and robotics, farmers can monitor soil conditions, moisture levels, and nutrient deficiencies in real time. This data-driven approach allows for precise application of water, fertilizers, and pesticides, reducing waste, and optimizing crop yield. In addition, AI-powered robots can perform labor-intensive tasks such as planting, weeding, and harvesting, minimizing the need for human intervention and increasing efficiency. Moreover, AI-enabled drones and satellites are revolutionizing the way we monitor crops and land conditions. These advanced technologies provide farmers with high-resolution imagery, helping them identify potential issues such as water stress, nutrient deficiencies, or disease outbreaks before they become critical.

The potential of AI and Agtech is vast and ever-expanding. As technology continues to evolve, we can expect even more groundbreaking innovations in the agricultural sector. From autonomous farming machinery to advanced robotics and smart irrigation systems, the possibilities seem endless. The future of agriculture is undoubtedly intertwined with AI and Agtech, and embracing these technologies is key to unlocking a sustainable and thriving agricultural industry.

III - Challenges and Limitations of AI in Agriculture

Based on the information stated in this article, AI is being integrated into climatic agriculture, resulting in the use of fewer resources and enabling precise cultivation, leading to higher crop yields and better quality. And while AI holds tremendous potential or solutions for improving crop productivity and ensuring sustainable agriculture for future generations, it is very important to acknowledge and address the challenges and limitations that come with their widespread adoption and implementation:

1. ***Limited availability*** or access to technology. There is a need to ensure that AI technologies are accessible and affordable for small-scale farmers, promoting equitable benefits across the agricultural sector.

2. ***Data quality.*** Ensuring the availability of reliable, accurate, and up-to-date data is crucial for the effectiveness of AI-powered systems and for making informed decisions. AI rely on high-quality data for accurate analysis and predictions. Obtaining consistent and high-quality data can be a challenge in agriculture due to factors such as varying environmental conditions, crop variability, and limited access to real-time data in remote areas. It also requires standardized data collection protocols, data sharing platforms, and collaboration among stakeholders.

3. ***Cost of implementing AI.*** Maintenance costs of AI-powered systems can be a barrier for small-scale farmers, especially those in developing countries. There is a need to make the technologies more affordable and accessible to farmers by increasing subsidies and financial incentives.

4. ***Farmer education and adoption.*** To fully benefit from the use of AI, farmers need to be educated and trained in using these AI-powered technologies effectively and have the necessary knowledge and skills to interpret AI-generated insights and implement data-driven farm management strategies.

5. ***AI expert.*** The interpretation of AI results may require expert knowledge and understanding. Farmers may need to invest time and effort into learning how to navigate and utilize AI systems effectively.

6. ***Job displacement.*** As AI technology automates certain tasks and processes in agriculture, there is a concern that it may lead to job losses in the industry. It is essential to find a balance between leveraging AI capabilities and preserving employment opportunities for farmers and agricultural workers.

7. ***Ethical and privacy concerns.*** As AI technologies become more prevalent in agriculture, ethical and privacy considerations need to be addressed. Farmers should have control over their data and understand how it is being used. Clear guidelines and regulations should be established to ensure data security, privacy protection, and responsible AI implementation.

IV - Conclusion

Artificial intelligence (AI) has emerged as a powerful tool in climatic agriculture and the future of AI in this sector is promising. The AI-powered technologies and the development of more cost-effective AI technologies, in recent years, have revolutionized various aspects of the agricultural industry and benefit small-scale farmers. Observations from soil health and monitoring to crop maturity, supply chain management to sustainability, and risk management, AI enables farmers to make data-driven decisions and adapt to the challenges posed by climate change. By adopting the potentials of AI, agriculture can become more sustainable, efficient, and resilient, helping to increase productivity and sustainability, secure food production, and reduce the impacts of environmental impact on a global scale.

The challenges that must be overcome to unlock the full potential of the use of AI in agriculture should be identified and its integration provides opportunities to increase efficiency and productivity and lead to a more efficient, sustainable, and productive ecosystem. Successful implementation of AI in agriculture requires a deep understanding and a well-crafted approach, which can be achieved through research, development, and collaborative efforts with technology companies from various industries to enhance agricultural technology advisory and software development services. AI can pave the way for a more resilient and sustainable future in agriculture, ensuring global food security for generations to come.

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Forests...

A free service from nature to humans and the climate

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Our lives depend entirely on the land and sea for both food and livelihood. Where forests are the most biologically diverse ecosystem on earth, as it contains more than 80% of the earth's species of animals, plants and insects.

Forests cover 30% of the earth's surface and are vital habitats for millions of species, as well as a source of clean air and water, and essential for combating climate change, which will have many catastrophic consequences on humans around the world in the coming decades, unless we act quickly to confront it.

