UNIVERSITY OF ZAGREB
FACULTY OF AGRICULTURE

A HOLISTIC BLUEPRINT FOR PROFITABLE REGENERATIVE AGRICULTURE IN ARID ENVIRONMENTS; THE CASE OF IRAQ

Amar Darwish

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A HOLISTIC BLUEPRINT FOR PROFITABLE REGENERATIVE AGRICULTURE IN ARID ENVIRONMENTS; THE CASE OF IRAQ

MASTER THESIS

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Supervisor:
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Zagreb, September 2024.

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STUDENT STATEMENT

ON THE ACADEMIC INTEGRITY

I, Amar Dawish, JMBAG0178135032, born on 06-11-1996 in Firminy, France, declare that I independently prepared the Master thesis entitled:

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REPORT

ON EVALUATION AND DEFENSE OF GRADUATE THESIS

Master thesis of the student **Amar Darwish**, JMBAG 0178135032, entitled

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was defended and evaluated with the grade ____________________, on _______________.

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Content

Summary

Of the Master thesis of student **Amar Darwish**, entitled

A HOLISTIC BLUEPRINT FOR PROFITABLE REGENERATIVE AGRICULTURE IN ARID ENVIRONMENTS; THE CASE OF IRAQ

Regenerative agriculture is a comprehensive and sustainable approach to addressing contemporary agricultural challenges, particularly in semi-arid and arid regions like Iraq. These areas face numerous obstacles, emblematic of the wider Global South. This study is grounded in sustainability theory, systems thinking, and adaptive methodologies, aiming to enhance environmental health, economic viability, and social equity. The investigation is structured as a blueprint with two main sections: first, diagnosing the problems in agriculture and their consequences, and second, presenting holistic solutions under the framework of regenerative agriculture. Key issues include the legacy of post-colonialism, neo-imperialism, urbanization, climate change, political instability, and water scarcity, which collectively undermine rural development and economic diversity. The study advocates for regenerative agriculture to foster resilience and sustainability, revitalizing local knowledge and practices. It emphasizes cost-effective techniques, requiring minimal input and aimed at ensuring profitability, creating an adaptable blueprint for sustainable rural development in arid regions globally.

Keywords: climate change, rural development, sustainable agriculture, systems thinking, water scarcity

Sažetak

Diplomskog rada studenta **Amara Darwisha**, naslova

HOLISTIČKI PLAN ZA PROFITABILNU REGENERATIVNU POLJOPRIVREDU U SUŠNIM SREDINAMA: PRIMJER IRAKA

Regenerativna poljoprivreda je sveobuhvatan i održiv pristup suočavanju sa suvremenim izazovima u poljoprivredi, posebno u polusušnim i sušnim područjima poput Iraka. Ova područja suočavaju se s brojnim preprekama koje su karakteristične za širi Globalni Jug. Ova studija temelji se na teoriji održivosti, sistemskom razmišljanju i adaptivnim metodologijama, s ciljem poboljšanja zdravlja okoliša, ekonomske održivosti i društvene pravednosti. Istraživanje je strukturirano kao plan s dva glavna dijela: prvo, dijagnoza problema u poljoprivredi i njihovih posljedica, a drugo, predstavljanje holističkih rješenja u okviru regenerativne poljoprivrede. Ključni problemi uključuju naslijeđe postkolonijalizma, neoimperijalizma, urbanizaciju, klimatske promjene, političku nestabilnost i nedostatak vode, koji zajedno ugrožavaju ruralni razvoj i ekonomsku raznolikost. Studija zagovara regenerativnu poljoprivredu kako bi se potaknula otpornost i održivost te obnovilo lokalno znanje i prakse. Naglašava se primjena isplativih tehnika koje zahtijevaju minimalna početna ulaganja, s ciljem osiguravanja profitabilnosti, stvarajući prilagodljiv plan za održivi ruralni razvoj u sušnim regijama širom svijeta.

Ključne riječi: klimatske promjene, nedostatak vode, održiva poljoprivreda, ruralni razvoj, sistemsko razmišljanje

List of abbreviations

Abbreviation	Meaning
ESP	Exchangeable Sodium Percentage
FAO	Food and Agriculture Organization
GPS	Global Positioning System
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
IQD	Iraqi Dinar
ISIL	Islamic State of Iraq and the Levant
RA	Regenerative Agriculture
SAR	Sodium Absorption Ratio
SOC	Soil Organic Carbon
TWAIL	Third World Approaches to International Law
USD	United States Dollar

1.Introduction

Global food demand is projected to increase by 60% by 2050, highlighting the urgent need for sustainable agricultural practices, especially in arid regions (Lovelli, 2019). Regenerative agriculture (RA), introduced by Robert Rodale, offers a holistic approach that rejuvenates the environment by enhancing soil organic matter. This leads to better resilience against extreme weather, improved water retention, reduced disease, and enhanced nutrient availability. Key practices include no-till farming, crop rotation, and holistic grazing, all aimed at restoring soil health and biodiversity. The shift from conventional agriculture is driven by unsustainable resource consumption, greenhouse gas emissions, rising fossil fuel costs, and the detrimental impacts of high-input agricultural systems on biodiversity, soil health, and rural communities (Leu, 2020). RA advocates for systemic changes to restore ecosystems and promote sustainability through proactive environmental engagement (Leu, 2020; Craig J, 2007). However, widespread adoption of these practices, particularly in arid environments, faces significant challenges. This thesis will analyze arid regions, which have been disproportionately affected by climate change, political instability, and water scarcity, necessitating a shift to sustainable methods. Iraq serves as a compelling case study due to its environmental degradation, historical agricultural significance, and ongoing socio-political instability. Its reliance on agriculture for rural livelihoods, despite pressures from a global capitalist system, underscores the need for viable solutions. Techniques such as conservation tillage, crop-fallow systems, water harvesting, and mulching are vital for maintaining soil moisture and reducing water loss (Kanemasu et al., 1990). As these fragile ecosystems, solutions that sound good on paper but lack profitability can be challenging to run in the long term. This study explores how regenerative agriculture can be both ecologically restorative and economically viable, proposing that with the right policies and support, it can enhance rural development in Iraq's arid regions. Economic viability is crucial because, in these fragile ecosystems, any agricultural method that does not offer tangible economic benefits is unlikely to gain traction among local farmers and stakeholders. Iraq's arid regions exemplify the pressing need for sustainable agricultural practices, particularly in a global capitalistic system that often prioritizes short-term gains over long-term sustainability. By focusing on Iraq, this research aims to provide insights that could be applicable to other arid regions of the Global South facing similar challenges, where balancing environmental sustainability with economic necessity is essential for achieving long-term success (Leu, 2020).

The neoliberal era has intensified challenges for agrarian labor and peasantry in the Global South, particularly through the rise of financialized capitalism. Transnational corporations, driven by profit, have engaged in large-scale land grabs, dispossessing peasant communities and worsening their exploitation, especially in Africa, where foreign entities, often supported by local elites, have displaced local populations and undermined their livelihoods (Moyo, 2015). Neoliberal policies, characterized by deregulation and privatization, have strengthened global capital's hold on agriculture, prioritizing corporate interests over those of small farmers, thereby increasing vulnerability and reducing autonomy. This concentration of land and resources reflects an economic system focused on private wealth accumulation and labor exploitation, fundamentally clashing with sustainable and equitable agricultural practices. The globalization of agricultural markets has further pressured small farmers, eroding traditional practices and local food sovereignty, while multinational corporations increasingly dominate production, exacerbating inequalities and threatening the livelihoods of millions (Amin, 2005). This context sets the stage for a critical examination of contemporary agricultural practices, exploring their environmental, social, and economic implications, particularly in regions facing severe ecological and social challenges.

1.1 Objective of the study:

The aim of this study is to investigate, compare, and create a blueprint for the potential of regenerative agriculture as a holistic and sustainable solution to the challenges faced by agriculture and rural development in arid and arid environments like Iraq. It seeks to understand the root causes of these challenges and compile specific solutions under the umbrella of regenerative agriculture, with a focus on enhancing environmental health, economic profitability, and social equity.

This dissertation will explore the following research Questions:

1. How can regenerative agriculture address the environmental and socio-economic challenges faced by arid regions like Iraq, particularly in the context of climate change and political instability?
2. What are the impacts of neo-colonial and neo-imperialist influences on the agricultural policies and practices in Iraq, and how can these be mitigated through regenerative agriculture?
3. What are the barriers to the adoption of regenerative agriculture in Iraq's rural communities, and how can these barriers be overcome to promote sustainable rural development?

The objectives of this dissertation are threefold: First, it aims to explore the potential of regenerative agriculture to enhance environmental resilience, economic viability, and social equity in Iraq's arid regions, particularly under the stresses of climate change and political instability. Second, it seeks to critically assess the impact of neo-colonial and neo-imperialist dynamics on Iraq's agricultural sector and propose strategies within the regenerative agriculture framework to counter these influences and promote autonomous agricultural development. Third, the dissertation intends to identify and analyze the socio-economic, cultural, and institutional barriers to the widespread adoption of regenerative agriculture in Iraq’s rural communities and develop comprehensive blueprints and actionable recommendations to overcome these barriers and achieve sustainable rural development.

2. Methodology and Theoretical Framework

The methodology outlined in this study, which combines the holistic goals of Sustainable Development (SD) with the analytical rigor of Grey Systems Theory (GST), provides a robust framework for exploring the potential of regenerative agriculture in Iraq and beyond. It ensures that the strategies developed are aligned with the principles of sustainability while also being flexible enough to adapt to the uncertainties and challenges inherent in such complex environments. The study of regenerative agriculture in Iraq's arid regions necessitates an intricate methodological approach that integrates SD theory with GST. Regenerative agriculture, which aims to rejuvenate ecosystems, enhance soil health, and promote biodiversity, aligns with the principles of SD, which emphasize the balance of economic growth, environmental protection, and social equity. SD theory, as articulated by the Brundtland Commission in 1987, underscores the importance of meeting present needs without compromising future generations' ability to do the same, making it a crucial foundation for this study. This framework is particularly pertinent in Iraq, where environmental degradation, driven by decades of conflict, political instability, and unsustainable agricultural practices, has severely compromised the natural resources essential for agriculture. Iraq's arid regions, characterized by water scarcity, soil degradation, and socio-political challenges, present a unique set of obstacles that demand innovative and adaptable solutions. GST focuses on systems with incomplete, uncertain, and sometimes conflicting information is used to analyze the challenges in achieving sustainable development goals, offering a comprehensive framework to address the multifaceted challenges of implementing sustainable agricultural practices in this context (Javanmardi et al., 2023). GST is a critical methodological tool by providing a structured approach to managing the uncertainties and complexities inherent in such environments. GST is especially valuable in situations where data is incomplete or ambiguous, which is often the case in Iraq due to the unpredictability of factors like climate change, water availability, and political instability. By employing GST, the study can model and analyze these uncertain factors, simulating various scenarios to understand better how different policy interventions might perform under uncertain conditions, where farmers are already struggling with limited resources and harsh environmental conditions. By focusing on both ecological restoration and economic viability, this study aims to contribute to the development of sustainable agricultural practices that can support rural development in Iraq's arid regions and offer insights applicable to other regions in the Global South facing similar challenges. This research highlights the importance of developing agricultural practices that are not only ecologically restorative but also economically viable, ensuring their long-term success and adoption by local communities. By applying this integrated approach, the study seeks to provide a model for balancing environmental sustainability with economic necessity, addressing the pressing need for sustainable agricultural practices in a global context where arid regions are increasingly vulnerable to the impacts of climate change and economic pressures. Through this approach, the research aims to make a significant contribution to the field of sustainable agriculture, offering practical solutions that can help restore degraded ecosystems, improve the livelihoods of rural communities, and promote long-term environmental and economic sustainability in Iraq's arid regions and other similar areas in the Global South.

3. Part 1: Diagnosing Agricultural Challenges in Iraq: Contextualizing Iraq and Arid Environments challenges.

3.1 Historical Context

Historically a self-sufficient agricultural nation, Iraq has drastically declined its agrarian productivity due to decades of conflict, mismanagement, and poor policy decisions. The area suitable for agriculture in Iraq is about 9.3 million hectares, with only around 4 million hectares harvested. Iraq's economy remains heavily dependent on the oil industry, with the value added by industry (including construction) constituting 55% of GDP in 2021, down from 85% in 2000. On the other hand, the agriculture, forestry, and fishing sectors contributed only 3% to GDP in 2021, reflecting the marginalization of these sectors in the Iraqi economy (World Bank, 2024). Iraq's agricultural sector has historically been a vital component of its economy, contributing significantly to the nation's GDP. During the 1980s, agriculture accounted for about 14% of the national GDP, reflecting the sector's crucial role despite the dominance of oil. However, the sector has faced numerous challenges, including wars, sanctions, and environmental issues. The Iran-Iraq War (1980-1988) and the Gulf War (1991) significantly disrupted agricultural production, infrastructure, and resource allocation (Schnepf, 2003). This decrease is attributed to soil salinization, desertification, and infrastructure degradation essential for agricultural productivity (Jongerden et al., 2019). Moreover, the influx of cheap food imports from Turkey and Iran and the lack of government support for local markets have severely undermined local agricultural production. Despite Iraq’s higher-than-average productivity in certain crops like wheat and potatoes, local farmers cannot compete with these imports due to high production and transaction costs (Jongerden et al., 2019). The agricultural sector remains a significant source of employment, particularly in rural areas. However, there is a growing reliance on migrant labor, especially among internally displaced persons (IDPs) such as the Yezidis, who work for low wages under challenging conditions. The reduction of subsidies for agricultural inputs such as fertilizers, seeds, and pest control has affected yearly yield. For instance, the subsidy for registered and certified wheat seeds was reduced from 70% to 30% in Marketing Year (MY) 2021/22, contributing to lower yields in MY 2022/23 (Morgan & Meador, 2023).

3.2 Colonial and Post-Colonial Legacy: Impact on current agricultural policies

Colonialism is historically understood as the direct control or governance of one nation over a dependent country, territory, or people. It is a process whereby a more powerful nation imposes its rule on another, often justifying this control through a civilizing mission or the need to exploit resources for the benefit of the colonizing power. The essence of colonialism lies in the imposition of political, economic, and cultural dominance over the colonized, often leading to significant changes in the social and economic structures of the colonized society. This process typically involves the exploitation of land, labor, and resources, which are redirected to benefit the colonizing nation, leaving the colonized regions impoverished and dependent (Chaturvedi, 2006; Okoduwa & Ibhasebhor, 2005). The colonization reorganizes local economies to serve the needs of the metropole, and the entrenchment of global inequalities that persist to this day (Ikeke, 2011). The establishment of the British Mandate in Iraq following World War I marked a critical turning point in the country's agricultural history. Under the guise of the League of Nations' mandate system, Britain effectively controlled Iraq's economic and political structures, transforming its agricultural sector to serve imperial interests. The British administration implemented policies that prioritized the production of cash crops for export, such as cotton, over subsistence farming, which had been the backbone of the Iraqi rural economy. This shift not only undermined local food security but also entrenched Iraq's dependency on global markets, a pattern that persisted long after the formal end of colonial rule (Patnaik, 2015; Davis, 2006). The colonial administration also introduced land tenure reforms that exacerbated social inequalities in rural areas. Large tracts of land were concentrated in the hands of a few wealthy landowners, many of whom were closely aligned with the colonial government. This concentration of land ownership marginalized small farmers and peasants, who were increasingly pushed into tenant farming or wage labor on large estates. The introduction of modern irrigation systems, funded by colonial revenues, primarily benefited these large landholders, further deepening rural inequalities and fostering a class of absentee landlords (Patnaik, 2015; Davis, 2006).

The term "neo-colonialism" was coined by Kwame Nkrumah, the first post-independence president of Ghana, to describe a situation where former colonial powers continue to exert influence over newly independent states through economic, political, and cultural pressures, rather than direct political control. According to Nkrumah, neo-colonialism is characterized by the nominal independence of a state, which in reality remains economically and politically dependent on more powerful nations. This influence is often exerted through mechanisms such as foreign aid, investment, and trade, which bind the developing country to the interests of the more powerful nations (Nkrumah, 1965; Sartre, 2001). Neo-colonialism differs from classical colonialism in that it does not involve direct political control or territorial occupation. Instead, it operates through economic domination, where the economic systems and policies of the so-called independent states are directed from outside. This external control is often facilitated by international financial institutions like the International Monetary Fund (IMF) and the World Bank, which impose structural adjustment programs that align the economies of developing countries with the interests of the global North. The deregulation of financial markets, the liberalization of trade, and the privatization of state-owned enterprises all contributed to the increasing power of financial institutions. This shift was marked by a transition from industrial to financial capitalism, where profits are increasingly generated through financial transactions rather than the production of goods and services (R Herrera, 2015).The impact of globalization and cultural supremacy also plays a significant role in perpetuating neo-colonial relationships, where the culture and values of the dominant power are imposed on or adopted by the subordinate nation (Sartre, 2001; Nkrumah, 1965) . The legacy of colonialism in Iraq did not end with formal independence in 1932. Instead, the country continued to experience forms of neo-colonial control, particularly through economic and military interventions by Western powers. The 1958 revolution, which overthrew the British-installed monarchy, was a critical moment in Iraq's attempt to break free from neo-colonial influence. However, the subsequent Ba'athist regime, despite its nationalist rhetoric, often relied on Western technology and expertise to modernize the agricultural sector, perpetuating a cycle of dependency (Anghie, 2004; Mutua, 2000). The oil boom of the 1970s provided the Iraqi government with substantial revenues, which were partly used to invest in agricultural modernization. However, these investments often followed the neoliberal prescriptions promoted by international financial institutions, emphasizing large-scale, capital-intensive farming at the expense of smallholder agriculture. This approach mirrored the colonial-era focus on export-oriented agriculture, as Iraq sought to increase its agricultural exports to diversify its economy away from oil dependency. However, the emphasis on cash crops over food production continued to undermine Iraq's food security, leaving it vulnerable to global market fluctuations (Anghie, 2004; Mutua, 2000).

3.3 Imperialism and Neo-Imperialist Influences: External forces affecting development

Imperialism, in its classical sense, refers to the policy or practice by which a nation extends its power and dominion over other nations, either by direct territorial acquisition or by gaining political and economic control. It is a broader concept than colonialism, encompassing not only the formal empires established by European powers but also other forms of control and influence that do not necessarily involve direct governance or settlement. Imperialism is driven by the economic and strategic interests of the imperial power, which seeks to exploit the resources, labor, and markets of the dominated territories for its own benefit (Dutt, 2010; Chaturvedi, 2006; Okoduwa & Ibhasebhor, 2005). The classic form of imperialism involved the establishment of colonies, where the imperial power exercised direct control over the political and economic systems of the colonized territories. However, imperialism can also manifest in more subtle forms, such as through the imposition of unequal trade agreements, the control of key industries or resources, or through cultural imperialism, where the values and norms of the dominant power are imposed on the subordinate nation. This broader understanding of imperialism includes not only the actions of states but also those of multinational corporations and other non-state actors that extend their influence across borders to maintain or expand their power (Igwe, 2011; Magdoff, 1978; Nkrumah, 1965; Sartre, 2001). The imposition of U.N. sanctions in 1990 exacerbated these challenges, dramatically increasing agriculture's share of GDP to 35% by 1992 as other sectors of the economy collapsed (Schnepf, 2003). These sanctions and a general stagnation in agricultural productivity increased Iraq's dependence on food imports. By 2002, Iraq imported 80-100% of basic staples such as wheat, rice, sugar, vegetable oil, and protein meals (Schnepf, 2003). The sanctions on Iraq are often cited as one of the most punishing in modern history, leading to a severe contraction of the Iraqi economy by half. The sanctions aimed to force Iraq to return looted Kuwaiti assets and account for its weapons programs. Despite these efforts, Saddam Hussein’s regime largely failed to comply, continuing to resist international pressure while the Iraqi population suffered immensely (Drezner, 2022). The economic impact of the sanctions was devastating. Meghan O’Sullivan estimated that Iraq lost between $175 billion and $250 billion in potential oil revenues due to the sanctions. The price of food supplies for families increased exponentially, highlighting the severe inflation and economic strain placed on ordinary Iraqis (O’Sullivan, 2003). The sanctions led to widespread humanitarian suffering, with estimates suggesting that child mortality rates more than doubled from 1989 to 1999, and reports claiming that one million Iraqis died because of the sanctions (UNICEF, 1999).

For Iraq USA imperialism follows, the 2003 US-led invasion of. The invasion, justified under the pretext of weapons of mass destruction and the promotion of democracy, resulted in the dismantling of the Iraqi state and the imposition of a neoliberal economic order. The Coalition Provisional Authority (CPA), under the leadership of Paul Bremer, introduced a series of sweeping economic reforms that liberalized Iraq's economy and opened it up to foreign investment. These reforms included the privatization of state-owned enterprises, the reduction of tariffs, and the removal of subsidies on essential goods, including agricultural inputs (Gathii, 2011; Penrose, 1978). The agricultural sector was significantly impacted by these reforms. The dismantling of state support systems left small farmers without access to affordable seeds, fertilizers, and credit, while the influx of cheap, subsidized agricultural imports from the United States and other countries further undermined local production. The result was a sharp decline in agricultural productivity and a deepening of Iraq's dependency on food imports. This period also saw the consolidation of land ownership as foreign agribusinesses acquired large tracts of land, often displacing local farmers and exacerbating rural poverty (Gathii, 2011; Penrose, 1978). Moreover, the occupation forces' focus on securing oil infrastructure at the expense of agricultural development further sidelined the sector. The prioritization of oil revenues for the reconstruction of Iraq meant that agriculture, which employed a significant portion of the population, received little attention in post-invasion planning. This neglect contributed to the further erosion of Iraq's agricultural base, as many rural communities were left without the means to sustain their livelihoods (Anghie, 2004; Mutua, 2000). The 1958 revolution, which approach mirrored the colonial-era focus on export-oriented agriculture, as Iraq sought to increase its agricultural exports to diversify its economy away from oil dependency. However, the emphasis on cash crops over food production continued to undermine Iraq's food security, leaving it vulnerable to global market fluctuations (Anghie, 2004; Mutua, 2000).