At COP26 - Glasgow, world leaders announced their commitment to stop deforestation and work on their safety, after reports by the Intergovernmental Panel on Climate Change (IPCC) revealed that deforestation is the second largest source of greenhouse gas emissions causing climate change after the energy sector. According to recent studies, the land sector is responsible for 25% of global emissions (1), and deforestation and forest degradation contribute to half of this percentage.

What is a forest?

There are an estimated three trillion trees on Earth (2), some of which are part of large forest ecosystems such as the Congo rainforests, while others are located in sparsely populated areas such as the edges of the Sahara Desert. Out of 60,000 known tree species, nearly a third are threatened with extinction (3), according to a recent assessment. Scientists have been unable to agree on a single definition of a forest due to disagreements over tree density, height and crown cover.

However, the most common and widely used is the FAO definition of forest (4): "Land extending over 5 hectares with trees taller than 5 meters and a crown cover of more than 10 percent."

Forests covered nearly one-third (5) of the world's land area in 2020, with more than half of them located in just five countries: Russia, Brazil, Canada, the United States, and China. The Taiga forest - also known as the Boreal forest - is the largest in the world, extending around the northern hemisphere through Siberia, Canada and Scandinavia.

Temperate, tropical, and boreal types are the three main types of forests that include a great diversity of ecosystems. There are cloud forests, rainforests, mangrove swamps, tropical dry forests, and many other types.

Why are forests important for climate?

Forests are among the most biodiverse places on the planet and constitute of huge carbon stocks, regulate the world's weather and climate, and billions of people depend on them for food, building materials and shelter.

Forests contain about 861 gigatons (6) of carbon – equivalent to a century of annual fossil fuel emissions at the current rate – and absorb twice as much carbon as in the past two decades.

Carbon is stored in forest's soil (44%), in living biomass (42%), and the rest is found in dead wood (8%) and forest litter (5 %). Forests, such as the Congo Basin rainforest, the world's second-largest forest, affect rainfall thousands of miles around the Nile .(7) We also see that forests are being cleared at a very rapid pace, and the world has lost about 10 percent of tree cover since the year 2000, according to Global Forest Watch. (8).

Although estimates vary, the land sector is the second-largest emitter of greenhouse gases and accounts for about a quarter of global emissions, according to the Intergovernmental Panel on Climate Change, of which deforestation is a major part. Many scientists say it would not be possible to limit global warming to 1.5°C above pre-industrial levels without stopping deforestation.

There is a close relationship between forests and carbon, forests are a natural store of carbon, meaning that in the case of deforestation, carbon dioxide is released into the atmosphere.

On the other hand, healthy forests have been shown to be a huge carbon sink that absorbs it from the atmosphere over time, and if this sink or carbon sink disappears, the land loses a free service provided by forests, as a natural store of carbon.

Old-growing forests protected from artificial human intervention and pollution are of particular importance to climate and biodiversity because of their great carbon storage capacity.

Proto-forests, they are ancient, carbon-intensive ecosystems that explode with life, such as parts of the Amazon Forest, the Białowieża forest in Poland and the forests of Papua New Guinea.

Primary forests are home to the largest trees and the widest variety of life forms, so conservationists are doubly focused on protecting these forests from fire, human intervention, and logging, as they account for only a third of the planet's forest cover.(9)

In contrast, young or restored forests store less carbon (10) and can sometimes take several years before they become effective ponds.

Tropical rainforests, mangrove forests and peat bogs – such as those in Southeast Asia – play a variously important role in climate regulation, due to the amount of carbon they store, their ability to cool the atmosphere and the protection they provide from flooding.

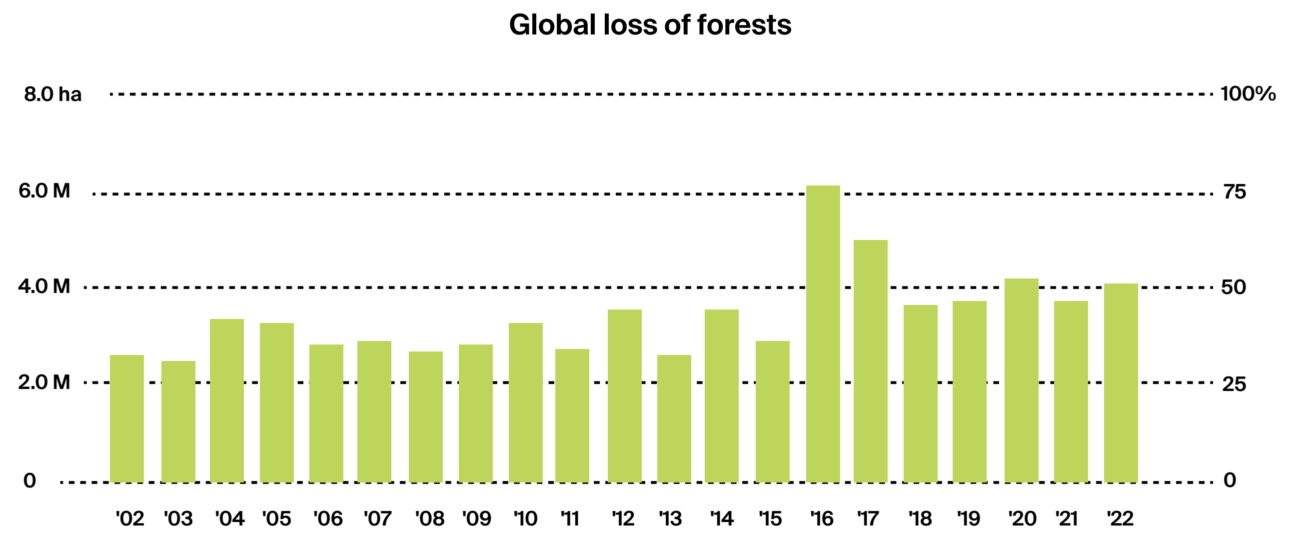
Boreal forests, covered in snow for large parts of the year, reflect more heat back into the atmosphere and have a net warming effect on the climate.