Recently Iran, a neighboring country of Iraq, received sanctions against the economic sanctions imposed on Iran, particularly following the US withdrawal from the Joint Comprehensive Plan of Action (JCPOA) in 2018, which have had significant impacts not only on Iran but also on neighboring Iraq's economy and agriculture. These sanctions have disrupted trade and economic activities between the two countries, affecting various sectors in Iraq. The re-imposition of sanctions on Iran led to a substantial decline in Iran's oil exports, which fell from 2.7 million barrels per day in June to around 1.7-1.9 million barrels per day by September 2018, with further declines expected by year-end (CSIS, 2018). This reduction in oil exports has strained Iraq's economy as it depends heavily on oil revenues, and the decrease in Iranian oil production has led to fluctuations in regional oil prices, affecting Iraq's export income (Segal & Gerstel, 2018). Moreover, the sanctions have disrupted agricultural trade between Iran and Iraq. Iran has been a significant supplier of farm products to Iraq, including fruits, vegetables, and processed foods. The sanctions have caused logistical challenges, increased costs, and reduced the availability of these products, leading to shortages and increased prices in the Iraqi market (Madani, 2021). For instance, empirical data from market surveys indicate that the prices of staple goods such as tomatoes and onions have increased by 15-20% due to the reduced supply from Iran (FAO, 2019). The environmental impact of sanctions on Iran has also had cross-border effects on Iraq. Iran's survivalist policies in response to sanctions have intensified the exploitation of natural resources, leading to environmental degradation. This has affected the shared water resources between the two countries, particularly the Tigris and Euphrates rivers. The over-extraction and pollution of these rivers in Iran have contributed to water scarcity and quality issues in Iraq, severely impacting agricultural productivity (Madani, 2021). Studies have shown that the water flow in the Tigris and Euphrates has decreased by 30-40% in certain areas, exacerbating the challenges Iraqi farmers face (UNEP, 2021). Additionally, the financial sanctions have hindered the ability of Iranian companies to engage in cross-border investments and trade with Iraq. Many foreign companies, fearing repercussions from the US, have withdrawn from the Iranian market, leading to a decline in joint ventures and business opportunities in Iraq (CSIS, 2018). This withdrawal has affected the availability of agricultural inputs such as fertilizers and pesticides, which are critical for Iraqi agriculture. The shortage of these inputs has reduced crop yields and increased production costs for Iraqi farmers (FAO, 2019).

3.4 War on terror, terrorizing agriculture

From 2014 to 2017, Daesh (ISIL), a terrorist organization, seized large parts of Iraq, leading to widespread violence, displacement, and significant political and humanitarian crises. The dual challenges of the ISIL conflict and the decline in oil prices have significantly impacted Iraq's economy. The country's economic stability relies heavily on oil extraction, which accounts for 99% of its exports and over 90% of government revenue (World Bank, 2017). In 2019, oil accounted for 55.8% of Iraq's GDP, while agriculture's contribution had dwindled to just 2%, down from 4.9% in 2014 (Sadiddin et al., 2023). This decline in agriculture’s economic contribution highlights the severe impact of the ISIL conflict on the sector. Iraq has one of the highest numbers of internally displaced persons (IDPs) in the world, with over 6 million people displaced at the peak of the ISIL conflict. By December 2020, nearly 4.83 million returnees had been identified, although the return process had been slow and challenging. Many areas of origin, particularly in Ninevah and Salaheddin governorates, still face severe conditions that hinder sustainable returns, including destroyed housing, lack of security, and inadequate livelihoods (Sadiddin et al., 2023). As a major source of livelihood in rural areas, agriculture has been slow to recover. Although some returnees have restarted their agricultural activities, the extent and intensity of these activities have not returned to pre-2014 levels. A significant proportion of the farm infrastructure remains damaged, and many farmers lack the necessary resources to resume farming fully. Without substantial improvements in local conditions, including security, infrastructure, and access to resources, the recovery of agriculture and the sustainable return of displaced farmers will remain limited (Sadiddin et al., 2023). The ISIL crisis had a devastating impact on Iraq's agricultural sector. The conflict led to massive population displacements, destruction of infrastructure, and disruption of farming activities. The seven governorates directly affected by the conflict—Anbar, Babel, Baghdad, Diyala, Kirkuk, Ninevah, and Salaheddin—accounted for a significant portion of Iraq's agricultural production. The conflict reduced the country's agricultural production capacity by 40%, severely damaging farm assets, irrigation systems, and value chains (Sadiddin et al., 2023). In Ninevah, for instance, ISIL looted and destroyed over 90% of the agricultural infrastructure, including pipes, sprinklers, water pumps, and wells. The conflict also caused substantial losses in the livestock sector, which accounted for one-third of Iraq's agricultural production before the crisis. In some areas, as much as 75-85% of livestock was lost due to the conflict. The World Bank estimated the total damage to agriculture to be USD 2.1 billion, with recovery and reconstruction needs amounting to USD 3.4 billion (World Bank, 2018).

3.5 Iraq Environmental Context

Iraq enters within the classification of dry climates, which has been a subject of extensive study, primarily due to the diverse factors influencing aridity, such as precipitation, temperature, evaporation, and relative humidity. The term "arid" is derived from the Latin word "arere," meaning to be dry, emphasizing the central characteristic of these climates—deficient rainfall. Arid climates, often referred to as desert climates, receive less than 250 mm of rainfall annually, making them unsuitable for arable farming unless supplemented by irrigation or water harvesting (Fuchs, 1973). Modern classifications incorporate more sophisticated indices, considering factors like evapotranspiration (ET) and temperature, which provide a more comprehensive understanding of the dryness of a region (Meher-Homji, 1980). One of the most widely recognized classification systems is the Koppen system, which categorizes climates based on vegetation as the best expression of climatic conditions (Koppen and Geiger, 1936; Trewartha, 1954).

Iraq's agro-climatic conditions, the relationship between a region's agricultural potential and climate, present significant challenges to sustainable agriculture. With a total surface area of 43.7 million hectares, only 9.5 million hectares are involved in farming activities, and much of this land is marginal and used primarily for seasonal grazing. The center-south region relies heavily on irrigation due to low rainfall, making it vulnerable to salinization, a persistent problem exacerbated by poor irrigation practices and a high water table (Schnepf, 2003). Adamo (2018) presents that in Iraq, the primary climatic challenges include increased temperatures, where temperatures have risen by 0.7°C to 2.2°C over the past century, such impacts are profoundly felt across the agricultural sector. Altered precipitation patterns further exacerbate water scarcity, a critical issue for Iraq's predominantly irrigation-dependent agriculture. Historically, the Tigris and Euphrates rivers have been the lifeblood of Iraqi agriculture, but climate change, coupled with upstream water management by neighboring countries, has significantly reduced water flow. The annual flow of these rivers could decline by up to 30% to 73% by the end of the century due to reduced precipitation and increased evaporation rates. This reduction in water availability has led to decreased agricultural productivity and has forced farmers to abandon traditional farming practices. Moreover, declining rainfall, particularly in northern Iraq, which relies on rain-fed agriculture, has compounded the problem, leading to frequent droughts that devastate crop yields (Lockwood, 1976).

Soil salinity is a significant environmental issue, affecting over 100 countries globally, with severe consequences in arid and semi-arid regions such as Iraq (Szabolcs, 1991). The rising salinity in soils, particularly in areas like Iraq, is a result of natural factors such as high temperatures, evaporation, and human activities like improper irrigation practices (Bressler et al., 1982). Understanding the chemical and physical properties of soil and groundwater is crucial in mitigating this issue, as they play a significant role in the salinization process (Cemek et al., 2007). Study revealed a wide variation in electrical conductivity (EC) in both soil and groundwater samples, ranging from 1.19 to 49.30 dS/m in groundwater and 6.33 to 199.80 dS/m in soils. The highest values were observed in areas with clay loam textures, such as the Kifl Shura site, indicating a significant accumulation of salts, especially in soils with high clay content (Black, 1965). This accumulation is exacerbated by the evaporation processes in arid climates, where the shallow water table facilitates the upward movement of salts to the soil surface (Richard, 1954). The pH values of soil and groundwater were generally alkaline, ranging from 7.0 to 8.0 in soils and 7.85 to 8.05 in groundwater (Ayers & Westcot, 1985). The presence of high sodium concentrations in the groundwater, ranging from 4.68 to 216.00 mmol/L, further exacerbates the salinity problem, as sodium ions replace calcium and magnesium on the soil exchange complex, leading to soil dispersion and reduced permeability (Ghafoor et al., 1988; Willcocks, 1911; Al-Simawi, 2011). Chemical soil fertility, which involves the availability of nutrients like nitrogen, phosphorus, and potassium, is therefore limited in drylands. High pH and salinity levels reduce nutrient availability, posing challenges for crop production (Pieri, 1989). The biological aspect of soil fertility, including the activity of beneficial microorganisms like mycorrhizae, plays a crucial role in nutrient cycling and maintaining soil health (Paul and Clark, 1996).

3.6 Climatic Challenges: Analysis of arid conditions, including desertification

The effects of climate change affect especially water availability and soil health, both crucial for sustaining agricultural productivity. Increased temperatures and changing precipitation patterns accelerate soil degradation processes, such as salinization, erosion, and loss of organic matter. In Iraq, soil salinity is a significant issue, particularly in the central and southern regions where irrigation practices have led to the accumulation of salts. It is estimated that about 60% of the irrigated land in Iraq is affected by salinity, reducing crop yields by 30% to 60%. Soil erosion, driven by wind and water, further diminishes the arable land, making it less productive and more susceptible to desertification. This is particularly problematic in the context of Iraq's fragile soils, which require careful management to maintain their fertility. Research indicates that crop yields could decrease by up to 50% in the region's worst-case scenarios of climate change impacts (IPCC, 2014). Moreover, desertification of Iraq has been significantly exacerbated by sand and dust storms (SDS), which profoundly impact agriculture. Studies show that an additional SDS event can decrease the value of crop production by 1.1%, translating to a 0.045% reduction in Iraq's GDP, approximately $0.1 billion (Ahmadzai, 2023). Crop yields are notably affected, with losses ranging from 0.9% to 3% per additional storm day, severely impacting vegetables and fruit crops. In 2012, Iraq experienced 122 dust storms and 283 dusty days, which is projected to rise to 300 dusty days per year within the next decade. These events not only directly impact crop health and yields but also disrupt agricultural activities and reduce the efficiency of farming operations. In specific cases, the late 1990s and early 2000s droughts provide a clear example of climate change impacts on Iraqi agriculture. Cereal production in rain-fed areas, particularly in northern Iraq, was drastically reduced during these periods. Even irrigated central and southern regions faced significant challenges as water shortages increased soil salinity and decreased crop viability (Adamo, 2018). The socioeconomic impacts of drought include poverty, loss of employment, and reduced income, particularly for small-scale farmers and landless laborers. The environmental impacts are equally severe, with the loss of biodiversity, the drying up of water bodies, and increased land degradation (Islam, 2023).

3.7 Water Scarcity: The backbone of agriculture

Iraq faces a severe and unprecedented water shortage crisis, primarily caused by construction of dams and water control structures in neighboring countries, particularly Turkey and Iran. These man-made structures have drastically reduced the flow of the Tigris and Euphrates rivers into Iraq, exacerbating drought conditions and significantly impacting Iraq's water security, agriculture, and overall economic stability (Janabi, 2012). Turkey's extensive dam-building program on the Euphrates and Tigris rivers have led to a decrease of about 10 billion cubic meters (BCM) per annum at the Iraqi-Syrian border. This trend seriously threatens Iraq's water availability (Janabi, 2012). As the most downstream country, Iraq is particularly vulnerable to unilateral water management practices by upstream nations. The absence of coordinated efforts and agreements means that upstream countries can control the quantity and timing of water releases, often to the detriment of Iraq's agricultural and ecological needs (Janabi, 2012). The reduced inflows from the Tigris and Euphrates have led to significant environmental degradation in Iraq. The decline in water availability has increased salinity levels, particularly in the Shatt Al-Arab, where the intrusion of Gulf waters has further exacerbated the situation. This salinization harms agriculture, reducing soil fertility and crop yields (Janabi, 2012).

The rains, when they do occur, often come in the form of heavy, localized showers, leading to challenges in water management and crop production (Trewartha, 1961). The disparity between water availability and demand leads to increased agricultural water stress. The largest increases in water demand are projected for the southern regions of Iraq, where temperatures are expected to rise significantly, exacerbating evapotranspiration and reducing effective water availability (Salman et al., 2021). This is particularly concerning as nearly 70% of Iraq's arable land depends on irrigation from these diminishing river flows (Salman et al., 2021). Crop yields are highly dependent on the ability of plants to recover from these intermittent stress periods (Virmani et al., 1980)

3.8 Socio-Economic Context: Reluctance for agricultural careers

The agrarian labor and peasantry in the Global South represent a complex and historically rooted aspect of global agriculture and socio-economic development. As the colonial legacy persisted into the post-independence era, where newly formed states continued to grapple with the challenges of rebuilding agrarian systems that had been disarticulated by decades of colonial rule (Herrera and Lau, 2015). The consequences of this colonial exploitation are evident in the persistent underdevelopment of agrarian economies in the Global South. These processes undermined the social value of peasant production, which traditionally relied on self-employed family labor and low-energy-intensive methods, leading to a deepening crisis of agrarian labor in the Global South (Moyo and Yeros, 2005).

This legacy led to contemporary social challenges in Iraq, were regions like the Al-Talyaa district in Babylon Province had a noticeable shift in the attitudes of rural youth towards agriculture as a profession. The study's results highlight the challenges faced by the agricultural sector in engaging younger generations and suggest strategies for fostering a more positive outlook on agriculture among rural youth. The Al-Talyaa district, located in Babylon Province, is a predominantly rural area where agriculture plays a crucial role in the livelihoods of the local population. According to the Central Statistical Organization (CSO, 2021), 79% of the district's population lives in rural areas, with a significant proportion of these individuals engaged in agricultural activities. However, the agricultural sector in Iraq faces numerous challenges, including soil salinity, water scarcity, and competition from imported crops, which have collectively contributed to a decline in agricultural productivity (Kshash & Oda, 2022). These issues have, in turn, influenced the attitudes of rural youth towards pursuing careers in agriculture; 59% of respondents exhibited moderately unfavorable attitudes towards agriculture, while 15% had highly unfavorable attitudes. Only 5% of the youth had moderately favorable attitudes, and a mere 1% expressed highly favorable attitudes towards agriculture (Kshash & Oda, 2023). The mean attitude score was 51.7, indicating a general trend of dissatisfaction with agriculture as a career option. This negative attitude can be attributed to several factors, including the perception of agriculture as a labor-intensive and low-prestige occupation. The study found that rural youth associate agriculture with hard manual labor and low income, which makes it less appealing compared to other professions (ILO, 2021). Furthermore, the lack of modern agricultural practices and the continued reliance on traditional farming methods have reinforced the perception that agriculture offers limited opportunities for economic advancement (FAO, 2021). The study found that younger respondents (aged 15-24) were more likely to have unfavorable attitudes towards agriculture compared to older youth (aged 35-44). This trend suggests that as youth mature, they may develop a more favorable view of agriculture, possibly due to increased responsibilities and a better understanding of the economic realities of rural life (Maurya et al., 2021). The youngest age group had the highest proportion of unfavorable attitudes (30% highly unfavorable and 59% moderately unfavorable), indicating a strong need for targeted interventions to engage younger individuals in agricultural activities. The study conducted in Al-Talyaa district reveals a clear trend of unfavorable attitudes towards agriculture among rural youth, driven by socio-economic factors such as age, education, family income, and cultivated area. To reverse this trend, it is essential to modernize agriculture, improve economic conditions for rural families, and change the cultural perceptions of farming as a low-prestige occupation. By implementing targeted policies and programs, there is potential to re-engage rural youth in agriculture and ensure the sustainability of this critical sector in Iraq.

3.9 Political Instability: Policy Framework and its limitations

In the years following the 2003 invasion, Iraq’s agricultural sector remained burdened by the legacy of past mismanagement, war, and sanctions. Challenges such as the degradation of irrigation infrastructure, widespread salinization, and soil fertility issues have persisted. The recent history of conflicts has also exacerbated the sector's vulnerability, significantly damaging irrigation systems and the agricultural supply chain (Janabi, 2012). While comprehensive, the farm policy framework in Iraq faces several limitations that impact its overall effectiveness. For example, the Agrarian Reform Law No. 117 of 1970, aimed at redistributing agricultural land to smallholders, has encountered challenges in implementation. Land redistribution has been hampered by bureaucratic inefficiencies and corruption, leading to delays and unequal distribution. A study by the World Bank (2019) highlighted those local officials often demanded bribes for land allocation, which skewed the distribution process in favor of wealthier individuals. Moreover, the lack of adequate support services for new landowners, such as access to credit, technical assistance, and infrastructure, has limited the productivity gains from land redistribution (Hassan, 2015; World Bank, 2019). For instance, a survey conducted in rural Iraq revealed that only 20% of new landowners received agricultural extension services, which are critical for improving farming practices and productivity (Ali, 2018).

To regulate and enhance the use of agricultural inputs, Law No. 46 of 2012 ensures the quality and safety of farming materials. However, limitations in enforcement and compliance have been reported. Farmers often rely on informal markets for seeds and fertilizers, which are not always subject to the rigorous controls stipulated by the law. This has resulted in the widespread use of substandard or counterfeit agricultural inputs, undermining productivity and posing health risks. According to a report by the FAO (2016), over 40% of fertilizers sold in local markets were below the required standards. Furthermore, the law's emphasis on regulatory control without adequate support mechanisms for farmers has been criticized for not addressing the root causes of inefficiency in the agricultural supply chain (Al-Mahdawi, 2020). For example, logistical challenges and lack of awareness about proper input use among farmers contribute significantly to inefficiencies (FAO, 2016). Environmental protection, integral to Iraq's agricultural policy framework, faces significant challenges. Law No. 27 of 2009 on the Protection and Improvement of the Environment and the Forests and Woodlands Law No. 30 of 2009 aims to prevent deforestation and protect waterways. However, enforcement of these laws has been weak due to insufficient funding, lack of technical expertise, and political instability. The continued deforestation and degradation of natural resources indicate that the policies have not been effectively implemented. For instance, UNEP (2019) reported that illegal logging increased by 30% due to inadequate monitoring and enforcement. Moreover, there is limited community involvement in environmental conservation efforts, reducing the overall impact of these initiatives (UNEP, 2019; Al-Obaidi et al., 2020). Studies have shown that despite the legal framework, environmental degradation continues at an alarming rate due to illegal logging and uncontrolled agricultural expansion (Jasim, 2021). Policies promoting modern technologies and practices for water conservation have shown mixed results. While the Ministry of Agriculture's initiatives to organize the marketing of national agricultural products and encourage technological adoption are steps in the right direction, the lack of infrastructure and investment has limited their success. Empirical data suggest that the adoption rate of advanced irrigation techniques, such as drip and sprinkler systems, remains low due to high initial costs and inadequate knowledge among farmers (Al-Ansari et al., 2014). A case study in the Diyala province indicated that only 15% of farmers had adopted modern irrigation methods, citing financial constraints and insufficient training as major barriers (FAO, 2017).

Additionally, water management policies are often not integrated with broader agricultural strategies, leading to inefficient water use and continued dependence on traditional irrigation methods, which are less efficient (FAO, 2017).

Limitations persist despite the positive impacts of reforestation programs and protected areas on forest conservation and biodiversity. The reforestation efforts have been criticized for focusing on quantity rather than quality, with many planted areas not receiving adequate follow-up care, leading to high mortality rates of new trees. For instance, a study by Ahmad (2020) found that 60% of newly planted trees in reforestation areas died within the first year due to lack of maintenance. Moreover, the protected regions often lack effective management plans and sufficient funding, resulting in inadequate protection and maintenance. Local communities are frequently excluded from conservation efforts, leading to conflicts and reduced cooperation (Hameed et al., 2018; UNEP, 2019). Studies have highlighted that without addressing these management and funding issues, the long-term sustainability of forest conservation efforts remains uncertain (Ahmad, 2020). In recent years, the government has recognized the importance of revitalizing agriculture to diversify economically. Policies have included attempts to improve water resource management, support for mechanization, and incentives for private investment in agriculture. However, these efforts have been hindered by political instability and inadequate infrastructure (Salim & Ahmed, 2021).

4. Part 2: Exploring Regenerative Agriculture as a Solution

4.1 Agricultural Practices: Industrial Agriculture environmental and social consequences

The impact of neoliberalism on rural livelihoods has been profound and often devastating. The shift towards export-oriented agriculture and the liberalization of markets has led to the marginalization of small farmers and the concentration of land and resources in the hands of large agribusinesses. This process has been accompanied by the commodification of land and the erosion of customary land rights, which has further marginalized indigenous communities and smallholders. In many parts of the Global South, the implementation of neoliberal policies has resulted in a dual agricultural economy, where a small number of large commercial farms coexist with a vast number of small, subsistence-oriented farms. This has led to increased inequality and the polarization of rural societies. The benefits of agricultural modernization and market integration have been unevenly distributed, with large agribusinesses and landowners reaping the rewards, while small farmers have often been left behind (Weis, 2015). The commodification of agriculture has also had significant environmental consequences. The expansion of monocultures and the increased use of chemical inputs have led to the degradation of soils, the loss of biodiversity, and the depletion of water resources. These environmental impacts have further undermined the livelihoods of small farmers, who are often the most vulnerable to changes in the natural environment. The focus on export production has also contributed to the displacement of traditional farming practices that were better suited to local ecological conditions, leading to a decline in agricultural resilience and sustainability (Weis, 2015). The rise of neoliberalism in agriculture has been facilitated by the growing power of global institutions and transnational corporations. The establishment of the World Trade Organization (WTO) in 1995 marked a significant shift in the global governance of agriculture, as it set in place new rules that strengthened investor rights and limited the ability of governments to regulate agricultural markets. These changes have been driven by the interests of large agribusinesses and seed companies, which have sought to expand their control over global agricultural markets (Weis, 2015). One of the most significant developments in this regard has been the spread of intellectual property regimes that protect the rights of corporations to control the use of seeds and other agricultural inputs. The introduction of genetically modified seeds and the extension of patent protections have made it increasingly difficult for small farmers to save and reuse seeds, forcing them to purchase proprietary seeds from multinational corporations. This has further entrenched the power of agribusinesses and undermined the autonomy of small farmers (Weis, 2015). The dominance of transnational corporations in the global agricultural market has also been reflected in the concentration of market power in a few key sectors, such as seeds, agrochemicals, and food processing. These corporations have used their market power to influence agricultural policies and practices, often to the detriment of small farmers and rural communities. The result has been a global agricultural system that prioritizes the interests of large agribusinesses over the needs of local communities and the environment (Weis, 2015).

The environmental impacts of conventional agriculture are well-documented and include the depletion of soil fertility, contamination of water sources, and loss of biodiversity. The reliance on chemical inputs has led to a decline in soil health, making soils more susceptible to erosion and less able to retain water. This, in turn, has made agricultural systems more vulnerable to the impacts of climate change, particularly in regions that are already prone to drought and extreme weather events (Wen, 2001; Herrera and Lau, 2015). Socially, the expansion of conventional agriculture has often led to the marginalization of small-scale farmers and the concentration of land in the hands of large agribusinesses. This process, sometimes referred to as "land grabbing," has been particularly pronounced in Africa, Asia, and Latin America, where foreign investors and local elites have acquired vast tracts of land to produce export crops. This has displaced local communities, undermined food security, and exacerbated rural poverty (Moyo and Yeros, 2005; Patnaik, 2011). The industrial model of agriculture also tends to be highly labor-intensive, particularly in the early stages of production, but labor-displacing as mechanization increases. This creates a paradox where agricultural employment initially rises but then declines as machines replace human labor. This has led to significant rural-urban migration, as displaced farmers seek work in cities, often ending up in precarious informal employment (Wen, 2001; Patnaik, 2011).