Agricultural tree farms with very few species are less carbon intensive and support much less life.

What is deforestation?

Deforestation is defined as a human-driven diversion to the use of forest land for purposes other than natural, such as raising livestock or producing soybeans, and forests are often machined and then burned.

Deforestation has gone hand in hand with human development for centuries, and all the temperate rainforests that once covered large parts of the British Isles have been cleared for agriculture, road construction and human settlements, for example.



Source: /https:/lwww.globalforestwatch.org

Forest land use change, in addition to being a major source of carbon emissions, is also one of the main factors for biodiversity loss, which scientists have warned11 as leading to the so-called sixth mass extinction of life on Earth.

Last year, Brazil, the Democratic Republic of Congo, Bolivia, Indonesia, and Peru were the top five countries in terms of primary tropical forest loss.

About 12 million hectares (30 million acres) of tree cover have been lost in the tropics. This includes 4.2 million hectares of primary forest, an area the size of the Netherlands, emitting emissions equivalent to the annual emissions of 570 million cars.

Experts say that the main reason behind deforestation is purely economic, as deforested forests are more monetary-value than living forests.

In Brazil, large parts of the Amazon forest have been cleared to pasture livestock for beef production. In Indonesia, forests and peatlands were cleared and drained to establish palm oil plantations. In other areas, forests have been cleared to grow coffee, cocoa, bananas, pineapples, coca leaves, etc. Most deforestation hotspots are located in the tropics, and are also profitable areas for agriculture.

Poverty, particularly in Africa, is one of the most important causes of deforestation, as there is demographic pressure in some areas, which drives many poor rural people to encroach on forests to earn a living.

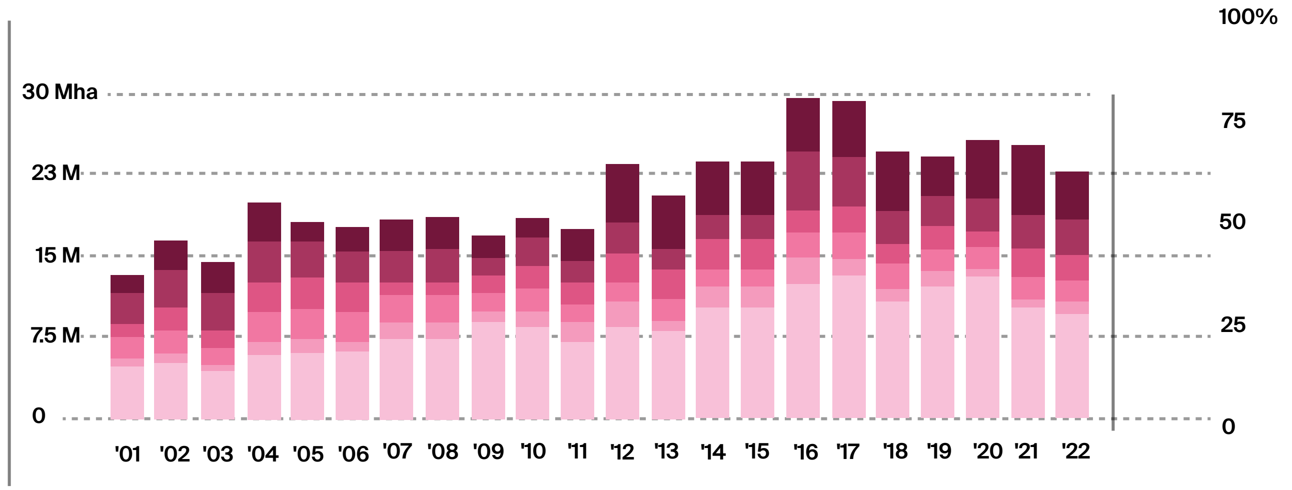
The importance of stopping deforestation

Reducing emissions from fossil fuels is the most urgent task to avoid further global warming. But if the world continues to lose forests, it risks tipping points with unintended consequences.

In 2021, world leaders in Glasgow committed to stopping forest encroachment, and it is hoped that major producers and consumers of deforestation-related goods will be involved in eradicating encroachment from the global supply chain.

The world needs to restore forests to meet climate and biodiversity goals (12), and to restore their role in combating climate change by absorbing and storing carbon. However, scientists say stopping deforestation is an urgent task because it immediately emits carbon while nature takes decades to recover and sequester carbon from the atmosphere.

Global annual tree cover loss



Source: /https:/lwww.globalforestwatch.org

Primary forests that have survived for thousands of years cannot be replaced by tree plantings, if encroachment continues, the Amazon can turn into a savannah (13), boreal forests can fade, and the carbon stock that took thousands of years to sequester can be released. Experts warn of the danger to food security, weather systems and millions of other species.

(REDD+)

Reducing emissions from deforestation and forest degradation, or REDD+, is an internationally recognized tool for mitigating the effects of climate change and preserving forests.

REDD+ reduces deforestation through conservation and sustainable forest management and supports developing countries in transforming their political commitments, as outlined in their Nationally Determined Contributions, into action on the ground.

Negotiations on reducing emissions from deforestation and forest degradation in developing countries, known as REDD+, were first negotiated under the United Nations Framework Convention on Climate Change (UNFCCC) in 2005, with the aim of reducing climate change by reducing net greenhouse gas emissions by strengthening forest management in developing countries (14).

The Rainforest States Alliance was created in response to what many see as a failure to address a major source of global greenhouse gas emissions, and in 2005 they proposed to the Conference of the Parties to the United Nations Framework Convention on Climate Change positive incentives to reduce greenhouse gas emissions from tropical deforestation and forest degradation as a measure to mitigate climate change.

During COP13 in Bali in 2007, the United Nations Climate Change Conference (REDD+) was endorsed as a tool to combat climate change. In 2009, at the Fifteenth Conference of the Signatories to the United Nations Framework Convention on Climate Change in Copenhagen, the meeting reached what became known as the Copenhagen Convention, which in section VI recalls the recognition of the critical role of reducing emissions from deforestation and reducing emissions from deforestation and forest degradation in developing countries, and the need to provide positive incentives for such actions by allowing the mobilization of financial resources from Developed countries.

Section VIII of the agreement goes on to indicate that the collective commitment of developed countries to new and additional resources, including afforestation and investments through international institutions, will be approximately US$30 billion for the period 2010-2012.

At the Seventeenth Conference, the Green Climate Fund (GCF) was established as a financial mechanism for the United Nations Framework Convention on Climate Change (UNFCCC), including financing for reducing emissions from deforestation and forest degradation.

It was formally adopted as a framework, the so-called Warsaw Framework, in 2013 at the nineteenth Conference of the Parties in Warsaw, and provides methodological and funding guidance for the implementation of REDD+ activities.

The Warsaw Framework for Action on Reducing Emissions from Deforestation and Forest Degradation (REDD) refers to the Global Cooperation Framework, which mandates developing countries to apply for financing.

The GCF currently funds REDD+ programmes in Phase I (NAP design and capacity building) and Phase II (Implementation of NAPs or NAPs).

The Paris Climate Agreement recognises the REDD+ programme and the central role of forests in Article V, with the final parts of the rulebook completed in 2015.

To date, 118 countries have included forest and land use in their INDCs. This represents 162 million hectares of restored, reforestation and afforestation land, which is in line with the Bonn Challenge and the New York Declaration on Forests.

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Sustainable Indoor Vertical Farming Initiatives Through Construction Waste Management:

Industry-Academia Partnerships

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Introduction

During and post-pandemic, when we faced the harsh realities of disruptions within the food supply chain, we, as a key player in the construction sector, started to reflect on how we could leverage our inherent strengths in the mechanical, electrical, and plumbing (MEP) engineering to contribute to food security and the agriculture sector in Dubai, United Arab Emirates.

Therefore, in December 2022, as part of our commitment to climate change action and regional circular economy initiatives, Bin Dasmal Contracting decided to combine a non-revenue-focused construction waste management program with the advancement of sustainable indoor vertical farming solutions into a new entity, officially established as ekthaar Agricultural L.L.C.

The new 'Made in UAE' agri-tech model would contribute to educating local communities on the immense potential of enhancing local food production, complementing the agriculture sector, and generating new careers in future.

Our current sustainable farming solutions comprise

- Sustainable Greenhouse with Controlled Environment Agriculture (CEA)
- Indoor Vertical Farm (IVF)
- IVF with movable container model
- Portable models for flats and villas

To date, we have effectively executed three fully operational initiatives within our factories in Dubai Investment Park and Dubai Industrial City.

Mission

Our mission is to educate regional developers, corporations, and universities about the possibilities of "reducing and recycling" construction waste materials while creating eco-friendly greenhouses and indoor vertical farms (IVFs). Through knowledge sharing, we aim to collaboratively empower communities and industries with alternative agri-tech sustainable urban farming models adaptable to any available or underutilized space.