4.2 Economic Inefficiencies: Challenges of maintaining profitability

Contemporary reliance on synthetic fertilizers and pesticides, while boosting short-term yields, leads to diminishing returns over time as soil becomes degraded and less fertile, requiring even greater inputs to sustain production levels. This cycle creates a dependency that increases production costs and reduces profit margins for farmers, making it increasingly difficult to sustain conventional farming economically (Patel, 2008; Weis, 2015). Furthermore, the global nature of conventional agriculture, characterized by long supply chains and the dominance of multinational agribusinesses, creates significant economic vulnerabilities. Small-scale farmers, particularly in the Global South, are often at the mercy of volatile global markets, where the prices of agricultural commodities can fluctuate widely due to factors beyond their control. This volatility can undermine the profitability of farming operations, leading to increased debt and, in many cases, the eventual abandonment of farming as a viable livelihood (Patel, 2008; Weis, 2015). A study focusing on eight provinces, synthesizing data from various sources to identify key themes, trends, and recommendations shows that there is a significant decline in agricultural productivity and a dependence on food imports, which undermines food security and economic stability in the region (Hafer, 2010). Among the most significant are outdated farming technologies, inadequate training and education for farmers, and the lack of access to credit and financial services. Additionally, the study highlights systemic issues such as corruption, poor governance, and inefficient market structures that further exacerbate these challenges (Hafer, 2010). The agricultural sector in southern Iraq is in dire need of comprehensive development.

4.3 Industrial agriculture comparison to its Regenerative counterpart

When talking about conventional agriculture one major event should be accounted for, “the green revolution”. The post-World War II period witnessed a significant transformation in global agriculture, often referred to as the Green Revolution. This period was characterized by the introduction of high-yielding varieties (HYVs) of staple crops, coupled with the increased use of chemical fertilizers, pesticides, and irrigation. While the Green Revolution led to substantial increases in food production, particularly in Asia and Latin America, it also brought about several challenges. One of the major consequences of the Green Revolution was the increased reliance on chemical inputs, which had long-term environmental, human, plant and soil long term health impacts. The widespread use of pesticides and fertilizers led to soil degradation, water contamination, and the loss of biodiversity. Historical data have shown a marked decline in the nutrient density of crops, attributed primarily to the focus on increasing yields through conventional farming practices (Mayer, 1997; Davis et al., 2004). These practices, characterized by intensive tillage, synthetic fertilizers, and pesticides, have been linked to disruptions in the symbiotic relationships between crops and soil organisms, which are crucial for nutrient uptake (Montgomery & Biklé, 2016). Additionally, the focus on a few high-yielding varieties resulted in the displacement of traditional crop varieties, further reducing genetic diversity in agriculture (Altieri and Toledo 2011). The Green Revolution also exacerbated social inequalities in rural areas. The introduction of capital-intensive agricultural practices favored wealthier farmers who could afford to invest in new technologies, while poorer farmers were often left behind. This led to the concentration of land in the hands of a few large landholders, increasing landlessness and rural poverty. In many cases, smallholders were forced to sell their land and migrate to urban areas in search of work, contributing to the growth of urban slums (Davis 2006). Moreover, the Green Revolution's emphasis on monocultures made global food systems more vulnerable to price fluctuations and market shocks. The concentration of food production in a few regions and the reliance on a narrow range of crops increased the risk of food insecurity, particularly in developing countries. This was evident during the global food crisis of 2007-2008 when rising food prices led to widespread hunger and social unrest in several countries (FAO 2017).

As historical injustice and new data about the limitations of conventional agriculture, many “organic” modalities appeared as contenders. The origins of the modern organic movement, which arose from concerns over declining crop quality and the harmful effects of synthetic fertilizers introduced in the late 19th and early 20th centuries. It underscores J.I. Rodale's pivotal role in popularizing "organic" farming, laying the foundation for regenerative agriculture—a holistic approach that not only sustains but actively rejuvenates resources. Regenerative agriculture, a term coined by Robert Rodale, emphasizes practices like no-till farming and crop rotation to increase soil organic matter, enhance resilience, and improve nutrient availability. Through a review of 229 journal articles and 25 practitioner websites, the diversity and complexity of the term “Regenerative agriculture” lacks a universally accepted definition, with descriptions varying from process-based approaches, such as the use of cover crops and integration of livestock, to outcome-based approaches, focusing on soil health improvement, carbon sequestration, and biodiversity enhancement. 41% of journal articles and 86% of practitioner websites emphasize soil health as a key outcome. In comparison, practices like reduced tillage and livestock integration were mentioned in 19% of scholarly articles and 41% of practitioner sites (Newton et al., 2020). The absence of a clear, shared definition may lead to confusion and misuse of the term, potentially diluting its significance. This variability also challenges developing effective policies, certification programs, and carbon sequestration initiatives. While a universal definition may not be necessary, clear and context-specific definitions are crucial for advancing RA in academic and practical domains (Newton et al., 2020).

Central to RA is enhancing soil health, particularly through increasing soil organic matter, which has been shown to significantly improve water retention, nutrient availability, and carbon sequestration. For instance, increasing soil organic matter by just 1% can boost water-holding capacity by 30-40% (Waterfield, 2020). These principles are applied under the overarching guideline of integrating all farm operations as much as possible. Unlike conventional farming, which typically separates crop and livestock production, regenerative agriculture combines them into circular ecosystems. In this model, animals and plants mutually benefit each other; for instance, regulated grazing by sheep or cows promotes plant growth and distributes natural nutrients via dung, while poultry fertilizes the land and controls pests and weeds. Additionally, some regenerative farmers strive to strengthen connections with workers and local communities, incorporating a social dimension into their agricultural vision. Comparing farming systems and their impact on soil organic matter and nutrient levels, with data showing that farms practicing regenerative methods, including no-till and high crop diversity with livestock integration, have significantly higher soil organic matter (up to 6.9%) and nutrient levels. This, in turn, contributes to better crop yields and resilience against environmental stressors like drought as drought tolerance refers to the ability to endure low water potentials without significant damage, often through the accumulation of osmoprotectants (Levitt, 1980).For example, diverse swards with a mix of grass, legumes, and herbs outperformed ryegrass-only swards in dry matter yield by 500 kg per hectare without the need for artificial nitrogen (Waterfield, 2020). Economically, regenerative agriculture offers potential savings in inputs such as fertilizers and feeds, as well as opportunities for diversifying income streams through added value or new enterprises. Regenerative agriculture is not just a fad but a viable, sustainable agricultural system that benefits both the environment and the economy, making it a promising model for the future of farming (Waterfield, 2020).

Another study in various states in the U.S., including North Carolina, Pennsylvania, and Montana, had regenerative farm was paired with a nearby conventional farm with similar soil types and crop varieties. Soil health was measured using soil organic matter content and the Haney soil health test, which gauges microbial activity and nutrient availability (Haney et al., 2018). The results were striking. Regenerative farms consistently showed higher soil organic matter, with values ranging from 3% to 12%, compared to 2% to 5% on conventional farms (Montgomery et al., 2022). The Haney soil health scores were similarly elevated on regenerative farms, with values between 11 and 30, as opposed to 3 to 14 on conventional farms. These differences suggest that regenerative practices significantly improve soil health, which is crucial for sustaining agricultural productivity and resilience (Baumhardt et al., 2015). The enhanced soil health on regenerative farms translated into more nutrient-dense crops. On average, crops from regenerative farms had 34% more vitamin K, 15% more vitamin E, and 14% more vitamin B1 compared to their conventional counterparts. Additionally, these crops contained 15% more total carotenoids, 20% more total phenolics, and 22% more total phytosterols, all of which are important for human health and disease prevention (Montgomery et al., 2022). Further comparisons were made between regenerative no-till vegetable farms and conventionally managed fields. The crops analyzed were cabbage, carrots, and spinach grown on regenerative farms in California and Connecticut. The results showed that regenerative cabbage had significantly higher levels of vitamins and minerals than conventionally grown cabbage, with 46% more vitamin K, 31% more vitamin E, and 41% more calcium (Montgomery et al., 2022). These findings highlight the potential of regenerative farming to produce nutrient-rich vegetables, which are vital for a healthy diet. When compared to standard USDA nutritional values, regenerative crops demonstrated even more pronounced differences. For instance, regenerative cabbage had 50% more zinc and magnesium and significantly lower sodium levels than conventionally grown cabbage (USDA SR28). Regenerative spinach and carrots contained 60% to 70% more total phenolics than conventionally grown samples from New York supermarkets, further supporting the claim that regenerative farming enhances nutrient density (Chun et al., 2005). The effects of regenerative practices on the mineral density of wheat grown in Oregon. Wheat from regenerative fields, which were cover-cropped and no-tilled, had higher levels of essential minerals such as boron (41%), magnesium (29%), calcium (48%), and zinc (56%) compared to conventionally grown wheat. These differences underscore the potential of regenerative practices to address mineral deficiencies in human diets, which have become increasingly common due to the declining nutrient content of modern crops (Fan et al., 2008).

Not only do crops show better results with regenerative agriculture but livestock production. For instance, fatty acid profiles of beef and pork raised on regenerative farms to those from conventional farms and a regional health-promoting brand. The results were again favorable for regenerative practices. Regenerative beef had three times more omega-3 fatty acids and six times more alpha-linolenic acid (ALA) than conventional beef. The omega-6 to omega-3 ratio, which is crucial for reducing inflammation and the risk of chronic diseases, was significantly lower in regenerative beef (1.3:1) compared to conventional beef (6.2:1) (Montgomery et al., 2022). Regenerative pork had nine times more omega-3s and three times more omega-6s than conventional pork, resulting in a much healthier fatty acid profile. These findings suggest that regenerative farming not only improves the nutritional quality of crops but also enhances the health benefits of animal products (Daley et al., 2010). RA has economic viability of such practices, the importance of knowledge dissemination, and the need for robust measurement and verification systems to scale regenerative practices effectively. Community engagement is identified as a critical factor, fostering consumer demand for regeneratively produced products and involving local communities in restoration efforts are essential for transitioning to sustainable agriculture (Vamshi et al., 2024). Moreover, RA calls for long-term impact studies to monitor ecosystem changes and assess the global scalability of regenerative agriculture. The integration of scientific research with policy analysis is deemed crucial for advancing innovations in regenerative techniques, particularly when aligned with precision agriculture (Vamshi et al., 2024).

I acknowledge the need for further research to fully understand the mechanisms through which regenerative practices influence nutrient density and human health. Given the complexity of soil ecosystems and the human microbiome, establishing these links will require interdisciplinary research that bridges agronomy, nutrition, and public health.

4.4 Regenerative agriculture for arid environment

Khangura et al. (2023) delves into the potential benefits and challenges of regenerative agriculture (RA), particularly in improving soil health in arid regions. It emphasizes that conventional farming practices have led to significant soil degradation, characterized by erosion, declining fertility, and low organic carbon levels. In contrast, RA focuses on enhancing soil health and biodiversity through minimum tillage, cover cropping, rotational grazing, and crop diversification practices. The effectiveness of RA practices across different agroecosystems, pointing out that while some practices, like no-tillage and cover cropping, have shown promise in increasing soil organic carbon (SOC) and improving soil structure in certain climates, their benefits are not universal. For instance, no-tillage practices have been associated with a SOC increase of approximately 4.6 Mg/ha in the topsoil layer over 10 years in certain global studies (Haddaway et al., 2017). However, the impact on SOC accumulation has been less significant in other contexts, such as warm semi-arid climates. While RA holds promise for improving soil health and resilience in arid regions, its success depends heavily on local conditions, and more rigorous scientific studies are needed to fully understand and optimize its benefits (Khangura et al., 2023).

In desert environments, water is the most critical resource in arid landscapes. Under severe water stress, photosynthetic rates can drop by more than 50%, directly impacting plant productivity (Arnon, 1992). The physiological effects of water stress on plants are profound, often leading to reduced photosynthesis due to stomatal closure, which limits carbon dioxide intake (Boyer, 1982), Additionally, water stress induces oxidative stress, resulting in the accumulation of reactive oxygen species (ROS) that can damage cellular structures if not mitigated by the plant's antioxidant systems (Foyer and Noctor, 2005).

4.5 Utilizing natural processes for Soil health and Water conservation: example of strategies for arid environments.

Regenerative agriculture has a goal: to create sustainable and resilient agricultural systems, particularly in arid and semi-arid regions where annual rainfall is only 20-35% of potential evapotranspiration. These farming practices emphasize water conservation, soil health, and minimal use of external inputs such as synthetic fertilizers and pesticides, which are critical in environments where water and nutrients are scarce. A key component of RA is the use of closed-loop systems. These systems are designed to recycle nutrients and organic matter within the farm ecosystem, reducing dependency on external inputs and enhancing sustainability. For instance, agroforestry—integrating trees and shrubs into agricultural systems—plays a vital role in dry climates by improving soil fertility, reducing erosion, increasing water retention, and providing shade and shelter for crops. This not only enhances the resilience of agricultural systems against extreme temperatures but also contributes to long-term soil health and productivity (Ren Jizhou, Hu Zizhi, and Fu Yikun, 1985). Water management is another critical aspect of these sustainable farming practices. Techniques such as drip irrigation are highly effective in dryland agriculture due to their water efficiency, minimizing usage while maximizing plant growth. However, sustainable water management also involves innovative approaches like using sand to store water, which can retain about 50% of its bulk in water, and employing siphons to transfer water between impoundments for long-term storage. These practices are particularly crucial in regions like Iraq, where water scarcity is a significant issue (Mollison, 1981; Al-Mohammed et al., 2021; Salman et al., 2021).

In Iraq, for example, the recycling of agricultural drainage water (ADW) through closed-loop irrigation systems represents a sustainable approach to water management. The Main Outflow Drain (MOD), known as Iraq's "third river," channels ADW with a moderate salinity level that is suitable for irrigating crops like palm and olive trees. This system not only conserves water but also reduces environmental impacts, improves soil health, and boosts crop yields (Abdulhameed et al., 2024). Moreover, the integration of solar-powered closed irrigation systems in desert reforestation projects further demonstrates the potential of renewable energy in supporting continuous and sustainable agricultural activities (Janabi, 2012).The choice of plant species is crucial in RA. Crops like citrus, grapes, apricots, pistachios, and almonds thrive in arid environments when water is available. Trees such as desert pines and hardy acacias are recommended for creating green belts that improve local microclimates and reduce evaporation. These agroforestry practices enhance soil fertility and contribute to the overall sustainability of the agricultural ecosystem (Sanchez, 1976; Brady and Weil, 2008).

Soil management is another cornerstone of these sustainable practices. In drylands, soils are often low in organic matter and essential nutrients, necessitating the use of regenerative techniques such as mulching, minimal tillage, and the incorporation of organic matter to improve soil structure and water retention. Mulching, for instance, helps conserve soil moisture, reduce soil temperature, and prevent rapid increases in soil pH, which can occur with drip irrigation. Materials like organic matter from native plants or stone mulch, which collects dew and condensation, are particularly effective in enhancing soil moisture in desert environments (Mollison, 1981). Windbreaks using native species like tamarisk and mesquite also play a crucial role in soil conservation by reducing wind erosion and providing valuable mulch material. These practices not only stabilize soils but also promote biodiversity, which is essential for maintaining resilient and productive ecosystems in arid regions (Mollison, 1981). By emphasizing the importance of soil health and water conservation, regenerative agriculture and dryland farming create self-sustaining ecosystems that are resilient to environmental challenges. Practices like crop rotation, cover cropping, and the integration of livestock into cropping systems further enhance these closed-loop systems by recycling nutrients within the farm and reducing the need for synthetic fertilizers and pesticides by up to 60% (Pearson, 2007; LaCanne & Lundgren, 2018). Additionally, these systems improve soil organic carbon (SOC) levels, with increases of 2-5% reported over two decades in semi-arid regions, and enhance water use efficiency, with no-till farming and mulching reducing water usage by up to 25% (Khangura et al., 2023; Rasheed & Al-Adil, 2016). RA represents a transformative approach to agriculture in arid and semi-arid regions. By focusing on closed-loop systems that mimic natural processes, these practices not only support sustainable food production but also contribute to the long-term environmental resilience of farming ecosystems (Rathore et al., 2022; Kumar & Furlong, 2024).

4.6 Biodiversity: Role in enhancing resilience

Regenerative agriculture plays a crucial role in enhancing biodiversity, it promotes diverse plant and animal life, creating more robust ecosystems that can better withstand environmental stresses such as droughts, pests, and diseases. For instance, studies have shown that regenerative practices like cover cropping, agroforestry, and crop rotations increase the variety of species within an agricultural landscape, leading to improved ecosystem stability and productivity (Rathore et al., 2022; Khangura et al., 2023). In arid regions, the integration of diverse plant species and livestock has been found to enhance soil health, reduce erosion, and improve water retention, all of which contribute to the overall resilience of the farming system (LaCanne & Lundgren, 2018; Pearson, 2007). The restoration of biodiversity through regenerative agriculture has been linked to higher carbon sequestration rates, which not only mitigate climate change but also improve soil fertility and crop yields over time (Rathore et al., 2022; Pearson, 2007). The role of animals in desert permaculture systems is also an important factor, particularly those species that are well-adapted to arid conditions. For instance, using pigeons as a source of food and fertilizer, noting that pigeon manure is one of the best natural fertilizers for desert soils. Reptiles, which thrive in desert environments, are also identified as a valuable food source, comparable to fish in coastal areas (Mollison, 1981). Biodiversity is crucial for ecosystem stability, as it enhances the resilience of agricultural systems to pests, diseases, and climatic variations (Al-Haboby et al., 2014). Furthermore, studies have shown that regenerative practices can lead to a 20-30% increase in biodiversity, particularly in areas previously dominated by monoculture practices (Abdulhameed et al., 2024). By rethinking resource consumption, regenerative agriculture also reduces the reliance on chemical inputs and promotes the natural regeneration of soil nutrients, which further supports the long-term sustainability and resilience of agricultural ecosystems (Salman et al., 2021). This shift towards sustainable practices is critical in regions like Iraq, where traditional agricultural methods have led to significant environmental degradation, highlighting the importance of adopting more resilient and diverse farming systems (Janabi, 2012).

4.7 Crop Protection

Crop protection in drylands is critical for managing the significant threats posed by weeds, insect pests, and diseases, all of which can severely reduce crop yields. Insect pests such as locusts, aphids, and caterpillars are particularly destructive, causing defoliation, reducing photosynthesis, and spreading plant diseases. Integrated Pest Management (IPM) strategies, which combine resistant crop varieties, biological control agents, and other sustainable practices, are essential for effectively managing these pests (Altieri, 1995; Pimentel, 2009). Additionally, plant diseases, especially in stressed crops, are a major concern in drylands, with pathogens like fungi and bacteria causing rusts, blights, and root rots that can lead to significant yield losses. Integrated Disease Management (IDM) strategies, including crop rotation, the use of resistant varieties, and careful fungicide application, are crucial for controlling these diseases (Agrios, 2005; Swanton and Murphy, 1996). Biological control, which uses natural enemies such as insects, pathogens, or grazing animals to manage weed and pest populations, offers a sustainable and environmentally friendly alternative to chemical inputs, particularly when combined with IPM programs (Van Driesche et al., 2008). However, careful management is necessary to ensure that these biological agents do not become invasive or cause unintended ecological consequences. In developing countries, where access to chemical pesticides may be limited, traditional methods such as botanical extracts and mechanical traps are often employed, though they may require more labor and may not always provide complete control (Pimentel, 2009). The use of antagonistic microorganisms, like *Trichoderma* species, to suppress soil pathogens further highlights the potential of biological control as a sustainable alternative, especially in organic farming systems and regions with limited chemical inputs (Harman, 2000).

4.8 Sustainable Energy choices for Arid Regions:

In arid regions like Iraq, where energy demands are high and resources limited, adopting sustainable energy solutions is crucial. Traditional reliance on cheap petroleum for farming operations is insufficient to meet contemporary challenges. Regenerative agriculture (RA) advocates for sustainable energy use despite the inherent challenges in arid environments. This discussion explores three promising energy systems—agrivoltaics, biogas, and pyrolysis—selected for their compatibility with arid climates, cost-effectiveness, and potential for local, independent construction.

Agrivoltaics (AV)

Agrivoltaic systems, which integrate crop production with photovoltaic (PV) energy generation on the same land, have emerged as a promising solution to the dual challenges of land-use efficiency and the transition to renewable energy. These systems allow simultaneous crop cultivation or livestock farming alongside solar energy generation, optimizing land use and contributing to sustainable development goals (Soto-Gómez, 2024). AV systems are particularly beneficial in arid and semi-arid regions, where they help reduce water consumption by up to 29% due to the shading provided by solar panels (Warmann et al., 2024). Additionally, AV systems can lower solar panel temperatures by 8.9°C during the day, increasing energy generation efficiency by 3% during the growing season (Barron-Gafford et al., 2024). The economic viability of AV systems is also significant, with studies showing that the benefits generated can be 22 to 115 times higher than those from traditional crop production alone (Sojib Ahmed et al., 2024). However, technical challenges remain, including the need for compatibility with existing agricultural practices and maintenance of solar panels in farming environments (Adelhardt et al., 2024). Innovations in PV technology, such as bifacial panels and tracking systems, are enhancing the efficiency and sustainability of AV systems, making them increasingly viable for widespread adoption (Krexner et al., 2024).

Biogas

Biogas production through anaerobic digestion of organic materials, such as animal manure, agricultural waste, and food residues, offers a renewable energy source that addresses both energy and waste management challenges. The anaerobic digestion process produces a mixture of gases, primarily methane (50-70%) and carbon dioxide (30-50%), which can be used for various energy needs (Kabeyi & Olanrewaju, 2022). Biogas is versatile, with applications ranging from cooking and heating to electricity generation using internal combustion engines, which are cost-effective for small-scale operations (Kabeyi & Olanrewaju, 2022). This flexibility makes biogas an attractive option for arid regions where resource optimization is essential. Moreover, biogas fuel upgraded to biomethane, which can be injected into natural gas grids, used as transport fuel, or processed into chemicals like methanol and hydrogen (Kabeyi & Olanrewaju, 2022). A DIY biogas reactor project in Paterna, Spain, demonstrated the feasibility of constructing a biogas system using affordable, readily available materials. This system, which included a fermentation chamber made from a 20-liter recyclable plastic bottle and a biogas storage system adapted from a motorcycle air chamber, was built for just EUR 106.77 (Vogel et al., 2023). Such low-cost, scalable solutions are particularly beneficial for resource-constrained environments and align with studies suggesting that co-digestion enhances the anaerobic digestion process, improving the degradation of organic matter and increasing biogas production (Misi & Forster, 2001).

Pyrolysis

Pyrolysis is a thermochemical process that decomposes organic material in the absence of oxygen, producing char, bio-oil, and gas. This process is crucial for converting biomass into renewable energy and valuable chemicals (Neves et al., 2011). An innovative open-source design, BREAD (Broadly Reconfigurable and Expandable Automation Device), developed at Michigan Technological University, offers a cost-effective method for controlling pyrolysis reactors. Built using Arduino Nano microcontrollers, BREAD controls various aspects of the pyrolysis process and can be assembled for under $580 as separate modules or under $350 as an integrated board, providing significant savings over commercial alternatives (Hafting et al., 2023). The by-products of pyrolysis, such as biochar, have significant environmental applications, especially in arid regions. Biochar is a carbon-rich material that can improve desert soils, which cover about 33% of the Earth's land surface and are characterized by minimal rainfall and poor soil quality (Zak & Whitford, 1988). Biochar, particularly when produced at higher pyrolysis temperatures, can enhance soil properties like water-holding capacity (WHC), nutrient availability, and carbon content, which are critical for supporting plant growth in harsh environments (Lehmann et al., 2011; Song & Guo, 2012). For example, biochar made from pine sawdust significantly increased the WHC of Kubuqi Desert soil in Inner Mongolia by up to 57% and reduced soil hydraulic conductivity by up to 42%, which enhances moisture retention capabilities (Kinney et al., 2012; Laghari et al., 2014). Additionally, biochar produced at higher temperatures increased soil organic matter and total carbon content, with the highest carbon increase of 42% under the T-800 treatment, improving soil fertility and crop yields (Busscher et al., 2010; Laghari et al., 2014). Sorghum grown in biochar-amended soils showed a significant yield increase of 19% to 32%, depending on the pyrolysis temperature, confirming that biochar is particularly effective in enhancing soil quality in desert environments (Laghari et al., 2014). Recent innovations in pyrolysis, such as steam-assisted methods, have further improved biochar's effectiveness by enhancing its specific surface area and pore structure, making it more efficient at adsorbing contaminants like sulfur dioxide from flue gases (Braghiroli et al., 2019; Rajapaksha et al., 2014). These advancements suggest that biochar could play a critical role in desert reclamation and sustainable agriculture, supporting long-term environmental and agricultural sustainability (Vohland, 2009; Uzoma et al., 2011; Al-Wabel et al., 2013; Wang et al., 2020).

In addressing the energy needs of arid regions like Iraq, where sustainable energy access is both essential and challenging, innovative approaches like agrivoltaics, biogas, and pyrolysis offer viable solutions. These technologies not only harness renewable energy but also enhance agricultural productivity and environmental sustainability. Agrivoltaics optimizes land use and improves crop resilience, biogas provides a versatile renewable energy source with significant waste management benefits, and pyrolysis, especially with innovations like BREAD and high-temperature biochar production, offers a cost-effective method for converting biomass into valuable products. Together, these technologies can drive sustainable development in arid environments, promoting energy independence and environmental stewardship while addressing the specific challenges of these regions.

4.9 Short-Term vs. Long-Term Profits: Economic viability of regenerative practices.

Regenerative agriculture presents a complex balance between short-term profits and long-term sustainability. Initially, farmers may experience reduced yields and increased labor costs during the transition to regenerative practices, which can lead to lower short-term profits. For example, regenerative systems often result in a 29% reduction in corn grain yields compared to conventional systems (LaCanne & Lundgren, 2018). However, these practices also reduce the need for expensive inputs like synthetic fertilizers and pesticides, leading to a significant decrease in input costs. Regenerative farms can achieve profitability nearly twice that of conventional systems, largely due to these reduced input costs and the premium prices often available for sustainably produced goods (LaCanne & Lundgren, 2018). Additionally, the enhanced soil health associated with regenerative practices improves water retention and nutrient cycling, leading to more stable yields and reduced vulnerability to environmental stressors over time, which supports long-term economic viability (Khangura et al., 2023). These factors collectively suggest that while regenerative agriculture may challenge short-term profitability, it offers substantial long-term economic benefits, balancing sustainability with economic resilience (Pearson, 2007). Regenerative agriculture presents a compelling economic model that balances profits with sustainability, particularly when considering the trade-off between short-term and long-term gains. In the short term, transitioning to regenerative practices may involve higher initial costs, such as investing in soil health improvements and adopting new technologies. For instance, initial investments in cover crops, composting, and no-till farming can increase upfront costs by 10-15%, potentially impacting short-term profits (Abdul Rahman et al., 2023). However, these practices enhance soil fertility, water retention, and biodiversity, leading to reduced input costs and increased yields over time. Studies indicate that regenerative farms can see a 20-30% reduction in input costs within five years, coupled with yield increases of 10-15%, thereby improving long-term profitability (Salman et al., 2021). Moreover, the resilience of regenerative systems to climate extremes can prevent significant losses during droughts or floods, contributing to more stable income streams over the long run (Adam-Bradford et al., 2020). Thus, while the economic viability of regenerative agriculture may seem challenging in the short term, the long-term benefits in terms of sustainability and profitability make it a sound investment for the future.

4.10 Cost-Friendly Techniques: Focus on minimal initial investment strategies

Regenerative agriculture emphasizes cost-effective techniques that require minimal initial investments, making it an attractive option for farmers in resource-constrained environments like Iraq. One of the key strategies involves the use of cover crops and crop rotation, which enhance soil fertility and reduce the need for expensive chemical fertilizers. For instance, research has shown that implementing these practices can increase soil organic matter by up to 5%, significantly improving crop yields without additional costs (Al-Haboby et al., 2014). Additionally, the adoption of low-cost irrigation techniques, such as drip irrigation systems powered by solar energy, has been effective in reducing water usage by 30-50%, which is crucial in arid regions (Abdulhameed et al., 2024). The focus on using locally available resources, such as organic compost produced from agricultural waste, further reduces the financial burden on farmers, making regenerative agriculture a sustainable and affordable approach (Salman et al., 2021). These methods not only lower the cost of production but also contribute to long-term soil health, ensuring continued productivity and environmental resilience. Regenerative agriculture offers cost-friendly techniques that require minimal initial investment, making it accessible to a wide range of farmers, including those with limited financial resources. For instance, practices such as cover cropping and no-till farming, which are central to regenerative systems, significantly reduce the need for expensive synthetic fertilizers and pesticides. Studies have shown that no-till farming can lower fuel costs by up to 50% compared to conventional tillage systems due to reduced machinery use and labor (LaCanne & Lundgren, 2018). Additionally, the integration of livestock into cropping systems, another key regenerative practice, enhances nutrient cycling and soil fertility without the need for costly chemical inputs, providing a dual benefit of improving farm productivity and reducing overall input costs (Pearson, 2007). Moreover, composting and the use of green manures can be implemented with minimal financial outlay while effectively increasing soil organic matter, which enhances water retention and reduces the need for irrigation in water-scarce regions (Khangura et al., 2023). These practices collectively demonstrate that regenerative agriculture not only promotes sustainability but also offers a viable economic model for farmers, particularly in resource-constrained settings.

4.11 Economic Resilience: Diversification and Market Access

In the arid environment of Iraq, regenerative agriculture can significantly enhance economic resilience through diversification and improved market access. Diversification, achieved by integrating crops such as drought-resistant cereals and legumes with perennial plants like date palms, can reduce farmers' dependency on a single crop, thereby mitigating risks associated with market fluctuations and climatic shocks. For instance, integrating date palms, which are well-suited to the Iraqi climate, with other crops can create a multi-layered agricultural system that not only improves soil health but also provides multiple revenue streams for farmers (Bray et al., 2023). Furthermore, regenerative practices such as the use of cover crops and minimal tillage have been shown to increase soil organic carbon by up to 5% over two decades, leading to enhanced soil fertility and water retention, which are critical for sustaining crop yields in arid conditions (Khangura et al., 2023). Market access can be improved through the production of high-value crops that appeal to both local and international markets, such as organic dates and grains, which command higher prices and cater to the growing demand for sustainable products. This approach not only stabilizes income but also creates opportunities for farmers to tap into premium markets, thereby enhancing their economic stability (Rasheed & Al-Adil, 2016). By developing roads and market facilities as part of larger environmental projects, Iraq can help ensure that smallholder farmers gain access to lucrative markets, thus boosting their economic resilience against the backdrop of an increasingly arid climate (Abdul Rahman et al., 2023; Salman et al., 2021).

4.12 Empowerment Through Local Knowledge: Integrating traditional practices

Regenerative agriculture in Iraq's arid environment has profound social implications, particularly in fostering community resilience and empowerment. By focusing on sustainable practices, regenerative agriculture helps communities restore degraded lands, which in turn strengthens local food systems and reduces dependency on external inputs. For example, the adoption of rainwater harvesting and sustainable irrigation practices in Iraq’s Green Belt Projects (forest project in front of desert lines) has improved soil health and increased agricultural productivity, thereby enhancing the community's ability to withstand environmental stresses such as droughts and desertification (Abdulhameed et al., 2024). Moreover, integrating traditional agricultural practices with modern regenerative techniques has empowered local communities by valuing and utilizing their indigenous knowledge. This approach not only preserves cultural heritage but also promotes a sense of ownership and responsibility towards environmental stewardship, leading to more sustainable and effective land management (Salman et al., 2021; Khangura et al., 2023). These practices not only enhance soil fertility and water retention but also foster a sense of ownership and agency among local farmers, who see their ancestral techniques validated and integrated into modern sustainable farming strategies. For example, the use of traditional qanat systems for water management has been revitalized, improving water use efficiency by up to 40% in some regions (Rasheed & Al-Adil, 2016; Fischer and Turner, 1978). This integration of local knowledge into regenerative agriculture enhances social cohesion and community resilience, as farmers collectively engage in sustainable practices that ensure long-term food security and economic stability (Pearson, 2007; Bray et al., 2023).

4.13 Looking at policy-led examples of agricultural and ecological transition: Exploring success and failures from China, Sri Lanka, and Iraq

Sri-Lankan failed sustainable transition

When studying the transition toward a new system, it is essential to investigate failures and success stories that could help shape the foundation of such a transition. Here we will study Sri Lanka's failure to transition to organic agriculture, a multifaceted issue deeply rooted in policy missteps, economic miscalculations, and environmental challenges. Sri Lanka was chosen as it tried to transition towards Organic Agriculture following newly imposed policies. In this section, we will explore which policy proved fatal to transitioning

In May 2021, the Sri Lankan government immediately banned synthetic fertilizers and agrochemicals, driven by the erroneous belief that these substances were the primary cause of chronic kidney disease of unknown etiology (CKDu) in the dry zone (Liyanage,2020). This decision led to a significant decline in crop yields, particularly rice, which saw a 40-50% reduction during the Maha 2021 growing season (Wijerathna-Yapa et al., 2023). The government ignored substantial scientific evidence and relied on controversial claims propagated by politically motivated groups, which inaccurately linked glyphosate to CKDu, despite numerous studies showing no definitive connection at the concentrations used in Sri Lanka. This policy shift, fueled by misinformation, undermined the credibility of scientific research and resulted in poorly informed decision-making processes. Additionally, the policy was implemented without adequate consultation with farmers, agricultural experts, and other stakeholders, leading to widespread resistance from farmers unprepared for the sudden transition to organic farming. The logistical challenges of sourcing and distributing organic fertilizers further exacerbated the situation, highlighting the consequences of this top-down approach (Wijerathna-Yapa et al., 2023). The transition to organic farming resulted in a significant decline in agricultural productivity. The importation of 300,000 metric tonnes of rice in early 2022, a twenty-fold increase compared to 2020 (Wijerathna-Yapa et al., 2023). The economic repercussions were severe, with agriculture, which constituted 7.4% of GDP in 2020, experiencing a drastic decline. The compounded effects of the COVID-19 pandemic, which had already weakened Sri Lanka's economy by reducing tourism and foreign exchange earnings, exacerbated the situation (Wijerathna-Yapa et al., 2023).

Moreover, the logistical challenges of sourcing and distributing adequate quantities of organic fertilizers further hindered the transition. The government's lack of preparedness was evident as farmers struggled to obtain organic fertilizers, which were both costlier and less effective than synthetic alternatives. Consequently, agricultural production plummeted by 54% during the 2021 season, severely impacting food security (Wijerathna-Yapa et al., 2023). Reports indicated that up to 25% of farmers considered abandoning farming due to these challenges, which would have further jeopardized national food security (Ekanayake, S., & Shakya, S. 2022). The environmental sustainability of the organic farming initiative also came into question. While the intent was to promote sustainable agriculture, the lack of a gradual transition plan led to increased pest infestations and weed growth due to the abrupt cessation of chemical pesticides. This, in turn, necessitated the use of alternative, often illegal and dangerous, chemicals, undermining the very goals of the policy (Wijerathna-Yapa et al., 2023). Moreover, the socio-economic impact on rural communities was profound, with increased malnutrition rates and a significant portion of the population unable to afford sufficient food due to inflated costs and reduced availability of locally produced crops (Wijerathna-Yapa et al., 2023; Ekanayake, S., & Shakya, S. 2022). A more effective approach to transitioning to organic agriculture in Sri Lanka could have been achieved by leveraging Grey System Theory (GST) and Sustainable Development (SD) principles to guide a phased implementation strategy, supported by extensive research and stakeholder engagement. Utilizing a multi-criteria decision-making (MCDM) framework within the GST context would have allowed for the evaluation of various policy options under conditions of uncertainty, balancing economic viability, environmental sustainability, and social equity (Wijerathna-Yapa et al., 2023). Additionally, applying SD theory to design robust educational campaigns could have mitigated misinformation and promoted scientifically backed agricultural practices, ensuring alignment with broader sustainability goals. The integration of empirical data and expert consultations, guided by GST, would have provided a structured, evidence-based approach to policy decisions, fostering a more resilient agricultural sector capable of meeting both environmental and food security objectives (Wijerathna-Yapa et al., 2023). Sri Lanka's unsuccessful transition to organic agriculture highlights the critical importance of GST and SD-driven policymaking, comprehensive risk assessment, and the dangers of allowing misinformation to influence significant policy shifts. The economic, social, and environmental repercussions of this misstep offer valuable insights for future agricultural and policy reforms.

The successful policy-led regenerative project in China

Sri Lanka offered insight into destructive agricultural transition; in this part, we will explore China's Grain for Green project to promote a successful regenerative transition.

China has implemented extensive policies aimed at ecological restoration, particularly through the Grain-for-Green Program (GFGP), which began in the late 1990s. The program's primary goal is to convert steep, erosion-prone farmland into forest and grassland, thereby reducing soil erosion and restoring ecological balance (Wang et al., 2014). By 2020, the GFGP had successfully converted over 15 million hectares of cropland, resulting in a significant increase in forest cover and a reduction in soil erosion (Wang et al., 2014). Socioeconomic gains complemented the ecological benefits. Farmers participating in the program received subsidies and food supplies as compensation, which improved food security and boosted household incomes by 28% (Liu et al., 2014). Moreover, establishing terraced fields, a key program component has significantly enhanced water retention and soil fertility, allowing for sustainable agricultural practices that further improve food production and income levels (Tsunekawa et al., 2014). The long-term success of these projects is largely attributed to the robust policy framework that supported their implementation—with financial backing from international bodies such as the World Bank, the Chinese government ensured that the policies were ecologically sound and economically viable for the local population (Liang et al., 2014). The policy framework included measures for continuous monitoring and adjustment, which addressed initial challenges such as uneven distribution of benefits and ensured the sustainability of the gains made (Li et al., 2014).

The Loess Plateau has been largely successful in reducing soil erosion and enhancing soil retention, these benefits have come at the cost of water availability. The findings underscore the need for more sustainable SWC strategies that balance ecological restoration with the preservation of water resources, particularly in regions where water scarcity is a critical concern. The study's insights provide valuable guidance for policymakers and conservationists aiming to implement effective and sustainable soil and water conservation practices in similar environments (Jiang et al., 2019). The study reveals that artificial afforestation, particularly the conversion of farmland to forest/shrub, resulted in soil moisture depletion. The rate of soil moisture decline (Rsmd) varied across different rainfall zones, with the highest decline observed in areas with more than 500 mm of annual rainfall ($-0.25\%\ yr^{-1}$). The conversion of farmland to forest/shrub had a more significant impact on soil moisture compared to other land-use changes, highlighting the challenges of afforestation in maintaining soil water balance (Jiang et al., 2019). In term, the regenerative agricultural practices implemented significantly improved the local population's livelihoods, with the per capita net income increasing by 159% from 1997 to 2003, rising from 114 USD to 295 USD (Tang et al., 2013). This dramatic increase was primarily due to the diversification of income sources, including a substantial rise in income from fruit sales, which surged by 59.5%, and labor sales, which increased by 14.2% (Tang et al., 2013). These shifts reduced the community's dependence on grain cultivation and government subsidies, providing more stable and diversified income streams (Tang et al., 2013). The environmental benefits of the regenerative practices were equally significant, with the conversion of 95% of sloped farmlands into terraces, forests, and grasslands leading to a 99% decrease in sediment yield from 1998 to 2007, illustrating a substantial reduction in soil erosion (Tang et al., 2013). This transformation stabilized the soil and contributed to the restoration of the natural ecosystem, promoting greater biodiversity and ecological resilience (Tang et al., 2013). Additionally, increasing vegetation coverage helped control soil and water loss, enhancing the region's environmental health (Tang et al., 2013). The long-term sustainability of the Yangou watershed's regenerative agriculture system is evident in several key outcomes, including improved land fertility and agricultural productivity (Tang et al., 2013). The successful implementation of these practices has demonstrated a model that can be replicated in other regions facing similar environmental and socioeconomic challenges (Tang et al., 2013). Policy-making played a crucial role in achieving these results, with the GfG project providing financial subsidies and technical support to farmers, facilitating the widespread adoption of sustainable practices (Tang et al., 2013). The project ensured coordinated efforts toward ecological restoration and sustainable rural development by clarifying the responsibilities and benefits for governments, research institutions, and farmers (Tang et al., 2013). Future ecological restoration efforts should move away from simple species-based approaches towards more complex, trait-based community strategies that consider the balance between water provision and soil retention. Additionally, they recommend a focus on natural restoration methods, which are less likely to deplete soil moisture and groundwater resources (Jiang et al., 2019).

Iraq Successful implementations of regenerative practices.

Example of Case Studies and Practices for Sustainable Theory and Systems Thinking in Iraq. Andrew Adam-Bradford et al. (2020) examines the concept of Stabilisation Agriculture, focusing on its role in enhancing the resilience of agricultural communities in conflict-affected regions, specifically in Afghanistan and Iraq. Stabilisation Agriculture and demonstrate its potential through practical case studies highlight the critical connection between agriculture, food security, and conflict. Food insecurity can exacerbate instability and lead to disputes, destroying agricultural infrastructure, displacing farmers, and disrupting food production systems. The cycle of food insecurity and conflict becomes self-reinforcing, often resulting in chronic food shortages and conflict-driven famines. Stabilization Agriculture seeks to break this cycle by rebuilding resilient agricultural systems in post-conflict settings (Adam-Bradford et al., 2020). Salah Al-Din Governorate, Iraq, demonstrates how Stabilisation Agriculture was implemented in areas recently retaken from the Islamic State (IS). The Human Relief Foundation (HRF), with funding from the UN Development Program (UNDP), executed short-duration but high-impact interventions to rehabilitate agricultural infrastructure and restore livelihoods. Activities included land preparation, irrigation system repairs, livestock restocking, and the establishment of composting systems. The project also focused on rebuilding social cohesion by encouraging the return of displaced families by restoring agricultural livelihoods (Adam-Bradford et al., 2020). the Al Hajaj District of Salah Al-Din, the project restored agricultural land by clearing weeds, repairing irrigation systems, and restocking livestock. A total of 20 cows, 50,000 poultry, and 20 bee hives were distributed to farmers. Additionally, 3 mainline irrigation pumps and 55 on-farm pumps were repaired to restore irrigation to farmland along the River Tigris (Adam-Bradford et al., 2020).

Another study conducted by ESCWA and ICARDA uses empirical data collected from 318 farms in Northern Iraq during the 2001-2002 season to assess the effectiveness of supplemental irrigation (SI) in improving land and water productivity. It was found that wheat yield under SI increased by 128% compared to rainfed conditions, with the highest yield observed in the Um Rabia variety, averaging 3.4 tons per hectare. The overall yield for all varieties under SI was 2.93 tons per hectare, significantly higher than the 1.28 tons per hectare under rainfed conditions (Shideed et al., 2003). The importance of water productivity, which is defined as the amount of food produced per unit of water used. Water productivity increased the most (63%) for the IPA 99 variety, and overall, SI improved water productivity by 31% across all wheat varieties. Specifically, water productivity for bread wheat increased by 32%, while durum wheat increased by only 15%. This significant improvement is attributed to the combined use of rainfall and supplemental irrigation, which alleviates moisture stress during critical growth periods (Shideed et al., 2003). The analysis also highlights the economic aspects of water use in agriculture. Efficient water use is crucial in regions with limited water resources, like Iraq. Farmers over-irrigate due to low water costs, leading to inefficiencies. Significant water savings can be achieved by implementing better water management practices and irrigation technologies. For instance, the cost of water to farmers is primarily the running cost, which does not reflect the actual value of water as a scarce resource. Therefore, there is a need for policies that encourage efficient water use through appropriate pricing and incentives (Shideed et al., 2003). Additionally, the role of different irrigation systems. It was found that the trickle irrigation system is the most efficient, with an average efficiency about 28% higher than sprinkler systems and 45% higher than furrow systems. This efficiency can lead to substantial water savings and increased crop yields, making it a vital technology for improving agricultural productivity in water-scarce regions (Dawood and Hamad, 1985). Farm water-use efficiency is the ratio of the required amount of water to produce a specific output level to the actual amount of water used by farmers. If the ratio is less than one, it implies over-irrigation, whereas a greater than one indicates under-irrigation. Achieving a ratio equal to one means that farmers are using water efficiently. Training and technical support are essential for farmers to adopt efficient irrigation practices and improve on-farm water-use efficiency (ESCWA/ICARDA, 2000 and 2001). In terms of long-term sustainability, improving on-farm water-use efficiency could save up to 23% of water resources, making more water available for other uses and increasing overall agricultural productivity (Shideed et al., 2003). The policy measures that supported these achievements were crucial. Government interventions, such as financial incentives and disseminating improved irrigation technologies, played a vital role in encouraging the adoption of SI and efficient water-use practices (Shideed et al., 2003). These policies ensured farmers had the necessary resources and knowledge to implement and maintain these sustainable practices, leading to long-term economic and environmental benefits. Implementing on-farm water-use efficiency measures in Iraq's wheat production significantly benefited the people by increasing their income and food security. It also enhanced the ecosystem by reducing water wastage and preventing land degradation. These practices promoted long-term sustainability by conserving water resources and improving agricultural productivity, supported by effective policy measures and government interventions (Shideed et al., 2003).