Caption 1: IVF with movable container model ©ekthaar

The objective is to also train the public and private sectors on the economic benefits of cultivating and harvesting fresh, local produce with excellent nutritional value; conveniently close to consumers. This approach also preserves the environment for next generations by increasing the production of fresh produce with less soil and water.

Industry-Academia Partnerships

Our commitment to addressing food security and taking action on climate changes has also led us to embark on an educational outreach effort. We chose to use our fully-operational initiatives as case studies to educate universities and developers by highlighting the significant potential of alternative agri-tech solutions.

In our ongoing pursuit of aligning our quality benchmarks with global standards for vertical farming, we are engaging with the education sector wherein we are willing to assign certain aspects of the R & D to university students in the UAE to get fresh insights into areas such as automation, remotely operated harvesting procedures, and so on.

This is in line with the UAE Green Agenda Programs (2015-2030) (The United Arab Emirates' Government portal, 2023)

- National Green Innovation Program: Research initiatives that support the emergence of a knowledge-based green economy
- Green Workforce & Talent Program: Promote partnership between academia and industry.

It also underpins the progress made by our country - the UAE ranked first in the Middle East and North Africa (MENA) region on the Global Food Security Index (GFSI) 2022, issued by Economist Impact, compared to the third place in the region for the year 2021. According to the index, the UAE ranked first in the overall food security index and in the food availability indicator, second in food quality and safety, and fifth in food sustainability and adaptation as well as affordability (WAM 2022).

Alignment With United Nations Sustainable Development Goals

At the project's outset, we decided to align our solutions with specific United Nations Sustainable Development Goals (UN SDGs), which would later be adopted by regional communities, corporates and universities alongside encouraging construction waste recycling


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at source by developers. The specific UN SDGs were (United Nations Sustainable Development, 2023):

- UN SDG Goal 2.4: By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality (Sustainable Development Solutions Network, 2023).
- UN SDG Goal 12.5: By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.

Market Potential

Our initial objective was to revitalize neglected urban industrial areas and transform vacant spaces within office compounds into productive agricultural spaces using the net house and polyhouse CEA models.

Today, our intent has strengthened further when we note that the global vertical farming market size will exceed USD 35.3 billion by 2032, up from USD 5.6 billion in 2022, and it is expected to achieve a compound annual growth rate (CAGR) of 20.8% from 2023 to 2032 (Market.us, 2023). Meanwhile, the value of the GCC market in 2022 was approximately USD 144 million and is expected to reach nearly USD 472 million in 2028 with a CAGR of about 22% during the forecast period (Infiniumglobalresearch.com, 2023).

On 4 September 2023, the Food and Agriculture Organization of the United Nations (FAO) and the Agriculture Innovation Mission (AIM) for Climate – a joint initiative by the United States and the United Arab Emirates – announced a new partnership to help governments spend smarter on agriculture to mitigate the adverse effects of climate change on food and agriculture (FAO, 2023).

In the light of the growing strain on public finances in many countries owing to socio-economic shocks, together with the visible impacts of climate change on food and agriculture, this initiative will offer governments a climate-conscious package of analyses and tools that could help expedite inclusive agricultural transformation.

The package includes policy-related evidence into the categories of agricultural expenditures that might require adjustments in response to the escalating influence of climate change, and is particularly valuable for guiding current decision-making, formulating national adaptation plans and strategies to meet climate commitments, as well as for crafting and implementing climate-specific projects and activities, said the partnership statement.

We hope to collaborate with public and private entities to further the UAE's goals to reduce its dependency on food imports.

Action Roadmap: From Construction Waste to Fresh Produce

To reach our goal of creating sustainable indoor vertical farming solutions, we devised an action roadmap with four key objectives.

Mindset shift: To ensure that waste generated from construction activities is handled in an eco-friendly, efficient, and sustainable manner, our first objective was to instigate a profound shift in mindset. We fostered an environment wherein engineering teams from different projects came together to share insights, challenges, and successes in waste repurposing. They underwent training to understand the importance of on-site waste segregation and sorting materials by type (wood, metal, concrete, etc.).

Today, discarded construction materials, previously destined for landfills, are carefully processed and transformed. This eco-conscious methodology not only reduces the environmental footprint but also demonstrates how sustainable practices can be seamlessly integrated between the construction and the modern agricultural sector.

This aligns perfectly with the collaborative efforts by the UAE to divert waste from landfills. Abu Dhabi Waste Management Centre (Tadweer) reported that during the first half of 2022, Tadweer successfully redirected 34% of all waste in Abu Dhabi away from landfills, and also diverted 50% of waste resulting from demolition and construction operations (Emirates News Agency – WAM, 2022).

Repurpose space: The second objective entailed converting the vacant spaces and scrap yards within office compounds into productive agricultural spaces using the net house and the polyhouse CEA model. The transformation would contribute to local food production and potential employment opportunities.