Another study (Jawad, 2021) shows that Iraqi commitment to environmental restoration can show success in the Iraqi setting, for instance, the southern marshes. A key policy was the large-scale re-flooding initiative, which began in the early 2000s. This policy aimed to reverse the damage caused by the drainage of the marshes under Saddam Hussein’s regime, which had reduced the marshland area by up to 90% by the mid-1990s. The re-flooding policy was not just about restoring water to the region; it was about restoring the entire ecosystem that depended on it. The policy was carefully planned to ensure that the reintroduction of water supported the natural regeneration of native vegetation, fish populations, and wildlife, which in turn supported the livelihoods of the Marsh Arabs (Jawad, 2021). Another critical aspect of the policy framework was the focus on the local communities who live in and around the marshes. The Marsh Arabs, who had been displaced and whose traditional ways of life were severely disrupted by the destruction of the marshes, were at the center of these policies. The government and international partners implemented policies that promoted sustainable livelihoods, ensuring that the Marsh Arabs could return to their ancestral lands and resume their traditional practices, such as fishing, buffalo herding, and reed harvesting. Importantly, these policies included provisions for education and training in sustainable practices, helping the community adopt methods that allow them to thrive without degrading the environment. This approach is a hallmark of the regenerative mindset, which sees human activity as part of the ecosystem rather than separate from it (Jawad, 2021).

Innovative Grain Storage Solutions in Iraq: Addressing Storage Challenges

The effective storage of grains is a critical component of Iraq's agricultural infrastructure, especially in a country where agriculture plays a pivotal role in food security and economic stability. Iraq's agricultural sector, particularly its grain production, has been hampered by insufficient and outdated storage facilities. As of 2019, the available storage capacity for grains was approximately 3.3 million tons, a figure that had remained static for many years despite increasing production and population growth. The lack of adequate storage solutions led to significant post-harvest losses, particularly in years of high yield, as existing storage facilities were overwhelmed (Alkarawy, 2019). The critical situation in the 1970s, where poor storage led to the spoilage of large quantities of grain, underscoring the importance of modern and efficient storage facilities. The introduction of innovative storage solutions became essential to prevent similar losses and to ensure that Iraq could manage larger quantities of domestically produced grains, thus reducing its reliance on imports (Alkarawy, 2019). In response to these challenges, a new grain storage initiative was proposed and implemented, led by engineer Ammar Khairallah. This project involved the rapid construction of low-cost, efficient grain storage facilities using pre-existing materials, particularly concrete blocks that had been repurposed from decommissioned military barricades and other sources. These storage facilities were designed to be both cost-effective and quickly deployable, addressing the urgent need for increased storage capacity ahead of the 2019 harvest season (Alkarawy, 2019). The project was implemented across multiple governorates in Iraq, including Wasit, Maysan, Dhi Qar, Muthanna, Karbala, and Diyala. The facilities were designed to handle large volumes of grain with minimal construction time and cost, achieving a storage capacity increase of approximately 2 million tons. This significant expansion allowed Iraq to manage the anticipated high yields of the 2019 season effectively, preventing the grain from spoiling due to inadequate storage (Alkarawy, 2019). The project was characterized by its innovative use of materials and rapid execution. A total of 33,000 concrete blocks were utilized in the construction of these storage facilities, with the entire project completed in a matter of months. The facilities were designed to be flexible, allowing for the storage of various types of grains, including wheat, barley, and rice. The project was supported by the Iraqi government, with funding and logistical support provided through the office of the Prime Minister (Alkarawy, 2019). The success of this initiative was not only in its ability to prevent the loss of grain but also in its economic efficiency. The total cost of constructing the new storage facilities was approximately $6-7 million, a fraction of the estimated $750 million that would have been required to build traditional silo storage with equivalent capacity. This cost-effectiveness made the project a model for future infrastructure developments in Iraq (Alkarawy, 2019). Moreover, the project had significant social and economic impacts. It provided employment opportunities for thousands of workers during the construction phase and reduced the time and cost for farmers to transport their grain to storage facilities, thereby increasing the efficiency of the entire grain supply chain. The proximity of these new storage facilities to farming areas also reduced transportation costs and time, benefiting both farmers and the broader economy (Alkarawy, 2019). Despite its successes, the project faced criticism and skepticism, particularly concerning the durability and long-term viability of the storage facilities. Critics argued that while the innovative approach was effective in the short term, traditional silo storage methods would provide better long-term solutions, particularly regarding protection from environmental factors such as humidity and pests (Alkarawy, 2019). The innovative grain storage project in Iraq represents a successful example of how practical, low-cost solutions can address critical infrastructure challenges in developing countries. By repurposing existing materials and focusing on rapid deployment, Iraq was able to significantly increase its grain storage capacity in a short time, preventing losses and improving food security.

5. Part 3: Developing a Scalable Regenerative Agriculture Blueprint for Iraq

5.1 Blueprint tables for regenerative agriculture in arid environment

This section delves into the potential of regenerative agriculture in Iraq, with a particular emphasis on drawing from examples and sources of inspiration that, while not necessarily grounded in extensive empirical evidence, provide valuable insights into less conventional agricultural methods. The primary objective of this exploration is to encourage a shift in perspective towards innovative and sustainable farming practices that may not yet be widely adopted but hold significant promise for addressing the unique challenges faced by farmers in Iraq's arid regions. Recognizing the limitations in the availability of empirical data specific to Iraq, this section does not seek to prescribe definitive solutions but rather to inspire a broader consideration of alternative agricultural practices Through the lens of Grey Systems Theory (GST), this exploration acknowledges the inherent complexity and variability of farming conditions, understanding that each farm and farmer operates within a unique set of environmental, economic, and social circumstances. GST, with its focus on managing uncertainty and incomplete information, provides a theoretical foundation for considering a range of potential agricultural strategies that could be tailored to the specific conditions encountered by farmers in Iraq's diverse and challenging landscapes. By applying GST, this research acknowledges that the agricultural solutions proposed are not one-size-fits-all but rather are meant to be adaptable to the specific needs and conditions of individual farmers and their environments. The aim of this section, therefore, is to explore a spectrum of potential choices that could be made within the framework of regenerative agriculture, particularly in the context of Iraq's arid environment. These choices are presented as preliminary blueprints or conceptual tables that outline various practices and strategies which could be implemented. These blueprints are not intended to be exhaustive or final; rather, they are meant to serve as a starting point for further refinement and adaptation by practitioners in the field. The proposed practices include a range of techniques designed to restore soil health, enhance water retention, increase biodiversity, and improve overall ecosystem resilience, all within the constraints and opportunities presented by Iraq's specific environmental conditions. By presenting these practices in a tabular format, the intention is to provide a clear, accessible, and flexible guide that can be easily updated and tailored to suit the evolving needs and circumstances of farmers in Iraq. The tables are structured to allow for continuous revision and customization, reflecting the dynamic nature of regenerative agriculture and the diverse challenges faced by those working in arid environments. These blueprints, therefore, are not prescriptive solutions but rather illustrative examples that demonstrate the potential of regenerative agriculture to transform agricultural practices in arid regions. They offer a framework within which farmers, policymakers, and researchers can experiment, adapt, and innovate, building upon the principles of regenerative agriculture to develop practices that are both ecologically sustainable and economically viable.

Therefore, this section seeks to inspire and guide the adoption of regenerative agriculture in Iraq by providing examples and blueprints that, while preliminary and non-empirical, offer a foundation for further exploration and development. By embracing the variability and uncertainty inherent in agricultural systems, as highlighted by GST, this approach encourages a more flexible and context-sensitive application of regenerative practices. The ultimate goal is to foster a deeper understanding of how regenerative agriculture can be adapted to the specific challenges of Iraq's arid regions, contributing to the broader discourse on sustainable agriculture in similarly challenging environments around the world. First, I have listed a comprehensive list of crops, livestock, bees, ect. My metrics were arid friendly varieties with the yield and local (Iraq) market cost numbers taken from FAO and World Bank (2024) [Table 1.].

Table 1 : Comprehensive list of potential agricultural choices for Iraq in the context of arid environment (FAO and World Bank).

Category	**Common Name (Scientific Name)**	**Initial Cost (USD per unit)**	**Yield per Year**	**Beneficial Properties**	**Soil Amendment**	**Potential Earning (USD/year per unit)**
Aquaculture	Common Carp (*Cyprinus carpio*)	1.32-3.30	10-15 kg/10 m²	Controls aquatic plants, enriches water	Fish manure for pond fertility	7.92-11.88
Aquaculture	Grass Carp (*Ctenopharyngodon idella*)	1.65-3.96	12-18 kg/10 m ²	Controls aquatic vegetation, rapid growth	Adds organic matter to water	9.50-14.26
Aquaculture	Silver Carp (*Hypophthalmichthys molitrix)*	0.99-2.64	10-15 kg/10m²	Phytoplankton control, enhances water quality	Organic enrichment of ponds	7.92-11.88
Aquaculture	Bighead Carp (*Hypophthalmichthys nobilis)*	1.32-3.30	9-13 kg/10m²	Controls zooplankton, improves water health	Natural pond fertilizers	7.13-10.30
Aquaculture	Tilapia (*Oreochromis niloticus)*	0.99-2.64	8-12 kg/10m²	High protein source, fast growth	Fish manure for pond fertility	6.34-9.50
Aquaculture	Barbus sharpeyi (Barbus sharpeyi)	1.98-3.96	10-15 kg/10m²	Indigenous species, enhances local biodiversity	Enriches water with nutrients	7.92-11.88
Aquaculture	Mosul Bleak (*Alburnus mossulensis)*	1.32-2.64	5-8 kg/10m²	Indigenous, supports aquatic ecosystems	Natural fertilizers in water	3.96-6.34
Aquaculture	Gattan (*Barbus xanthopterus)*	2.31-4.62	15-20 kg/10m²	Endemic species, supports biodiversity	Enriches soil via water systems	11.88-15.84
Aquaculture	Shabout (*Arabibarbus grypus)*	1.98-3.96	10-15 kg/10m²	Native species, essential for ecosystems	Adds nutrients to water	7.92-11.88

Category	**Common Name (Scientific Name)**	**Initial Cost (USD per unit)**	**Yield per Year**	**Beneficial Properties**	**Soil Amendment**	**Potential Earning (USD/year per unit)**
Aquaculture	Catfish (*Silurus triostegus)*	1.65-3.63	10-15 kg/10m²	Bottom feeder, controls aquatic pests	Enriches water with organic matter	7.92-11.88
Livestock	Sheep (*Ovis aries)*	132-330	50-70 kg meat/sheep	Grazes on natural pastures, manure production	Improves soil fertility	990-1,650
Livestock	Goat (*Capra aegagrus hircus)*	99-264	30-50 kg meat/goat	Browses on shrubs, improves biodiversity	Manure for soil improvement	594-990
Livestock	Cattle (*Bos taurus)*	660-1,980	3,000-5,000 liters milk/cow	Manure production, enhances soil fertility	Improves organic matter in soil	7,920-13,200
Livestock	Buffalo (*Bubalus bubalis)*	792-2,310	2,000-4,000 liters milk/buffalo	Improves wetland ecosystems, manure production	Enhances wetland soils	6,600-10,560
Livestock	Camel *(Camelus dromedarius)*	1,320-3,300	1,500-2,000 liters milk/camel	Drought-resistant, manure for dry soils	Enhances arid soil structure	9,900-19,800
Livestock	Donkey (*Equus asinus)*	330-990	Utility animal, not primarily for yield	Manure for soil improvement	Low-cost feed, pasture grazing	
Livestock	Chicken (*Gallus gallus domesticus)*	3.30-6.60	250-300 eggs/year, 2-3 kg meat	Pest control, manure production	Enriches nitrogen in soil	330-528
Livestock	Turkey (*Meleagris gallopavo)*	13.20-33.00	8-10 kg meat/turkey	Pest control, manure production	Adds organic matter to soil	660-990
Perennial Crops	Date Palm (*Phoenix dactylifera)*	16.50-33.00	100-150 kg fruit/tree	Provides shade, windbreaks, soil stabilization	Mulching with palm fronds	3,300-4,950

Category	Common Name (Scientific Name)	Initial Cost (USD per unit)	Yield per Year	Beneficial Properties	Soil Amendment	Potential Earning (USD/year per unit)
Perennial Crops	Olive (*Olea europaea)*	6.60-13.20	20-40 kg fruit/tree	Drought-resistant, supports biodiversity	Olive leaves for mulching	528-1,056
Perennial Crops	Pomegranate (*Punica granatum)*	13.20-26.40	20-30 kg fruit/tree	High in antioxidants, supports local biodiversity	Mulching with pomegranate leaves	396-594
Perennial Crops	Fig (*Ficus carica)*	9.90-19.80	20-30 kg fruit/tree	Supports soil stability, attracts pollinators	Mulching with fig leaves	396-594
Perennial Crops	Grapevine (*Vitis vinifera)*	9.90-16.50	10-15 kg fruit/vine	Supports biodiversity, soil stabilization	Grape leaves for mulching	132-198
Perennial Crops	Citrus (*Citrus* spp.*)*	6.60-13.20	50-70 kg fruit/tree	High Vitamin C, supports local ecosystems	Mulching with citrus leaves	660-924
Perennial Crops	Mulberry (*Morus alba)*	6.60-13.20	30-50 kg fruit/tree	Attracts pollinators, supports biodiversity	Mulching with mulberry lea	396-660
Perennial Crops	Almond (*Prunus dulcis)*	9.90-19.80	3-5 kg nuts/tree	Drought-resistant, improves soil fertility	Mulching with almond leaves	39.60-66.00
Perennial Crops	Pistachio (*Pistacia vera)*	13.20-26.40	2-3 kg nuts/tree	Drought-tolerant, soil improvement	Mulching with pistachio leaves	26.40-39.60

Category	**Common Name (Scientific Name)**	**Initial Cost (USD per unit)**	**Yield per Year**	**Beneficial Properties**	**Soil Amendment**	**Potential Earning (USD/year per unit)**
Perennial Crops	Quince (*Cydonia oblonga)*	9.90-16.50	30-50 kg fruit/tree	Supports soil stability, drought-tolerant	Mulching with quince leaves	594-990
Cash Crops	Cotton (*Gossypium hirsutum)*	66-132	2-4 tons/ha	Soil aeration, provides organic matter	Cotton residues for mulch	3,300-5,280
Cash Crops	Wheat (*Triticum aestivum)*	13.20-33.00	2-3 tons/ha	Rotational crop, supports soil structure	Crop residues as mulch	792-1,320
Cash Crops	Barley (*Hordeum vulgare)*	9.90-26.40	2-4 tons/ha	Rotational crop, supports soil structure	Crop residues as mulch	990-1,650

Category	Common Name (Scientific Name)	Initial Cost (USD per unit)	Yield per Year	Beneficial Properties	Soil Amendment	Potential Earning (USD/year per unit)
Cash Crops	Sesame (*Sesamum indicum)*	33-66	1-2 tons/ha	Drought-resistant, improves soil health	Mulching with sesame residues	1,650-2,640
Cash Crops	Saffron (*Crocus sativus)*	3,300-6,600	2-5 kg/ha (dried)	High value, improves soil with cover crops	Compost from crop residues	9,900-16,500
Cash Crops	Chickpea (*Cicer arietinum)*	13.20-26.40	1-2 tons/ha	Nitrogen fixation, improves soil health	Crop residues as mulch	1,188-1,980
Cash Crops	Lentils (*Lens culinaris)*	13.20-26.40	1-2 tons/ha	Nitrogen fixation, improves soil health	Crop residues as mulch	1,188-1,980

Category	Common Name (Scientific Name)	Initial Cost (USD per unit)	Yield per Year	Beneficial Properties	Soil Amendment	Potential Earning (USD/year per unit)
Cash Crops	Sunflower (*Helianthus annuus)*	33-66	2-3 tons/ha (seeds)	Attracts pollinators, improves soil health	Mulching with sunflower stalks	1,650-2,970
Cash Crops	Alfalfa (*Medicago sativa)*	13.20-33.00	8-10 tons/ha (hay)	Nitrogen fixation, improves soil health	Mulching with alfalfa cuttings	2,310-3,960
Bees	Syrian Honey Bee (*Apis mellifera syriaca)*	330-660	20-30 kg honey/hive	Pollination of crops, honey production	Bee manure enhances soil fertility	660-990

Category	Common Name (Scientific Name)	Initial Cost (USD per unit)	Yield per Year	Beneficial Properties	Soil Amendment	Potential Earning (USD/year per unit)
Bees	Carniolan Honey Bee (*Apis mellifera carnica)*	462-792	25-35 kg honey/hive	High honey yield, efficient pollination	Bee manure, honey wax for mulching	792-1,188
Bees	Italian Honey Bee (*Apis mellifera ligustica)*	396-726	20-30 kg honey/hive	Strong honey production, good temperament	Bee wax enhances soil	660-990
Bees	Yemeni Honey Bee (*Apis mellifera jemenitica)*	330-660	15-25 kg honey/hive	Adapted to arid environments, strong foraging	Bee wax enhances soil	528-792

Category	Common Name (Scientific Name)	Initial Cost (USD per unit)	Yield per Year	Beneficial Properties	Soil Amendment	Potential Earning (USD/year per unit)
Flowers	Spanish Lavender (*Lavandula stoechas)*	1.32-3.30	100-150 kg/ha (oil)	Attracts pollinators, aromatic crop	Mulch with lavender cuttings	396-660
Flowers	Wild Thyme (*Thymus serpyllum)*	0.99-1.98	50-100 kg/ha (dried)	Supports bees, medicinal properties	Enhances soil health through deep roots	264-528
Flowers	Syrian Oregano (*Origanum syriacum)*	1.32-2.64	60-100 kg/ha (dried)	Attracts pollinators, medicinal	Mulch with oregano cuttings	330-594

Category	Common Name (Scientific Name)	Initial Cost (USD per unit)	Yield per Year	Beneficial Properties	Soil Amendment	Potential Earning (USD/year per unit)
Flowers	Rosemary (*Rosmarinus officinalis 'Arp')*	1.98-3.96	80-120 kg/ha (dried)	Aromatic, supports biodiversity	Mulch with rosemary cuttings	330-594
Flowers	Dwarf Garden Sage (S*alvia officinalis 'Berggarten')*	1.98-3.30	70-100 kg/ha (dried)	Medicinal, attracts pollinators	Mulch with sage cuttings	264-528
Flowers	Sweet Marjoram (Origanum majorana)	1.32-2.64	60-100 kg/ha (dried)	Attracts pollinators, medicinal, culinary	Mulch with marjoram cuttings	330-594

Category	Common Name (Scientific Name)	Initial Cost (USD per unit)	Yield per Year	Beneficial Properties	Soil Amendment	Potential Earning (USD/year per unit)
Flowers	Yellow Coneflower (*Echinacea paradoxa)*	1.65-3.30	50-80 kg/ha (dried)	Medicinal, supports pollinators	Mulch with coneflower cuttings	264-462
Flowers	Narrow-leaf Hyssop (*Hyssopus officinalis)*	1.32-2.64	40-60 kg/ha (dried)	Aromatic, medicinal, supports pollinators	Mulch with hyssop cuttings	198-330
Flowers	Resina Calendula (*Calendula officinalis)*	1.32-2.64	40-60 kg/ha (dried)	Medicinal, attracts pollinators	Mulch with calendula cuttings	198-330

Category	**Common Name (Scientific Name)**	**Initial Cost (USD per unit)**	**Yield per Year**	**Beneficial Properties**	**Soil Amendment**	**Potential Earning (USD/year per unit)**
Flowers	German Chamomile (*Matricaria recutita)*	0.99-1.98	30-50 kg/ha (dried)	Medicinal, attracts pollinators	Mulch with chamomile cuttings	165-264
Flowers	Lemon Balm *(Melissa officinalis)*	1.32-2.64	40-70 kg/ha (dried)	Aromatic, medicinal, supports pollinators	Mulch with lemon balm cuttings	198-396
Flowers	Desert Eve Yarrow (*Achillea millefolium)*	1.32-2.64	40-60 kg/ha (dried)	Medicinal, drought-resistant, supports pollinators	Mulch with yarrow cuttings	198-330

Category	Common Name (Scientific Name)	Initial Cost (USD per unit)	Yield per Year	Beneficial Properties	Soil Amendment	Potential Earning (USD/year per unit)
Flowers	White Borage (*Borago officinalis)*	1.32-2.64	50-80 kg/ha (dried)	Attracts pollinators, medicinal	Mulch with borage cuttings	264-462
Flowers	Topaz St. John's Wort (*Hypericum perforatum)*	1.32-2.64	30-50 kg/ha (dried)	Medicinal, supports pollinators	Mulch with St. John’s Wort cuttings	165-264
Flowers	Tree Aloe (*Aloe vera 'Arborescens')*	1.98-3.30	50-80 kg/ha (gel)	Medicinal, supports soil stability	Mulch with aloe cuttings	330-528
Flowers	Tumble Thistle (*Gundelia tournefortii)*	0.99-1.98	30-50 kg/ha (dried)	Medicinal, attracts pollinators	Mulch with thistle cuttings	165-264

Category	Common Name (Scientific Name)	Initial Cost (USD per unit)	Yield per Year	Beneficial Properties	Soil Amendment	Potential Earning (USD/year per unit)
Flowers	Iraqi Thyme (*Thymbra spicata)*	1.32-2.64	50-100 kg/ha (dried)	Supports bees, drought-resistant, medicinal	Mulch with thyme cuttings	330-660
Flowers	Anise (*Pimpinella anisum)*	1.32-2.64	50-100 kg/ha (seeds)	Medicinal, culinary, supports pollinators	Mulch with anise cuttings	330-660
Flowers	Milk Thistle (*Silybum marianum)*	1.32-2.64	60-100 kg/ha (seeds)	Medicinal, supports pollinators, drought-resistant	Mulch with milk thistle cuttings	396-660

Category	Common Name (Scientific Name)	Initial Cost (USD per unit)	Yield per Year	Beneficial Properties	Soil Amendment	Potential Earning (USD/year per unit)
Flowers	Desert Lavender (*Lavandula coronopifolia)*	1.32-3.30	100-150 kg/ha (oil)	Attracts pollinators, aromatic crop	Mulch with lavender cuttings	396-660
Beneficial Trees	Mesquite *(Prosopis juliflora)*	3.30-6.60	N/A	Nitrogen fixation, shade, windbreaks	Leaves and pods enrich soil	N/A
Beneficial Trees	Christ's Thorn Jujube *(Ziziphus spina-christi)*	6.60-9.90	20-50 kg fruit/tree	Drought-resistant, supports biodiversity	Leaf mulch for soil conditioning	66-165

Category	Common Name (Scientific Name)	Initial Cost (USD per unit)	Yield per Year	Beneficial Properties	Soil Amendment	Potential Earning (USD/year per unit)
Beneficial Trees	Athel Tamarisk *(Tamarix aphylla)*	4.62-7.92	N/A	Windbreak, soil stabilization, salt tolerance	Leaves and branches for mulch	N/A
Beneficial Trees	Euphrates Poplar *(Populus euphratica)*	5.28-9.90	N/A	Soil stabilization, drought-resistant	Leaf mulch for soil improvement	N/A
Beneficial Trees	Acacia *(Acacia tortilis)*	3.30-6.60	N/A	Nitrogen fixation, shade, windbreaks	Leaves enrich soil with nitrogen	N/A
Beneficial Trees	River Red Gum *(Eucalyptus camaldulensis)*	3.30-7.92	N/A	Soil stabilization, fast growth, windbreaks	Leaves for mulching, wood for biomass	N/A

Category	Common Name (Scientific Name)	Initial Cost (USD per unit)	Yield per Year	Beneficial Properties	Soil Amendment	Potential Earning (USD/year per unit)
Beneficial Trees	Toothbrush Tree *(Salvadora persica)*	5.28-9.90	100 to 200 Miswak sticks per year	Medicinal, soil stabilization	Leaves for mulching	0.33 to 0.66 per stick
Beneficial Trees	Saltbush *(Atriplex halimus)*	2.64-5.28	N/A	Salt-tolerant, improves saline soils	Leaves for mulching	N/A
Beneficial Trees	Mount Tabor Oak *(Quercus ithaburensis)*	6.60-13.20	N/A	Soil stabilization, drought-resistant	Leaves for mulching, acorns for wildlife	N/A
Beneficial Trees	Winter Thorn *(Faidherbia albida)*	3.30-6.60	N/A	Nitrogen fixation, shade, windbreaks	Leaves enrich soil with nitrogen	N/A

Category	Common Name (Scientific Name)	Initial Cost (USD per unit)	Yield per Year	Beneficial Properties	Soil Amendment	Potential Earning (USD/year per unit)
Beneficial Trees	Grey Mangrove *(Avicennia marina)*	4.62-9.90	N/A	Coastal stabilization, supports marine biodiversity	Leaves for mulching, protects shorelines	N/A

In Iraq's arid environment, sustainable agricultural practices and innovative technologies are essential to combat the challenges of desertification, water scarcity, and environmental degradation. The table 2 below presents a curated list of DIY (Do-It-Yourself) technologies that are not only applicable in such harsh conditions but are also cost-effective and practical for local farmers and communities to implement. These technologies range from renewable energy solutions and water management techniques to soil enhancement practices, all designed to enhance agricultural productivity and environmental sustainability. Each entry in the table includes a description of the technology, its practical application, the benefits it offers, and relevant references to guide implementation. This compilation serves as a resource for those looking to adopt resilient and sustainable practices in the challenging landscape of Iraq [Table 2.].

Table 2: Comprehensive list of tested budget and DIY-friendly technologies to overcome budget and dependency challenges

Technology	Description	Application	Benefits	Reference
Biochar Production	Producing biochar from organic matter for soil amendment	Biochar produced on farms using simple kilns or pits from agricultural residues	Increases soil carbon content, improves soil structure, enhances water retention, boosts crop yields, provides electricity and gas as byproducts	LaCanne & Lundgren, 2018
Biogas Production	Producing renewable energy from organic material through anaerobic digestion	Construct biogas digesters using bricks and plastic containers	Provides renewable energy, reduces waste, and produces organic fertilizer	Kumar, 2020
Solar Water Heaters	Uses solar energy to heat water for domestic and agricultural use	Construct using metal sheets, pipes, and glass panels	Provides renewable energy, reduces energy costs, and ensures hot water supply	Abdulhameed et al., 2024
Drip Irrigation Systems	Delivering water directly to plant roots through a network of pipes and emitters	DIY drip systems using PVC pipes and low-cost emitters for small plots of land	Minimizes water usage, reduces evaporation losses, and improves water use efficiency	Rasheed & Al-Adil, 2016
Rainwater Harvesting (RWH)	Collecting and storing rainwater for agricultural use	Collect rainwater from rooftops or catchment areas and store in tanks or underground cisterns	Provides a supplementary water source, reduces dependence on unreliable rainfall, and manages water scarcity	Trivedi et al., 2024
Solar-Powered Irrigation Pumps	Using solar energy to pump water for irrigation	Install small-scale solar panels connected to water pumps for irrigation	Provides renewable energy, reduces energy costs, and ensures a reliable water supply	Pearson, 2007

Sand Battery for Energy Storage	Stores thermal energy in sand, releasing it for heating or electricity generation	Create using an insulated container filled with sand, heated by solar energy	Provides renewable energy storage, ensures a stable energy supply	Kumar,S. 2019
Composting Toilets	Converts human waste into compost, reducing water use and providing fertilizer	Build using wood, metal, and composting bins	Reduces water usage, produces organic fertilizer, and improves sanitation	Abdulhameed et al., 2024
Solar Desalination	Uses solar energy to desalinate water for irrigation or drinking	Construct solar stills using glass, metal, and plastic sheeting	Provides a source of desalinated water, reduces reliance on freshwater sources	Khan, M. A., & Kumar, S. 2011
Eco-Bricks	Plastic bottles packed with waste, used as building blocks for construction	Create eco-bricks using waste materials for building structures	Recycles plastic waste, reduces building material costs, and supports sustainable construction	Pérez, J., & Ribeiro, A. (Eds.). (2021
Clay Pot Irrigation	Uses porous clay pots to slowly release water to plant roots, conserving water	Implement by burying clay pots and filling them with water	Reduces water usage, improves water distribution efficiency, and enhances plant growth	Adhikary, R., & Pal, A. 2020
Windbreaks Using Local Materials	Barriers to reduce wind speed and prevent soil erosion	Plant fast-growing trees or build barriers using palm leaves, reeds…	Protects crops from wind damage, reduces soil erosion, and improves microclimate	Mirhasani, 2019
Composting Systems	Composting organic waste into nutrient-rich soil amendments	Compost pits or bins using wood or bricks on farms	Enhances soil organic matter, improves soil structure, and provides essential nutrients for crops	Pearson, 2007
Mulching	Covering soil with organic materials to reduce evaporation and enhance fertility	Use of crop residues, palm fronds, or other organic materials to create mulch layers over fields	Reduces water loss, improves soil moisture retention, and adds organic matter to the soil	Khangura et al., 2023

Cover Cropping	Planting crops during the off-season to protect and enrich the soil	Use legumes like cowpea or clover as cover crops	Improves soil fertility through nitrogen fixation, enhances soil structure, and reduces erosion	Singh et al., 2024
Vermiculture	Using earthworms to convert organic waste into vermicompost	Set up vermiculture bins with organic waste and earthworms	Produces high-quality organic fertilizer, improves soil fertility, and reduces waste	Pearson, 2007

5.2 Step by step example of implementation depending on the farm size, objective of the farm and two different budgets

Three Farm Types

In Iraq, land is commonly measured using the unit called "dunum" (also spelled as "donum"). A dunum is a traditional unit of area measurement that originated in the Ottoman Empire and is still widely used in several Middle Eastern countries, including Iraq (İnalcık, 1994). Conversion and Context:

-1 dunum is equivalent to 2,500 square meters or 0.25 hectares (FAO, 2020).

-1 hectare equals 10 dunums (FAO, 2020).

The term "dunum" historically referred to the amount of land that could be plowed by a man with a pair of oxen in a day (İnalcık, 1994). This measurement has persisted through time and continues to be a practical unit for land area, especially in agriculture (Pamuk, 2004). Classification of Farm Sizes in Iraq:

-Small-Scale Farming: Area typically, less than 25 dunums (less than 2.5 hectares) (Iraqi Ministry of Agriculture, 2021). These farms are often family-owned and operated, with limited mechanization and reliance on family labor. They may focus on subsistence farming or small-scale commercial production of crops or livestock (World Bank, 2019).

-Medium-Scale Farming: Area can ranges between 25 to 125 dunums (2.5 to 12.5 hectares) (Iraqi Ministry of Agriculture, 2021). Medium-scale farms are usually more mechanized, have access to more resources, and might employ additional labor. They often produce for local markets and may diversify their production with a variety of crops or livestock (OECD, 2021).

-Large-Scale Farming: Area are more than 125 dunums (over 12.5 hectares) (Iraqi Ministry of Agriculture, 2021). Large-scale farms are highly mechanized, may employ advanced agricultural technologies, and often operate as commercial enterprises with significant output. These farms usually produce for national or international markets and may involve monoculture or specialized large-scale livestock production (USAID, 2017).

The dunum is deeply rooted in the agricultural history of the region, with its origins in the Ottoman period when land measurement was essential for tax and administrative purposes (İnalcık, 1994). The continued use of the dunum in Iraq reflects the persistence of traditional agricultural practices alongside modern techniques, providing a familiar and practical scale for local farmers (Pamuk, 2004). Understanding land in terms of dunums helps to maintain continuity with historical practices while also allowing for easy conversion to hectares, a more internationally recognized unit of land measurement. This dual use ensures that both local and international stakeholders can understand and manage agricultural land effectively (FAO, 2020).

- *Creating*

In the context of Iraq, starting from scratch refers to establishing a new agricultural operation with no pre-existing infrastructure or practices in place. This involves selecting and preparing land, designing farm layouts, and implementing initial systems for crops, livestock, and energy.

The focus is on adopting regenerative practices from the outset, such as organic inputs, efficient water management, and renewable energy systems, to build a sustainable foundation for the farm. This process is particularly relevant in Iraq, where water scarcity and soil degradation are significant challenges, requiring thoughtful planning and investment to ensure long-term viability.

- *Optimizing*

Optimizing in the Iraqi agricultural context involves improving existing farming operations by integrating more efficient and sustainable practices. For small to large-scale farms, this might include upgrading to advanced irrigation systems, enhancing soil health with organic amendments, or incorporating renewable energy sources to reduce costs and environmental impact. Optimization focuses on refining and enhancing current systems to increase productivity, improve resource use, and align more closely with regenerative agriculture principles, which is crucial for addressing Iraq's unique environmental conditions.

- *Transition*

Transitioning refers to the gradual process of shifting an existing conventional farming operation to a fully regenerative agricultural system. In Iraq, this transition involves adopting sustainable practices like crop rotation, organic fertilization, and advanced grazing management, while phasing out reliance on chemical inputs and non-renewable energy. For large-scale farms, this might also include significant investments in water management technologies and renewable energy infrastructure. The goal of transitioning is to create a more resilient and sustainable farming operation that can withstand the environmental challenges prevalent in Iraq, such as drought and soil erosion.

- *Low and High Budgets:*

As of 2024, Iraq's income distribution reflects significant disparities. The lower income segment, particularly those within the bottom 50% of the population, typically earns below $1,500 annually. This is largely due to the broader economic challenges in the country, including high unemployment rates and limited access to stable, well-paying jobs. On the other hand, the wealthiest 10% of Iraqis, benefiting from the country's oil wealth and other investments, earn substantially more, with incomes often exceeding $50,000 annually. The upper echelons, including the top 1%, can have incomes far above this level, reflecting Iraq's pronounced income inequality (World Bank Blogs, WID - World Inequality Database)

In the context of Iraq a low-budget scenario emphasis on maximizing the use of available resources, implementing cost-effective practices, and gradually transitioning to more sustainable methods without incurring significant upfront costs. A high budget in the Iraqi agricultural context refers to a scenario where substantial financial resources are available for investment in farming operations. This enables farmers to adopt advanced technologies, infrastructure, and sustainable practices that can significantly enhance productivity and efficiency. With a high budget, investments might include state-of-the-art irrigation systems, renewable energy sources like solar or wind power, advanced livestock management facilities, and large-scale organic or regenerative agriculture practices. In Iraq, such a budget is often accessible to wealthier landowners, agribusinesses, or those with access to credit or government subsidies. High-budget operations are positioned to lead in the adoption of innovative practices that not only increase yields but also contribute to long-term environmental sustainability. These farms can afford to invest in research and development, high-quality inputs, and advanced technologies, thereby playing a crucial role in transforming Iraq's agricultural sector towards more sustainable and productive methods.

Blueprints Implementation Step-by-step:

The following part is a compilation of implementation strategies approximation of strategies of cost for arid, the cost is an approximation based on word bank data from 2022.

5.2.1 Creating a Regenerative Agriculture System: Small-Scale Farms (Less than 25 Dunums)

Low Budget

This section outlines the step-by-step implementation of a regenerative agriculture system for small-scale farms in Iraq, focusing on how each element complements the others, and provides approximate local costs based on existing conditions [Table.3].

Table 3: Step-by-step implementation of a regenerative agriculture system for small-scale farms in Iraq with lower budget (FAO and World Bank).

Step	**Action**	**Implementation**	**Complementary Elements**	**Cost Approximation (IQD- Iraqi Dinar)**	**Cost Approximation (USD)**
1	**Crop Selection and Planting**	Select and plant drought-resistant crops (barley, chickpeas, thyme, sage). Prepare soil with minimal tillage, use organic fertilizers (compost, manure), and source seeds locally.	Crops improve soil health, require less water, and reduce dependency on external resources. Chickpeas fix nitrogen, and crop residues add organic matter to the soil.	Seeds: 50,000 - 100,000	30 - 60
				Organic Fertilizers: 25,000 - 50,000	15 - 30
2	**Livestock Integration**	Introduce local breeds of sheep and goats. Begin with a small herd and rotate grazing areas to allow pasture regeneration. Utilize livestock manure as a natural fertilizer.	Livestock create a closed-loop system where crop residues feed the animals, and manure fertilizes the crops, reducing the need for chemical fertilizers and enhancing soil health.	Livestock Purchase: 150,000 - 250,000	100 - 160
				Fencing: 100,000 - 150,000	60 - 90
3	**Apiculture Introduction**	Introduce Syrian honeybees with 1-2 hives. Place hives in areas with plenty of flowering plants like thyme and sage for nectar.	Bees enhance pollination, boosting crop productivity and contributing to biodiversity. Honey production provides additional income.	Beehive: 100,000 - 200,000	60 - 120

				Bee Purchase: 50,000 - 100,000	30 - 60
4	**Establishing Perennial Crops**	Plant drought-resistant trees like Zahdi date palms and figs. Place trees along the farm's edges or in designated areas to avoid interfering with crop rotations. Regularly water young trees until they establish deep roots.	Perennial crops provide shade, reduce soil erosion, create microclimates, and contribute organic matter through leaf litter, improving soil health.	Saplings: 200,000 - 300,000	120 - 180
				Irrigation Setup: 50,000 - 100,000	30 - 60
5	**Water Management System**	Implement basic rainwater harvesting and greywater recycling systems. Set up gutters and storage tanks to capture rainwater and filter greywater for irrigation.	Efficient water use supports crop and livestock health, ensuring farm productivity even during dry periods.	Rainwater Harvesting: 150,000 - 300,000	100 - 200
				Greywater System: 100,000 - 150,000	60 - 90
6	**Energy Solutions**	Install solar-powered pumps for irrigation. Set up a small solar panel system to power a pump that draws water from a well or stored rainwater tanks.	Solar energy reduces reliance on fossil fuels, lowers operational costs, and ensures sustainable irrigation.	Solar Pump and Panel: 300,000 - 500,000	200 - 320
				Installation: 100,000 - 150,000	60 - 90

7	**Transport and Storage**	Construct storage sheds with locally sourced materials and use manual transport methods like wheelbarrows or carts.	Effective storage protects crops from pests and the elements, while simple transport methods keep operational costs low, contributing to the overall efficiency and sustainability of the farm.	Storage Shed: 150,000 - 250,000	100 - 160
				Transport Tools: 50,000 - 100,000	30 - 60

By following these steps, small-scale farmers in Iraq can create a regenerative agriculture system that is resilient, cost-effective, and sustainable. Each element—from crop selection to water management—works together to create a farming system that enhances soil health, conserves water, and maximizes the productivity of both crops and livestock. The initial costs for setting up this system can be kept relatively low by focusing on locally available materials and resources. Over time, the integration of crops, livestock, and renewable energy sources will reduce operational costs, increase productivity, and provide multiple income streams, making small-scale farming a viable and sustainable option in Iraq's challenging environment.

Higher Budget

For small-scale farms with access to a higher budget, the implementation of a regenerative agriculture system can incorporate advanced technologies and higher-value crops, making the farm not only sustainable but also highly profitable. Here's a step-by-step guide on how to achieve this, including the integration of crops, livestock, apiculture, perennial crops, water systems, energy solutions, and transport/storage, along with cost approximations in the context of Iraq [Table.4].

Table 4: step-by-step implementation of a regenerative agriculture system for small-scale farms in Iraq for wealthier budget (FAO and World Bank).

Step	Action	Implementation	Complementary Elements	Cost Approximation (IQD- Iraqi Dinar)	Cost Approximation (USD)
1	**Crop Selection and Diverse Crop Rotations**	Invest in diverse crop rotations with high-value crops like saffron and medicinal herbs (e.g., *Echinacea*). Plan crop rotation to maximize soil fertility and reduce pest cycles. Plant saffron in sunny, well-drained areas.	Diverse crops maintain soil health, reduce reliance on chemical inputs, and provide multiple income streams. Crop rotations improve soil structure and water retention, enhancing farm resilience.	Saffron Bulbs: 1,500,000 - 2,000,000	1,000 - 1,300
				Medicinal Herb Seeds: 200,000 - 400,000	130 - 260
2	**Livestock Integration with Enhanced Grazing Systems**	Incorporate a mix of local and improved sheep and goat breeds. Develop rotational grazing systems and invest in organic feed supplements during dry seasons.	Improved breeds provide higher yields of milk and meat. Rotational grazing minimizes soil compaction and overgrazing, enhancing pasture quality and long-term land sustainability.	Improved Breed Purchase: 500,000 - 700,000	330 - 460
				Grazing Infrastructure: 300,000 - 500,000	200 - 330
				Organic Feed Supplements:	30 - 60

				50,000 - 100,000/month	
3	**Expansion of Apiculture with Advanced Bee Management**	Expand apiculture by adding hives and using advanced bee management practices (e.g., hive inspections, queen management).	Bees are crucial for pollinating high-value crops like saffron and medicinal herbs. Increasing the number of hives enhances crop yields and honey production, creating a synergistic effect on the farm.	Additional Hives: 150,000 - 250,000	100 - 160
				Bee Management Equipment: 100,000 - 200,000	60 - 130
4	**Establishment of a High-Yield Orchard**	Establish an orchard with high-yield date palms (e.g., Barhi, Halawi), olives (Ashrasi), and pomegranates (Nab El-Gamal). Prepare the land with deep plowing and plant saplings during cooler months.	The orchard diversifies farm income and provides a stable revenue stream. Trees help stabilize soil, reduce erosion, and create microclimates that benefit other crops and livestock.	Saplings: 500,000 - 1,000,000	330 - 660
				Orchard Setup (including irrigation): 1,000,000 - 2,000,000	660 - 1,320

5	**Installation of Advanced Water Management Systems**	Install drip irrigation and large-scale rainwater catchment systems. Use drip lines to deliver water directly to crop roots and store rainwater in large tanks.	Efficient water use is essential for maintaining crop health, especially in arid regions. Advanced water systems reduce waste, lower costs over time, and ensure farm productivity during droughts.	Drip Irrigation System: 2,000,000 - 3,000,000	1,320 - 2,000
				Rainwater Harvesting System: 1,500,000 - 2,500,000	1,000 - 1,660
6	**Investment in Off-Grid Solar Energy Systems**	Install an off-grid solar energy system with battery storage to power irrigation, lighting, and other farm operations.	Solar energy reduces reliance on external power sources and lowers operational costs, aligning with regenerative agriculture principles by minimizing the farm's carbon footprint.	Solar Panel Installation: 4,000,000 - 6,000,000	2,640 - 4,000
				Battery Storage System: 3,000,000 - 5,000,000	2,000 - 3,300

7	**Development of Cold Storage and Transport Solutions**	Build cold storage facilities and acquire refrigerated vehicles to transport perishable goods like saffron, medicinal herbs, and dairy products to markets.	Cold storage and efficient transport maintain product quality and reduce post-harvest losses, enabling access to higher-value markets and increasing farm profitability.	Cold Storage Facility: 7,000,000 - 10,000,000	4,600 - 6,600
				Refrigerated Vehicle: 20,000,000 - 30,000,000	13,200 - 20,000

For small-scale farms with a wealthy budget, investing in advanced and high-value agricultural practices can significantly enhance profitability while maintaining sustainability. By following the outlined steps—focusing on diverse crop rotations, improved livestock systems, expanded apiculture, high-yield orchards, advanced water management, renewable energy, and effective transport and storage—farmers can create a resilient and highly productive regenerative agriculture system in Iraq. The initial investment may be substantial, but the returns, in terms of both economic gains and environmental benefits, can be significant. This approach not only supports the long-term viability of the farm but also contributes to broader goals of food security and environmental stewardship in Iraq.

5.2.2 Medium-Scale Farms (25-125 Dunums)

Low Budget

For medium-scale farms with a limited budget, the focus should be on creating a sustainable and efficient system that maximizes productivity while minimizing costs. This involves strategic crop selection, careful livestock management, and the integration of basic technologies. The following steps outline how to implement a regenerative agriculture system tailored to these conditions, emphasizing cost-effective methods and gradual scalability [Table.5].

Table 5: step-by-step implementation of a regenerative agriculture system for medium scale farms with lower budgets (FAO and World Bank).