Currently, we are engaged in discussions with other developers who have vacant spaces within their projects; we are enthusiastic about the prospect of applying similar agri-tech models to educate them on how to grow farm produce and supply fresh produce to the community.

Portable models: Our third objective was to develop a solution for individuals living in flats and villas to cultivate basic day-to-day fresh produce, thereby, reducing reliance on imports and enhance healthier lifestyles; excess produce could be readily distributed within the local community. We are currently in the process of creating templates and models leveraging our innate capabilities across the construction sector. Through our capacity to provide turnkey services, we anticipate cost reductions by 30-40%, further enhancing the feasibility of these initiatives.

Careers in sustainability: Our fourth objective is centered around educating university students who are aspiring to pursue a career in sustainability, and provide them with opportunities to engage in research and developmental efforts with us, particularly, in the field of upgrading our initiatives. Currently, we have established collaborations with final year mechanical engineering students from Herriott-Watt who have the opportunity to choose and work on different projects such as next-level automation and mitigation studies. This hands-on experience not only benefits the students but also contributes to the growth and enhancement of our agri-tech initiatives.

Operation: Philosophy, Design, and Implementation

Central to ekthaar's operational philosophy is the deployment of CEA, an advanced hydroponics-based methodology that orchestrates a meticulous balance between horticultural and engineering techniques.

Through this method, ekthaar's indoor vertical farms ensure optimal crop production, quality, and efficiency. This agri-tech approach sharply diverges from conventional farming practices and involves careful management of water resources, reduced soil dependency, and the creation of tailored microclimates.

In conventional agriculture, soil serves as the primary medium for accessing essential nutrients. However, in hydroponics, the need for soil is eliminated by directly supplying the roots with a nutrient-rich solution in a precise and timely manner.

Nutrient Film Technique

The Nutrient Film Technique (NFT), a hydroponic method well known for its efficiency, simplicity, and scalability, has been aptly harnessed by ekthaar to suit their unique agricultural requirements.

In this method, a controlled environment is created to supply nutrient-rich cold water to a plant's root zone by regulating temperature, humidity, and lux through the use of LED grow lights. Simultaneously, parameters such as water temperature, pH, electric conductivity, and dissolved oxygen are continuously monitored to maintain them at the desired levels, all with minimal human intervention.

Fundamental Design

The basic components of a container model comprise:

- **Anchor medium:** Hydroponics is soil-less growth, but plants still require a support structure; ekthaar employs inert mediums such as rock wool or coconut coir as a support framework without influencing the nutrient composition.
- **Channels or troughs:** Plants are placed at regular intervals in specially-designed and slightly sloped channels or troughs to ensure the unobstructed flow of nutrient solution.
- **Nutrient flow:** A thin film of nutrient-rich water continuously circulates over the roots of the plants to ensure consistent access to the nutrients and oxygen. We maintain optimal plant health and growth by closely monitoring and adjusting the pH and nutrient levels.
- **Dynamic lighting:** The system utilizes highly-efficient LED lights and power modes to optimize lights for accelerated growth and efficiency.
- **Reservoir:** The reservoir serves as the container for the nutrient solution and requires regular checks to ensure optimal nutrient and pH levels.

Circulation system

The circulation system comprises:

- **Pump:** A pump is employed to circulate the nutrient solution from the reservoir to the higher end of the channels. Due to the slope and gravity, the solution flows down thus ensuring a continuous film over the roots. This set-up ensures that the reservoir remains cool and well-aerated to prevent any root diseases.
- **Return System:** At the lower end of the slope, any surplus nutrient solution is collected and directed back to the reservoir for re-circulation, thus, ensuring minimal wastage and consistent nutrient availability to the plants.

Monitoring and Maintenance

This comprises:

Nutrient Balance: The system's nutrient balance is upheld at an optimal level through regular monitoring of the nutrient solution's pH and electrical conductivity (a measure of nutrient concentration). Adjustments are made as necessary to ensure peak efficiency.

Cleaning: The channels and system components are regularly cleaned to prevent clogging and ensure a steady flow of the nutrient solution.

Successful Pilot Case Studies

Study 1: We successfully transformed the scrap yard behind our factory into a thriving agricultural space with a nethouse to grow fresh local vegetables such as eggplants, corn, cucumbers, okra, and tomatoes; irrespective of the temperature and soil conditions.

Caption 2: From a factory scrapyard to thriving nethouse ©ekthaar

Study 2: In another instance, we converted an empty parking lot into a greenhouse at one of our factories. Both of these models are versatile and can be implemented in any industrial, commercial or residential spaces, where under-utilized areas can be repurposed into spaces growing fresh produce.So far, we have reached out to property developers, including Dubai Investment Park, to establish collaborative partnerships. These entities have embraced our container model to educate the entire community, encompassing both residents and schools, about the transformative potential of repurposing unused/limited spaces into productive, sustainable agricultural areas.