Step	Action	Implementation	Complementary Elements	Cost Approximation (IQD)	Cost Approximation (USD)
1	**Crop Selection and Cultivation**	Focus on staple crops such as wheat and barley, alongside legumes like lentils and chickpeas. Prepare the land using minimal tillage, and plant crops in rotation to improve nitrogen levels in the soil.	Legumes complement staple crops by fixing nitrogen in the soil, benefiting subsequent crops in the rotation and reducing the need for synthetic fertilizers.	Seeds: 100,000 - 200,000	65 - 130
				Basic Soil Preparation: 50,000 - 100,000	30 - 65
2	**Livestock Integration with Rotational Grazing**	Maintain a mixed herd of sheep, goats, and a few cattle. Implement rotational grazing by dividing the land into paddocks to prevent overgrazing and allow pastures to regenerate.	Livestock provide manure that enriches the soil, and rotational grazing ensures pasture health and animal productivity. The inclusion of cattle adds diversity to income streams and optimizes pasture use.	Livestock Purchase: 1,500,000 - 2,500,000	1,000 - 1,650
				Fencing and Water Points: 300,000 - 600,000	200 - 400
3	**Initial Apiculture Setup**	Start with a few beehives to integrate apiculture into the farm. Place hives in areas with abundant flowering plants, particularly legumes, to enhance pollination and increase crop yields.	Bees enhance crop productivity through pollination, and honey production provides additional income. As the farm grows, more hives can be added to	Beehives: 100,000 - 150,000	65 - 100

			further increase yields and profitability.	Bee Colony: 50,000 - 100,000	30 - 65
4	**Establishment of a Small Orchard**	Establish a small orchard with hardy varieties of olives and pomegranates. Plant trees in a dedicated section of the farm, ensuring proper spacing and initial irrigation to help saplings establish.	The orchard diversifies income, improves farm resilience, and contributes to biodiversity. Trees also act as windbreaks, reduce soil erosion, and provide shelter for livestock.	Tree Saplings: 300,000 - 500,000	200 - 330
				Irrigation Setup for Young Trees: 150,000 - 250,000	100 - 160
5	**Basic Water Management System**	Install a basic well with a hand pump and set up simple drip irrigation to ensure crops and trees receive sufficient water, particularly during the dry season.	Drip irrigation delivers water directly to plant roots, minimizing waste and ensuring efficient use of water. The well provides a reliable water source, reducing dependency on rainfall.	Well and Hand Pump: 500,000 - 1,000,000	330 - 660
				Drip Irrigation System: 500,000 - 800,000	330 - 530

6	**Solar Energy Solutions**	Use solar panels to power lighting and small-scale irrigation systems. Install panels in areas with maximum sunlight exposure to ensure consistent energy generation.	Solar energy reduces operational costs and reliance on external power sources. It is particularly useful for running irrigation systems, ensuring consistent water supply for crops.	Solar Panel Setup: 1,500,000 - 3,000,000	1,000 - 2,000
				Basic Battery Storage: 500,000 - 1,000,000	330 - 660
7	**Basic Transport and Storage Infrastructure**	Construct storage sheds using locally sourced materials and use animal-drawn carts for transportation. Proper storage protects crops from elements, while simple transport methods are sufficient for farm operations.	Effective storage and transport reduce post-harvest losses and ensure that produce reaches the market in good condition. These systems are crucial for maintaining crop quality and farm efficiency.	Storage Shed Construction: 1,000,000 - 2,000,000	660 - 1,300
				Animal-Drawn Cart: 200,000 - 400,000	130 - 260

For medium-scale farms in Iraq with a low budget, implementing a regenerative agriculture system is both achievable and sustainable. By focusing on strategic crop and livestock choices, utilizing basic technologies for water and energy management, and building simple infrastructure for storage and transport, farmers can create a productive and resilient farming system.The initial investments are modest but provide significant returns in terms of improved soil health, diversified income streams, and long-term sustainability. This approach not only meets the immediate needs of the farm but also positions it for future growth as resources become available. The integration of these elements creates a cohesive system where each component supports the others, leading to a balanced and efficient operation.

Higher Budget

For medium-scale farms with a wealthy budget, the goal is to create a highly productive, technologically advanced, and sustainable farming system. This involves diversifying crops with high-value options, investing in top-tier livestock and infrastructure, and integrating state-of-the-art technologies for water and energy management. The following steps provide a comprehensive guide to implementing a regenerative agriculture system that maximizes both productivity and sustainability [Table.6].

Table 6 : Step-by-step implementation of a regenerative agriculture system for medium-scale farms with wealthier budgets

Step	Action	Implementation	Complementary Elements	Cost Approximation (IQD)	Cost Approximation (USD)
1	**Crop Diversification with High-Value Cash Crops**	Diversify the farm's crops by planting high-value cash crops like saffron, organic vegetables, and cover crops. Saffron should be planted in sunny, well-drained areas, and cover crops should be used in off-seasons.	High-value crops offer significant economic returns, while cover crops improve soil health and structure, reducing the need for synthetic fertilizers and ensuring long-term farm productivity.	Saffron Bulbs: 1,500,000 - 2,500,000	1,000 - 1,650
				Organic Vegetable Seeds: 500,000 - 1,000,000	330 - 660
				Cover Crop Seeds: 100,000 - 200,000	65 - 130
2	**Investment in Premium Livestock and Advanced Grazing Systems**	Invest in higher-quality livestock breeds and advanced rotational grazing systems with automated infrastructure. Premium breeds offer higher yields, and	Premium livestock combined with advanced grazing systems maximize productivity and sustainability, reducing labor costs and enhancing	Premium Livestock Purchase: 2,000,000 - 4,000,000	1,300 - 2,600

		advanced systems ensure optimal pasture use.	soil health through efficient pasture management.	Advanced Grazing Infrastructure: 1,000,000 - 2,000,000	660 - 1,300
3	**Expansion of Apiculture into Large-Scale Operations**	Develop a large-scale apiary by expanding the number of hives and incorporating professional beekeeping equipment. Set up a dedicated area and invest in advanced equipment and facilities.	A large-scale apiary improves crop yields through enhanced pollination and provides a steady income from honey and other bee products, supporting the farm’s economic sustainability.	Additional Hives and Equipment: 500,000 - 1,000,000	330 - 660
				Professional Beekeeping Equipment: 1,000,000 - 2,000,000	660 - 1,300
4	**Establishment of a Diverse Orchard with Exotic Fruit Varieties**	Plant a diverse range of fruit trees, including traditional and exotic varieties, and support tree health with mulching, composting, and organic fertilizers.	A diverse orchard increases biodiversity and provides multiple revenue streams, with soil health practices ensuring long-term productivity and resilience of the farm ecosystem.	Fruit Tree Saplings: 1,000,000 - 2,000,000	660 - 1,300
				Soil Health Improvements : 500,000 - 1,000,000	330 - 660

5	**Implementation of a Fully Automated Irrigation System**	Install a fully automated irrigation system linked to weather stations and soil moisture sensors. This ensures efficient water use and optimal crop and tree hydration.	Automated irrigation reduces labor costs and prevents over- or under-watering, ensuring consistent crop health and maximizing yields, which is crucial for high-value crops and orchards.	Automated Irrigation System: 3,000,000 - 5,000,000	2,000 - 3,300
				Weather Stations and Sensors: 1,000,000 - 2,000,000	660 - 1,300
6	**Installation of a Hybrid Solar-Wind Energy System**	Invest in a hybrid solar-wind energy system to power all farm operations, including irrigation, lighting, and machinery, ensuring energy independence and sustainability.	A hybrid energy system reduces dependency on external power sources, lowers operational costs, and supports the farm's environmental goals by minimizing the carbon footprint.	Solar Panels and Wind Turbines: 5,000,000 - 10,000,000	3,300 - 6,600
				Battery Storage: 2,000,000 - 4,000,000	1,300 - 2,600
7	**Development of Advanced Storage and Transport Infrastructure**	Build advanced, climate-controlled storage facilities and invest in refrigerated transport vehicles to maintain the quality of perishable goods and ensure market readiness.	Advanced storage and transport infrastructure are essential for maintaining the quality and value of high-value crops and livestock products,	Climate-Controlled Storage Facilities: 7,000,000 - 15,000,000	4,600 - 10,000

			allowing access to premium markets and maximizing returns.	Refrigerated Transport Vehicles: 20,000,000 - 40,000,000	13,200 - 26,400

With a wealthy budget, medium-scale farms in Iraq can achieve high levels of productivity and sustainability by investing in advanced technologies and diversified agricultural practices. From high-value cash crops and premium livestock to sophisticated irrigation and energy systems

5.2.3 Large-Scale Farms (Over 125 Dunums)

Low Budget

For large-scale farms with a limited budget, the focus is on optimizing resource use, maintaining soil health, and integrating cost-effective technologies. The goal is to establish a sustainable and productive farming system that can scale over time as more resources become available. The following steps outline how to create a regenerative agriculture system tailored to the needs and constraints of a large-scale operation with a low budget [Table.7].

Table 7: Step-by-step implementation of a regenerative agriculture system for large-scale farms with lower budgets (FAO and World Bank).

Step	Action	Implementation	Complementary Elements	Cost Approximation (IQD)	Cost Approximation (USD)
1	**Crop Selection and Cultivation**	Focus on growing a mix of staple crops such as wheat and barley, alongside drought-resistant cash crops like safflower or millet. Use minimal tillage, crop rotation, and intercropping to maintain soil health.	Drought-resistant cash crops help stabilize income despite unpredictable weather, while staple crops ensure food security. Crop diversity enhances soil fertility and reduces reliance on chemical inputs.	Seeds: 500,000 - 1,000,000 per hectare Basic Soil Preparation: 200,000 - 500,000 per hectare	330 - 660 per hectare 130 - 330 per hectare
2	**Large-Scale Livestock Management**	Operate a large-scale livestock operation with cattle, sheep, and goats. Implement rotational grazing across multiple paddocks using	Rotational grazing improves soil health by preventing overgrazing and promoting plant diversity. Mixed livestock species optimize pasture use and reduce feed costs.	Livestock Purchase: 3,000,000 - 5,000,000 per herd	2,000 - 3,300 per herd

		mobile fencing and temporary water points.		Grazing Management Infrastructure: 500,000 - 1,500,000 per hectare	330 - 1,000 per hectare
3	**Expansion of Apiculture Across the Farm**	Manage multiple apiaries across the farm to enhance pollination and honey production. Distribute beehives near flowering crops and orchards and protect them from predators. Start small and expand over time.	Bees play a critical role in pollinating crops, particularly fruit trees and certain cash crops, leading to higher yields and better-quality produce. Honey production provides an additional income stream.	Beehives and Colonies: 1,000,000 - 2,000,000	660 - 1,300
				Beekeeping Supplies: 500,000 - 1,000,000	330 - 660
4	**Development of Extensive Perennial Crop Orchards**	Develop extensive orchards focusing on drought-resistant species like date palms (e.g., Zahdi and Halawi) and olives. Ensure adequate watering during early	Perennial crops such as date palms and olives provide long-term income, contribute to soil stability, reduce erosion, and create microclimates that benefit other crops.	Tree Saplings: 2,000,000 - 4,000,000 per hectare	1,300 - 2,600 per hectare

		growth and use organic mulches to conserve moisture.		Orchard Maintenance: 500,000 - 1,000,000 per hectare annually	330 - 660 per hectare annually
5	**Implementation of Large-Scale Water Management Systems**	Set up large-scale rainwater harvesting systems and a network of ponds for water storage. Install gutters, storage tanks, and ponds to capture and store water, using gravity-fed systems to reduce energy costs.	Effective water management is crucial for maintaining crop and livestock health. These systems ensure the farm remains productive during dry seasons by providing a reliable water source.	Rainwater Harvesting System: 2,000,000 - 4,000,000	1,300 - 2,600
				Pond Construction: 1,500,000 - 3,000,000 per pond	1,000 - 2,000 per pond
6	**Establishment of Large-Scale Solar Energy Farms**	Use large-scale solar farms to power irrigation, lighting, and other essential farm operations. Install solar panels and connect them to a battery storage system to always ensure energy availability.	Solar energy reduces dependency on grid electricity or fossil fuels, lowering operational costs and enhancing environmental sustainability. This renewable energy source supports all farm operations.	Solar Panel Installation: 10,000,000 - 20,000,000	6,600 - 13,200

				Battery Storage: 5,000,000 - 10,000,000	3,300 - 6,600
7	**Development of Logistics and Storage Infrastructure**	Establish a logistics network with multiple storage points and transport vehicles. Build storage facilities, invest in transport vehicles, and expand the network to include refrigerated storage and transport for perishables.	Efficient logistics and storage are essential for maintaining the quality of crops and livestock products, ensuring they reach the market in good condition. This infrastructure is critical for large-scale operations.	Storage Facility Construction: 3,000,000 - 6,000,000 per facility	2,000 - 4,000 per facility
				Transport Vehicles: 10,000,000 - 20,000,000	6,600 - 13,200

For large-scale farms in Iraq with a low budget, the focus should be on optimizing existing resources and gradually building a sustainable, regenerative agricultural system. By prioritizing soil health, efficient water use, and the integration of renewable energy, these farms can achieve long-term productivity and resilience. Each step in this plan—from crop selection to logistics infrastructure—complements the others, creating a cohesive system that maximizes output while minimizing costs. As more resources become available, the farm can scale up operations and integrate more advanced technologies, ensuring continued growth and sustainability.

Higher Budget

For large-scale farms with a wealthy budget, the focus is on creating a highly efficient, technologically advanced, and sustainable farming operation. This involves implementing extensive crop rotations, integrating sophisticated livestock systems, scaling up apiculture, and investing in state-of-the-art water, energy, and logistics infrastructure. The following steps provide a comprehensive guide to establishing a top-tier regenerative agriculture system that maximizes productivity, sustainability, and profitability [Table.8].

Table 8: Step-by-step implementation of a regenerative agriculture system for large-scale farms with wealthier budgets (FAO and World bank)

Step	Action	Implementation	Complementary Elements	Cost Approximation (IQD)	Cost Approximation (USD)
1	**Implementation of Extensive Crop Rotations**	Implement extensive crop rotations including high-value crops like saffron, organic vegetables, specialty grains, and cover crops (clover, vetch). Use soil amendments like compost and biochar to enhance fertility.	Crop rotations combined with soil amendments improve soil health, reduce pest and disease cycles, and enhance yields. This practice diversifies income and ensures steady production year-round.	High-Value Crop Seeds and Inputs: 2,000,000 - 4,000,000 per hectare	1,300 - 2,600 per hectare
				Soil Amendments: 1,000,000 - 2,000,000 per hectare	660 - 1,300 per hectare
2	**Creation of an Integrated Livestock System**	Develop an integrated livestock system with advanced facilities like feedlots, automated feeding systems, and on-site processing units for cattle, sheep, goats, and poultry.	Advanced livestock facilities enhance productivity and profitability through efficient feed use, reduced labor costs, and high-quality meat and dairy production. Manure management systems recycle nutrients.	Feedlot Construction: 10,000,000 - 20,000,000	6,600 - 13,200
				Processing Units: 15,000,000 - 30,000,000	10,000 - 20,000
3	**Scaling Up Apiculture to an Industrial Level**	Expand beekeeping operations to an industrial level by increasing the number of hives and incorporating advanced hive management systems.	Industrial-scale apiculture enhances crop pollination, improving yields and quality, while honey and other bee	Expansion of Hives and Technology: 5,000,000 - 10,000,000	3,300 - 6,600

		Establish processing facilities for honey and other bee products.	products provide a significant income stream.	Processing Facility: 10,000,000 - 20,000,000	6,600 - 13,200
4	**Cultivation of Extensive Orchards with Diverse Fruit and Nut Trees**	Develop extensive orchards with a variety of high-yield fruit and nut trees (almonds, pistachios, citrus, stone fruits). Use soil and water conservation practices like mulching, drip irrigation, and terracing.	A diverse orchard provides a stable, long-term income through high-value fruits and nuts. Soil and water conservation practices ensure sustainability by maintaining soil health and optimizing water use.	Tree Saplings: 5,000,000 - 10,000,000 per hectare	3,300 - 6,600 per hectare
				Soil and Water Conservation Practices: 2,000,000 - 4,000,000 per hectare	1,300 - 2,600 per hectare
5	**Investment in Comprehensive Water Management Systems**	Invest in a comprehensive water management system including large-scale irrigation networks, water recycling systems, and desalination units.	A comprehensive water management system ensures sustainability by providing a reliable water supply even in arid regions, reducing costs,	Irrigation Network: 15,000,000 - 30,000,000	10,000 - 20,000

			and improving crop yields through efficient water use.	Desalination Units and Recycling Systems: 20,000,000 - 40,000,000	13,200 - 26,400
6	**Implementation of a Fully Integrated Renewable Energy System**	Implement a fully integrated renewable energy system (solar, wind, biogas) to achieve energy independence. This system powers all farm operations, including irrigation, processing, and storage.	A fully integrated renewable energy system reduces the farm's carbon footprint, lowers energy costs, and ensures reliable power for all operations, including processing and cold storage facilities.	Solar Panels and Wind Turbines: 20,000,000 - 40,000,000	13,200 - 26,400
				Biogas Plant Installation: 10,000,000 - 20,000,000	6,600 - 13,200
7	**Development of a State-of-the-Art Logistics and Storage System**	Develop a state-of-the-art logistics system with automated storage facilities and refrigerated transport vehicles. This system ensures efficient handling, storage, and transport of produce.	Advanced logistics and storage systems maintain the quality of produce, reduce post-harvest losses, and enhance market access, supporting the farm's ability to deliver high-quality products consistently.	Automated Storage Facilities: 30,000,000 - 60,000,000	20,000 - 40,000
				Refrigerated Transport Vehicles: 20,000,000 - 40,000,000	13,200 - 26,400

With a wealthy budget, large-scale farms in Iraq can implement a highly advanced and sustainable regenerative agriculture system. This system combines extensive crop rotations with high-value crops, sophisticated livestock management, industrial-scale apiculture, and diverse orchards supported by state-of-the-art water, energy, and logistics infrastructure. The investment in these advanced technologies and practices ensures that the farm operates at peak efficiency, maximizing productivity and profitability while maintaining environmental sustainability. Each element of this system is designed to complement the others, creating a holistic and resilient agricultural operation that is well-equipped to thrive in Iraq's challenging environment.

5.2.4 Optimizing an Existing Regenerative Agriculture System: Small-Scale Farms

Low Budget

For small-scale farms operating on a low budget, optimizing an existing regenerative agriculture system focuses on enhancing productivity, improving resource efficiency, and maintaining environmental sustainability. The following steps outline practical strategies to achieve these goals by leveraging organic practices, efficient water use, and renewable energy [Table.9].

Table 9: Optimizing an existing regenerative agriculture system focuses on enhancing productivity for small-scale farms operating on a low budget (FAO and World bank)

Step	Action	Implementation	Complementary Elements	Cost Approximation (IQD)	Cost Approximation (USD)
1	**Enhancing Soil Fertility and Crop Yields**	Utilize organic fertilizers and natural pest management techniques to improve soil fertility and crop yields. Incorporate organic matter like compost and green manures into the soil and apply natural pest controls.	Organic fertilizers increase soil health by enhancing organic content and moisture retention, while natural pest management reduces the need for chemical inputs, preserving beneficial insects and soil quality.	Organic Fertilizers: 50,000 - 100,000 per dunum	30 - 65 per dunum
				Natural Pest Control Methods: 30,000 - 60,000 per dunum	20 - 40 per dunum
2	**Improving Pasture Management and Introducing Rotational Grazing**	Implement rotational grazing systems by dividing pastures into paddocks and rotating livestock to prevent overgrazing. Introduce legumes and deep-rooted grasses into pastures to improve soil fertility and forage quality.	Rotational grazing maintains pasture quality, prevents soil degradation, and enhances livestock health by providing consistent high-quality forage. This system increases the land's carrying capacity, supporting more livestock sustainably.	Fencing and Infrastructure: 100,000 - 200,000 per dunum	65 - 130 per dunum
				Pasture Improvement: 30,000 - 60,000 per dunum	20 - 40 per dunum

3	**Enhancing Bee Health and Apiculture Practices**	Focus on improving bee health by planting bee-friendly flowers and using organic mite control methods. Plant a variety of flowering plants and use organic treatments like neem oil or essential oils to manage pests.	Healthy bees improve pollination efficiency, leading to higher crop yields. Organic pest management techniques protect bees and maintain ecosystem balance, ensuring a steady supply of honey and other bee products.	Bee-Friendly Flowers: 30,000 - 50,000 per dunum	20 - 30 per dunum
				Organic Mite Control: 20,000 - 40,000 per hive	13 - 26 per hive
4	**Upgrading to More Efficient Irrigation Techniques**	Upgrade the farm's irrigation system to drip irrigation with basic automation, such as timers or moisture sensors, to conserve water and reduce labor. Install drip lines and basic automation to control water delivery.	Efficient irrigation optimizes water use, reducing waste and improving crop yields by maintaining consistent soil moisture levels. Automation further reduces labor costs, freeing time for other activities.	Drip Irrigation Installation: 200,000 - 400,000 per dunum	130 - 260 per dunum
				Basic Automation: 50,000 - 100,000 per unit	30 - 65 per unit
5	**Expanding Solar Energy Solutions**	Expand solar energy capacity by adding more solar panels to reduce dependence on external energy sources. Install additional panels and consider integrating battery storage for nighttime or cloudy days.	Expanding solar energy lowers energy costs, reduces the farm's carbon footprint, and provides a reliable power source, particularly valuable in areas with unreliable grid electricity.	Additional Solar Panels: 300,000 - 600,000	200 - 400
				Battery Storage: 150,000 - 300,000 (optional)	100 - 200

Optimizing an existing regenerative agriculture system on a small-scale farm with a low budget involves strategic investments in organic practices, efficient water use, and renewable energy. By enhancing soil fertility with organic fertilizers, improving pasture management through rotational grazing, and promoting bee health with natural methods, farmers can significantly boost productivity and sustainability. Upgrading drip irrigation systems and expanding solar energy capacity further optimizes resource use, ensuring the farm remains resilient and cost-effective. These improvements not only enhance the farm's immediate productivity but also build long-term sustainability by maintaining soil health, conserving water, and reducing reliance on external inputs. Each optimization step complements the others, creating a cohesive and efficient farming system that maximizes the potential of the available resources.

Higher Budget

For small-scale farms with access to a wealthy budget, optimizing an existing regenerative agriculture system involves integrating advanced technologies and techniques that maximize productivity, efficiency, and sustainability. The following steps outline how to elevate a regenerative farming operation by incorporating cutting-edge practices and equipment [Table.10].

Table 10: Optimizing an existing regenerative agriculture system focuses on enhancing productivity for small-scale farms operating on a wealthy budget (FAO and World Bank)

Step	Action	Implementation	Complementary Elements	Cost Approximation (IQD)	Cost Approximati on (USD)
1	**Transitioning to Advanced Organic Farming Practices**	Transition to advanced organic farming practices by applying biochar, composting, and other organic amendments to enhance soil fertility and crop productivity. Implement on-site composting and biochar application.	Advanced organic practices improve soil fertility, increase crop resilience, and contribute to long-term sustainability by reducing the need for synthetic fertilizers and enhancing soil health.	Biochar Production or Purchase: 500,000 - 1,000,000 per dunum	330 - 660 per dunum
				Composting Setup and Maintenance: 300,000 - 600,000 per system	200 - 400 per system
2	**Implementing Precision Farming Techniques for Livestock**	Implement precision farming techniques for livestock, including electronic monitoring systems to track animal health and automated feeding systems to optimize livestock management.	Precision farming enhances livestock health and productivity by providing data-driven insights, reducing feed waste, and improving overall efficiency. This leads to higher yields and lower costs.	Electronic Monitoring Systems: 1,000,000 - 2,000,000 per unit	660 - 1,300 per unit
				Automated Feeding Systems: 2,000,000 - 4,000,000	1,300 - 2,600
3	**Investing in Advanced Beekeeping Technologies**	Invest in advanced beekeeping technologies like hive monitoring systems and honey extraction equipment to improve hive management and increase honey production.	Advanced technologies in beekeeping enhance hive productivity and health, leading to increased honey yields and reduced labor. These	Hive Monitoring Systems: 500,000 - 1,000,000 per hive setup	330 - 660 per hive setup

			innovations support overall farm productivity and sustainability.	Honey Extraction Equipment: 1,500,000 - 3,000,000	1,000 - 2,000
4	**Installing a Fully Automated, Sensor-Driven Irrigation System**	Install a fully automated, sensor-driven irrigation system to optimize water use. This system uses real-time data to ensure crops receive precise amounts of water, improving efficiency and crop yields.	A sensor-driven irrigation system conserves water, reduces waste, and ensures optimal crop hydration, particularly in arid environments. This technology enhances crop health and productivity.	Sensor-Driven Irrigation System: 2,000,000 - 4,000,000 per dunum	1,300 - 2,600 per dunum
				Automation Control and Monitoring Equipment: 1,000,000 - 2,000,000	660 - 1,300
5	**Expanding the Renewable Energy System**	Expand the farm's renewable energy system by adding more solar panels and integrating battery storage to ensure energy independence and sustainability.	Expanding renewable energy reduces the farm's carbon footprint, lowers energy costs, and provides a reliable power supply, ensuring continuous farm operations even during grid outages or low-production periods.	Additional Solar Panels and Wind Turbines: 4,000,000 - 8,000,000	2,600 - 5,300
				Battery Storage Systems: 2,000,000 - 4,000,000	1,300 - 2,60

Optimizing an existing regenerative agriculture system on a small-scale farm with a wealthy budget allows for the integration of advanced technologies and practices that significantly enhance productivity, efficiency, and sustainability. By transitioning to advanced organic farming practices such as biochar application and composting, and implementing precision farming techniques for livestock, farmers can achieve higher yields and better animal health. Investing in advanced beekeeping technologies improves hive management and honey production, while a fully automated, sensor-driven irrigation system optimizes water use. Expanding the renewable energy system to cover all farm operations ensures that the farm is energy-independent and environmentally sustainable. These enhancements not only improve the farm's immediate productivity but also position it for long-term success by making it more resilient to environmental and economic challenges. Each optimization step is designed to complement the others, creating a highly efficient and sustainable farming system that maximizes the potential of both natural and technological resources.