Caption 3: From parking lot to greenhouse in an industrial area©ekthaar

Sustainable Greenhouse Model with CEA vs Traditional Agriculture Models

A comparison between sustainable farming and conventional farming methods yielded the following results:

a. **Agriculture value chains:** Sustainable farming greenhouses can be built in any neighborhood, enabling enhanced local self-sufficiency throughout the year, irrespective of temperature and other factors. Since we have the in-house knowhow to build the controls, the supply chain is nearly eliminated as we reduced the cost of transporting produce from farm to store.

b. **Needs only 5% of traditional soil requirement:** Soil is the life support of conventional agriculture. We rely on soils for 95% of the food we consume. It is alarming to note that we lose the equivalent of one soccer pitch of soil every five seconds, and it takes a staggering 1,000 years to produce just a few centimetres of topsoil. On this course, by 2050, 90% of all soils are set to be degraded. Without change, degrading soils will put our ecosystems, our climate, and food security in jeopardy (FAO, 2023).

Conventional agriculture also relies on soil as a medium for plants to access essential nutrients. In a sustainable farming greenhouse, the very concept of soil becomes obsolete by directly supplying the roots with a precise nutrient-rich solution at the right time. Hence, farmers can cultivate crops most beneficial to their community without worrying about soil degradation.

c. **Space optimization:** In contrast to traditional farming techniques that require 100% of available space, our combination of sustainable farming with IVF techniques showed that the root system of each plant took up to just 5% of space. This innovative technique enables cultivating a significantly larger number of plants in smaller areas, maximizing space utilization and productivity.

d. **Produces higher yields:** Establishing ideal conditions ensures far higher yields than traditional farming methods. In fact, our sustainable farming greenhouses produced yields that far exceed those achieved through other farming practices.

e. **Less labor:** Sustainable farming is less labor-intensive and requires lesser man-hours, making it a cost-effective way of crop production. In fact, a small sustainable farming greenhouse can be entirely managed by a single part-time worker.

f. **Water conservation:** A CEA system uses a closed-loop fertigation protocol achieving 95% of nutrients and 98% of water savings compared to traditional growing methods. Using re-circulated water allows plants to absorb only about 0.1 percent of the water through the roots and return the rest back into the system.

Caption 4: Vertical farming ensures 98% water savings ©ekthaar

g. **Year-around growth:** In sustainable farming greenhouses, we have precise control over factors like temperature, humidity, circulation, and CO_2 levels. This capability allows us to cultivate plants all year-round, regardless of the weather outside. Each greenhouse space is insulated from the challenges encountered with conventional farming techniques. Additionally, the controlled environment could also mean benefits such as reduced or entirely eliminating the reliance on pesticides and contributing to more sustainable and eco-friendly agriculture.

h. **Crop variety:** Many plants have strong preferences for a particular soil type and traditional farmers can only grow a few crops suitable to their local soil conditions. Besides, one witnesses wide variations in soil quality from one location to another. However, our sustainable farming greenhouse model removes soil constraints and offers the flexibility to grow broader variety of crops.

i. **Crops grow faster:** A controlled environment (precision and adaptability) offers better control over every aspect of the growing process compared to traditional farming. Our greenhouse is completely temperature and light controlled, enabling year-round local harvest by utilizing our unique MEP equipment, which is integrated during construction.

j. **Predictability:** Traditional farming methods are fraught with unpredictable weather challenges. Besides, calamities such as floods, fires, drought, and pest infestations can occur anytime. Any crop impacted by calamities or weather challenges may create a negative ripple effect throughout the entire food supply chain.

In contrast, a sustainable farming model can maintain precise environmental control with complete visibility and insight into farming operations through the use of software. Hence, the protective insulation and carefully calibrated interior climate protects the farmer against temperature fluctuations, pests, and plant diseases.

k. **Improved food quality:** Since we constantly monitor temperature and nutrition levels, we can ensure the best natural harvest concerning taste, nutrients, and freshness.

Benefits to Local Communities

Randy Frederick, CEA Consultant, urban-gro team, opines that CEA can really help benefit local communities when done right. “There’s enough data that shows that local and fresh are key and consumers will spend more to get that. Over 50% of the population is moving toward urban areas, and, in 10 years, it will be over 60%, so there are practical reasons why CEA produce makes sense. Local and fresh is what CEA can provide.” (Wiklund, 2023).

Our sustainable green houses employ uniquely-designed farming techniques that require only 5% of soil and water compared to the 100% requirement of water and soil in traditional farming techniques.

The facility can provide fresh, residue-free leafy greens, lettuces, and micro-greens with high nutrient content throughout the year. Consequently, issues related to seasonality and unpredictable weather conditions can be effectively addressed.

Thus, ekthaar can potentially reduce the gaps in the UAE food supply chain as the IVF container model can be built in any neighborhood. When combined with innovative sustainable farming techniques, the model offers a solution without excessive use of space, soil, or water. It is likely that this method of agriculture may emerge as an alternative source of fruits and vegetables in the future.

Global Recognition: SIF Certification

On 16 August, 2003, ekthaar Agricultural L.L.C. in Dubai, United Arab Emirates earned the distinction of becoming the first ever Vertical Farm to receive the Sustainable Indoor Farming (SIF) Certification jointly administered by the Association for Vertical Farming (AVF) and Control Union United Kingdom (UK).

In designing and administering the SIF Certification, AVF partnered with Control Union UK, which is globally respected for its independent services in auditing, certification, inspections, chain of custody assessments, and sustainability solutions – encompassing sustainability aspects of the supply chain in the agriculture, energy, feed, fisheries food safety and forestry industries, among others.

CONTROLUNION

CERTIFICATE N.: CU-SIF-001

Sustainable Indoor Farm Certified

CERTIFICATE

Issued to:

Ekthaar Agricultural LLC

Control Union declares that the practices adopted by the farm listed on this certificate have been found to be compliant with the Sustainable Indoor Farming Standard Criteria (v.1) and Standard Process (v.1), and shall be maintained for the period of validity with annual inspections.

Address	Product	Number of production sites
Sheikh Mohammed Bin Zayed Road – Dubai - UAE	Lettuce	1

Valid from: 16/08/23
Valid to: 15/08/27

On behalf of the Managing Director
Authorized by:
Marina Merola

CONTROL UNION (UK) LIMITED LONDON

Certifier
Control Union UK Limited
7th floor, 5 Greenwich View Place
E14 9NN, London
United Kingdom
http://www.controlunion.com
tel.: +44(0)20-7488-2210

Date of Certification decision:

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Conclusions

We take great care to use food-grade materials, resulting in produce of higher quality than other organic products available in the market. Our produce is notably sourced through sustainable farming practices and adheres to the strictest environmental standards. In addition to our renowned SIF certification, we are committed to ongoing investment in research and development. This commitment underscores ekthaar's pursuit of innovation and continuous improvement in agricultural endeavors to enhance our "Made in UAE" agri-tech educational model.

Our future goals include, but not limited to:

Independent testing: We will work with testing centres, municipalities, and regional governments to get the fresh produce tested independently for consumption quality.

- **Independent assessments:** We will seek detailed inputs from consultants before considering at ekthaar as a revenue model.
- **Ongoing Stewardship:** We aim to collaborate with public and private sectors and academia to become one of the leading industry benchmarks for rejuvenating and transforming industrial areas into spaces for sustainable indoor farming.
- **Enhancing regional affiliations:** We will endeavor to connect with green building councils and learn from the regional industry bodies who can provide us with updated sustainability best practices.
- **Knowledge sharing platform:** In future, we will combine our learnings with government initiatives where we will use empty areas as incubators wherein we invite farmers to discuss new technologies and implement new findings.

Conflict of Interest

At the time of writing this article, our solutions are still not revenue-focused but offer a pure sustainability initiative model for educational purposes through industry-academia partnerships.

Acknowledgments

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Under the esteemed patronage of Mr. Mohamed K. Bin Dasmal, CEO & MD of Bin Dasmal Group, we received essential support and guidance for our agri-tech initiative, Ekthaar Agricultural L.L.C. Mr. Bhaskar Rao, a distinguished Hydroponics specialist, provided technical insights that added depth and precision to our sustainable farming solutions. Additionally, Ms. Sona Nambiar, an accomplished Content Strategist, played a pivotal role in editing and enhancing the overall content of this publication.

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Climate Changes and its impact on the agricultural sector aim to adapt and reduce the impact of agriculture on climate change, which comes in response to the challenges facing the agricultural sector in general, as a result of increasing climatic changes, such as temperature increase, rainfall fluctuations, natural disasters, etc. Climatic agriculture aims to promote food production in a sustainable and climate-resistant manner, to improve farmers' sustainability and increase their resilience to increasing climatic challenges. Such agriculture is an important part of responding to the climate change crisis and ensuring the world's food security, facing increasing climatic challenges.

Climatic agriculture includes a range of practices, techniques and procedures, including selecting climatic varieties that has tolerance to high temperatures or rely on lower amounts of irrigation water, improving water consumption using effective irrigation techniques to conserve water, improving soil management and using agricultural techniques that promote soil health and improve its ability to store water and organic matter, reducing greenhouse gas emissions by lowering the use of pesticides and chemical fertilizers, planting trees to absorb carbon dioxide, and using modern technologies, such as the use of sensors, and information and communication technology to monitor and manage farms more effectively, as well as promote biodiversity.

The present book, published by the General Secretariat of Khalifa International Award for Date Palm and Agricultural Innovation, is part of the Award's participation in the Climate Change Conference (COP28), hosted by the United Arab Emirates, from the 30th of November to the 12th of December, 2023, with the participation of a group of concerned experts.

Dr. Abdelouahhab Zaid, Prof.,

Secretary General of Khalifa Int'l Award
for Date Palm and Agricultural Innovation