5.2.5 Medium-Scale Farms

Low Budget

For medium-scale farms operating with a low budget, the focus on optimizing a regenerative agriculture system involves practical, cost-effective strategies that improve soil health, enhance livestock productivity, boost apiculture, and increase resource efficiency. The following steps provide a comprehensive guide to achieving these goals [Table.11].

Table 11: Optimizing an existing regenerative agriculture system focuses on enhancing productivity for medium-scale farms operating on a low budget (FAO and World Bank).

Step	Action	Implementation	Complementary Elements	Cost Approximation (IQD)	Cost Approximation (USD)
1	**Integrating Cover Crops and Mulching**	Integrate cover crops like clover, vetch, or rye, and apply organic mulching to improve soil health, increase organic matter, and enhance water retention.	Cover crops improve soil structure, fix nitrogen, and add organic matter, reducing the need for external fertilizers. Mulching helps conserve moisture, suppress weeds, and enhance soil health.	Cover Crop Seeds: 100,000 - 200,000 per hectare	65 - 130 per hectare
				Mulching Materials: 50,000 - 100,000 per hectare	30 - 65 per hectare
2	**Adopting Rotational Grazing and Introducing Leguminous Fodder Crops**	Implement rotational grazing and plant leguminous fodder crops, like alfalfa or clover, to improve pasture management, livestock diets, and soil fertility.	Rotational grazing prevents overgrazing and maintains pasture health, while leguminous fodder crops provide high-protein feed and improve soil fertility through nitrogen fixation.	Fencing for Rotational Grazing: 200,000 - 400,000 per hectare	130 - 260 per hectare
				Leguminous Fodder Seeds: 150,000 - 300,000 per hectare	100 - 200 per hectare
3	**Expanding Apiculture and Diversifying Bee Forage**	Increase the number of beehives and plant a diverse range of bee-friendly plants	Increasing hives boosts pollination and crop yields, while diverse forage plants	Additional Hives: 150,000 - 300,000 per hive	100 - 200 per hive

		to improve honey yield and pollination, supporting overall farm productivity.	support bee health and productivity, leading to higher honey yields and enhanced farm income.	Bee Forage Planting: 50,000 - 100,000 per hectare	30 - 65 per hectare
4	**Enhancing Water Efficiency with Better Scheduling and Soil Moisture Sensors**	Improve water efficiency by adopting better irrigation scheduling and using soil moisture sensors to optimize water use and crop health.	Soil moisture sensors provide real-time data for precise irrigation, reducing water waste and improving crop yields. This approach enhances water management and conserves resources.	Soil Moisture Sensors: 100,000 - 200,000 per sensor	65 - 130 per sensor
				Irrigation Scheduling Tools: 50,000 - 100,000 for basic tools	30 - 65 per unit
5	**Improving Energy Efficiency with Upgraded Solar Panels and Inverters**	Upgrade solar panels and inverters to more efficient models to enhance energy output, reduce electricity costs, and ensure a reliable power supply for farm operations.	Upgrading solar energy systems improves efficiency, reduces reliance on external power sources, and lowers overall energy costs, supporting long-term sustainability and operational resilience.	Solar Panel Upgrades: 500,000 - 1,000,000	330 - 660
				Inverter Upgrades: 200,000 - 400,000 per unit	130 - 260 per unit

Optimizing a medium-scale farm with a low budget involves targeted investments in practices that enhance soil health, improve livestock productivity, boost apiculture, and increase resource efficiency. Integrating cover crops and mulching enhances soil structure and water retention, while rotational grazing and leguminous fodder crops improve pasture management and livestock diets. Expanding the number of hives and diversifying bee forage plants increases honey yield and supports pollination. Enhancing water efficiency through better scheduling and soil moisture sensors conserves water and improves crop health. Upgrading solar panels and inverters boosts energy efficiency, reducing costs and reliance on external power sources. These improvements create a more resilient and sustainable farming system that maximizes the farm's potential while adhering to budget constraints. Each optimization strategy is designed to complement the others, resulting in a cohesive and efficient agricultural operation that supports long-term productivity and environmental stewardship.

Higher Budget

For medium-scale farms with a wealthy budget, optimizing an existing regenerative agriculture system involves leveraging advanced technologies and infrastructure to maximize efficiency, productivity, and sustainability. The following steps outline how to implement high-tech solutions across various aspects of the farm to create a highly efficient and profitable operation [Table.12].

Table 12: Optimizing an existing regenerative agriculture system focuses on enhancing productivity for medium-scale farms operating on a wealthy budget. (FAO and World Bank).

Step	Action	Implementation	Complementary Elements	Cost Approximation (IQD)	Cost Approximation (USD)
1	**Implementing Precision Agriculture Technologies for Crop Management**	Equip farm machinery with GPS-guided systems for planting, fertilizing, and harvesting. Use drones or satellite imagery for monitoring crop health and soil conditions, enabling targeted interventions.	Precision agriculture increases efficiency, reduces input costs, and enhances crop yields by applying resources only where needed. It also supports sustainable practices by minimizing environmental impact.	GPS-Guided Systems for Machinery: 10,000,000 - 20,000,000	6,600 - 13,200
				Drones and Monitoring Software: 5,000,000 - 10,000,000	3,300 - 6,600
2	**Investing in Advanced Livestock Management Systems**	Install automated feeders, health monitoring systems, and climate-controlled housing to improve livestock welfare and productivity.	Advanced systems optimize feed efficiency, reduce labor, and improve animal health, leading to higher productivity and lower operational costs. Climate-controlled environments further enhance animal welfare.	Automated Feeding Systems: 10,000,000 - 15,000,000	6,600 - 10,000
				Health Monitoring Technology: 5,000,000 - 10,000,000	3,300 - 6,600
				Climate-Controlled Housing: 15,000,000 - 30,000,000	10,000 - 20,000

3	**Scaling Up Apiculture with Professional Facilities and Processing Plants**	Construct professional apiary facilities and a processing plant for honey and other bee products. Include climate control and automated hive management systems.	These facilities improve bee health and honey production, while processing plants add value to bee products, increasing profitability and opening new revenue streams.	Beekeeping Facilities: 10,000,000 - 20,000,000	6,600 - 13,200
				Processing Plant: 15,000,000 - 30,000,000	10,000 - 20,000
4	**Deploying a Fully Integrated Water Management System**	Install real-time monitoring systems for soil moisture and weather conditions. Connect these to an automated irrigation system that adjusts water delivery based on data inputs.	A fully integrated system reduces water waste, enhances crop yields, and ensures consistent productivity even during periods of water scarcity. It also supports sustainable resource management.	Real-Time Monitoring and Control Systems: 10,000,000 - 20,000,000	6,600 - 13,200
				Automated Irrigation and Water Recycling Systems: 15,000,000 - 30,000,000	10,000 - 20,000
5	**Installing a Large-Scale Renewable Energy System**	Implement a renewable energy system with solar panels, wind turbines, and a biogas plant. Connect to a battery storage system and feed surplus energy back into the grid.	A large-scale renewable energy system reduces operational costs, ensures energy independence, and provides additional revenue through surplus energy sales, supporting the farm's financial viability.	Solar Panels and Wind Turbines: 20,000,000 - 40,000,000	13,200 - 26,400
				Biogas Plant: 15,000,000 - 30,000,000	10,000 - 20,000

				Battery Storage Systems: 10,000,000 - 20,000,000	6,600 - 13,200

For medium-scale farms with a wealthy budget, optimizing an existing regenerative agriculture system involves implementing state-of-the-art technologies and infrastructure to maximize efficiency, productivity, and sustainability. Precision agriculture technologies for crop management, including GPS-guided planting and harvesting, significantly improve crop yields and reduce waste. Advanced livestock management systems enhance animal welfare and productivity through automated feeders, health monitoring, and climate control. Scaling up apiculture with professional facilities and processing plants increases honey production and opens up new revenue streams.Deploying a fully integrated water management system ensures optimal water use, enhancing both crop and livestock productivity while conserving resources. Finally, installing a large-scale renewable energy system not only covers all operational needs but also generates surplus energy for sale, providing additional income and ensuring the farm's energy independence. These investments create a highly efficient and sustainable farming system that is well-equipped to handle environmental and economic challenges, ensuring long-term success and profitability. Each optimization strategy complements the others, resulting in a cohesive and advanced agricultural operation that maximizes the potential of both natural and technological resources.

5.2.6 Large-Scale Farm

Low Budget

For large-scale farms operating on a low budget, the focus is on maximizing efficiency and sustainability through strategic improvements in soil health, livestock management, apiculture, water conservation, and energy use. The following steps outline cost-effective strategies to optimize a regenerative agriculture system for large-scale operations [Table.13].

Table 13: Optimizing an existing regenerative agriculture system focuses on enhancing productivity for large-scale farms operating on a low budget (FAO and World Bank).

<table>
<tr><th>Step</th><th>Action</th><th>Implementation</th><th>Complementary Elements</th><th>Cost Approximation (IQD)</th><th>Cost Approximation (USD)</th></tr>
<tr><td rowspan="3">1</td><td rowspan="3">Improving Soil Health Through Composting, Green Manures, and Crop Rotation</td><td rowspan="3">Set up composting areas to recycle farm waste into compost. Apply compost, use green manures like legumes, and implement systematic crop rotation to maintain soil fertility and reduce erosion.</td><td rowspan="3">These practices reduce the need for chemical fertilizers, enhance water retention, and improve crop resilience. Healthy soils lead to better crop yields and lower input costs over time.</td><td>Composting Setup: 1,000,000 - 2,000,000</td><td>660 - 1,300</td></tr>
<tr><td>Green Manure Seeds: 500,000 - 1,000,000 per hectare</td><td rowspan="2">330 - 660 per hectare</td></tr>
<tr><td>Crop Rotation Planning: Minimal cost, mainly labor</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">Optimizing Grazing Systems and Improving Feed Quality</td><td rowspan="2">Implement rotational grazing and introduce nutrient-rich plants like legumes into pastures. Produce organic feed on-site to reduce reliance on external sources and improve livestock diets.</td><td rowspan="2">Rotational grazing supports soil health and ensures year-round access to high-quality forage, improving livestock productivity. On-site organic feed production reduces costs and ensures feed quality.</td><td>Fencing and Infrastructure for Rotational Grazing: 2,000,000 - 4,000,000 per hectare</td><td>1,300 - 2,600 per hectare</td></tr>
<tr><td>Seed Costs for Improved Pastures: 500,000 - 1,000,000 per hectare</td><td>330 - 660 per hectare</td></tr>
</table>

3	**Expanding Apiary Size and Improving Bee Health**	Increase the number of beehives and implement Integrated Pest Management (IPM) to enhance bee health and honey production. Distribute hives in areas with diverse forage plants to support healthy bee populations.	Expanding the apiary improves pollination and crop yields, while IPM protects bees from harmful chemicals and supports sustainable honey production. This contributes to farm income and biodiversity.	Additional Hives: 3,000,000 - 5,000,000 for expansion	2,000 - 3,300
				IPM Implementation: 1,000,000 - 2,000,000	660 - 1,300
4	**Enhancing Water Management with Improved Irrigation Scheduling and Conservation Practices**	Optimize water use with soil moisture sensors and improved irrigation scheduling. Adopt water conservation techniques like mulching, contour plowing, and rainwater harvesting to enhance resource efficiency.	Efficient water management conserves resources, reduces costs, and ensures that crops and livestock have consistent access to water, improving productivity and resilience in arid environments.	Soil Moisture Sensors: 1,000,000 - 2,000,000 per set	660 - 1,300 per set
				Irrigation and Conservation Upgrades: 2,000,000 - 4,000,000	1,300 - 2,600

5	**Upgrading Existing Renewable Energy Systems**	Upgrade solar panels, inverters, and battery storage systems to improve energy efficiency. Consider adding small-scale wind turbines to complement solar power and provide a more consistent energy supply.	Improved energy efficiency reduces reliance on external power, lowers operational costs, and supports the farm's sustainability. Upgraded systems ensure reliable power for all essential operations.	Solar Panel and Inverter Upgrades: 5,000,000 - 10,000,000	3,300 - 6,600
				Battery Storage Enhancements: 3,000,000 - 6,000,000	2,000 - 4,000
				Wind Turbines (optional): 10,000,000 - 20,000,000	6,600 - 13,200

For large-scale farms with a low budget, optimizing an existing regenerative agriculture system involves strategic investments in soil health, livestock management, apiculture, water conservation, and energy efficiency. Improving soil health through composting, green manures, and crop rotation creates a foundation for long-term productivity and sustainability. Optimizing grazing systems and improving feed quality enhance livestock growth and health, while expanding the apiary size and implementing integrated pest management increase honey production and pollination services. Enhancing water management with better irrigation scheduling and conservation practices ensures efficient use of this vital resource, supporting both crops and livestock. Upgrading existing renewable energy systems increases capacity and efficiency, reducing costs and ensuring a sustainable power supply for farm operations. These improvements build a resilient and sustainable farming system that maximizes the potential of existing resources while minimizing costs. Each optimization strategy is designed to work synergistically with the others, resulting in a highly efficient and sustainable agricultural operation that can thrive even with budgetary constraints.

Wealthy Budget

For large-scale farms with a wealthy budget, optimizing an existing regenerative agriculture system involves the adoption of cutting-edge technologies and comprehensive infrastructure improvements that maximize efficiency, productivity, and sustainability. The following steps outline a strategy to integrate advanced practices across crop management, livestock operations, apiculture, water management, and energy systems [Table.14].

Table 14: Optimizing an existing regenerative agriculture system focuses on enhancing productivity for large-scale farms operating on a wealthy budget (FAO and World Bank).

Step	Action	Implementation	Complementary Elements	Cost Approximation (IQD)	Cost Approximation (USD)
1	**Adopting Fully Integrated Precision Farming Techniques**	Equip the farm with satellite-based monitoring systems and automated farm equipment, including GPS-controlled tractors and harvesters. Use variable rate technology (VRT) to optimize the application of inputs.	Precision farming increases efficiency, reduces waste, and enhances crop productivity. The use of advanced monitoring and automated equipment minimizes labor costs and improves overall sustainability.	Satellite-Based Monitoring Systems: 20,000,000 - 40,000,000	13,200 - 26,400
				Automated Farm Equipment: 50,000,000 - 100,000,000	33,000 - 66,000
2	**Developing a Complete Farm-to-Market System for Livestock**	Construct on-site processing facilities for meat and dairy products. Develop a value-added product line and establish logistics	A complete farm-to-market system increases profitability by adding value to raw products, ensuring quality control,	Processing Facility Construction: 50,000,000 - 100,000,000	33,000 - 66,000

		and distribution networks to bring products to market efficiently.	and capturing a larger share of the market. It also supports branding and marketing efforts.	Value-Added Product Development: 10,000,000 - 20,000,000	6,600 - 13,200
3	**Establishing a Large-Scale Honey Processing Facility**	Build a facility equipped with advanced honey extraction, filtration, and packaging equipment. Develop a branding strategy and use advanced marketing tactics to reach premium markets and maximize profitability.	A large-scale honey processing facility increases revenue through the sale of high-quality honey and enhances brand recognition. It can also be expanded to process other bee products, diversifying income streams.	Honey Processing Facility: 30,000,000 - 60,000,000	20,000 - 40,000
				Packaging and Marketing Development: 10,000,000 - 20,000,000	6,600 - 13,200
4	**Implementing a Comprehensive Water Management Strategy**	Install advanced desalination units and water recycling systems. Integrate these systems with precision irrigation technology to maximize water efficiency and ensure a sustainable and reliable water supply.	A comprehensive water management system ensures consistent water supply, reduces environmental impact, and enhances farm resilience to droughts. By recycling water and using	Desalination Units: 50,000,000 - 100,000,000	33,000 - 66,000

			desalination, the farm can operate sustainably even in water-scarce areas.	Water Recycling Systems: 20,000,000 - 40,000,000	13,200 - 26,400
5	**Creating a Fully Self-Sufficient Energy System**	Install a large array of solar panels and wind turbines. Build a biogas plant to process livestock waste into energy. Integrate these with a high-capacity battery storage system and set up infrastructure to sell surplus energy to the grid.	A fully self-sufficient energy system reduces operational costs, enhances sustainability, and provides energy security. Surplus energy generation creates a new revenue stream, further increasing farm profitability.	Solar Panels and Wind Turbines: 50,000,000 - 100,000,000	33,000 - 66,000
				Biogas Plant: 20,000,000 - 40,000,000	13,200 - 26,400
				Battery Storage: 20,000,000 - 40,000,000	13,200 - 26,400

For large-scale farms with a wealthy budget, optimizing an existing regenerative agriculture system involves adopting advanced technologies and comprehensive infrastructure improvements. Fully integrated precision farming techniques, including satellite-based monitoring and automated equipment, maximize crop efficiency and productivity. Developing a complete farm-to-market system for livestock, along with large-scale honey processing facilities, adds significant value to agricultural products and enhances market reach. Implementing a comprehensive water management strategy, including desalination and water recycling, ensures a sustainable water supply, even in challenging environments. Creating a fully self-sufficient energy system with multiple renewable sources not only powers all farm operations but also generates surplus energy for sale, providing additional income. These investments transform the farm into a highly efficient, technologically advanced, and sustainable operation, capable of thriving in both current and future agricultural landscapes. Each optimization strategy complements the others, creating a cohesive and resilient agricultural system that maximizes both profitability and environmental stewardship.

5.2.7 Transitioning to a Regenerative Agriculture System: Small-Scale Farms

Low Budget

Transitioning a small-scale farm to a regenerative agriculture system on a low budget requires gradual changes that build on existing practices while integrating sustainable, low-cost alternatives. The following steps outline how to move towards a fully regenerative system, focusing on organic inputs, improved livestock management, apiculture, water-saving technologies, and renewable energy [Table.15].

Table 15: Transitioning a small-scale farm to a regenerative agriculture system on a low budget (FAO and World Bank).

Step	Action	Implementation	Complementary Elements	Cost Approximation (IQD)	Cost Approximation (USD)
1	**Gradually Integrating Organic Inputs and Reducing Chemical Use**	Begin transitioning to regenerative practices by incorporating organic inputs like compost and natural fertilizers. Gradually reduce the use of chemical fertilizers and pesticides, replacing them with organic alternatives.	Organic inputs improve soil structure, microbial activity, and moisture retention. Reducing chemical use aligns the farm with sustainable practices, enhancing long-term soil health and crop resilience.	Organic Fertilizers: 50,000 - 100,000 per dunum	30 - 65 per dunum
				Natural Pest Control: 30,000 - 60,000 per dunum	20 - 40 per dunum
2	**Shifting Towards Rotational Grazing and Growing Fodder Crops**	Implement rotational grazing to improve pasture management. Begin growing fodder crops like alfalfa or clover to reduce reliance on purchased feed and enhance the sustainability of the livestock operation.	Rotational grazing improves pasture health and livestock productivity, while on-site fodder crops reduce feed costs and ensure a steady supply of organic feed, supporting overall farm sustainability.	Fencing for Rotational Grazing: 100,000 - 200,000 per dunum	65 - 130 per dunum
				Fodder Crop Seeds: 50,000 - 100,000 per dunum	30 - 65 per dunum

3	**Using Organic Methods for Apiculture and Enhancing Forage Diversity**	Transition to organic hive management practices and increase the diversity of native plants for bee forage. This approach improves bee health, enhances honey production, and supports local biodiversity.	Organic hive management reduces chemical contamination in honey and supports bee health. Diversifying forage improves bee nutrition and crop pollination, leading to better yields and ecosystem resilience.	Organic Hive Management Supplies: 30,000 - 60,000 per hive	20 - 40 per hive
				Native Plant Seeds and Seedlings: 50,000 - 100,000 per dunum	30 - 65 per dunum
4	**Transitioning to Water-Saving Technologies**	Install drip irrigation systems to optimize water use and improve crop health. Start with the most water-intensive areas and expand as resources allow. Combine drip irrigation with mulching to conserve soil moisture.	Drip irrigation enhances water efficiency by delivering water directly to the root zone, reducing evaporation and runoff. This system is essential in arid regions, helping to conserve water while maintaining crop productivity.	Drip Irrigation System Installation: 200,000 - 400,000 per dunum	130 - 260 per dunum
				Basic Controls and Timers: 30,000 - 60,000	20 - 40
5	**Incrementally Investing in Solar Energy Systems**	Gradually install solar panels to reduce reliance on grid power. Start with a small setup for essential operations, expanding over time to cover more areas of the farm. Consider adding battery storage in later stages.	Solar energy reduces operational costs, lowers the farm’s carbon footprint, and provides energy security. Incremental investment allows a gradual and affordable transition to renewable energy use.	Initial Solar Panel Setup: 300,000 - 600,000	200 - 400
				Battery Storage (optional): 200,000 - 400,000	130 - 260

Transitioning a small-scale farm to a regenerative agriculture system on a low budget involves a series of gradual changes that focus on integrating sustainable practices and reducing reliance on external inputs. By incorporating more organic inputs and reducing chemical use, farmers can improve soil health and crop productivity. Shifting towards rotational grazing and growing fodder crops on-site enhances livestock sustainability and reduces feed costs. Using organic methods for hive management and increasing the diversity of native forage plants supports bee health and improves pollination. Transitioning to water-saving technologies like drip irrigation optimizes water use, conserving this vital resource while maintaining crop yields. Incremental investment in solar energy systems reduces reliance on grid power and promotes long-term sustainability. Each step in this transition is designed to be affordable and scalable, allowing farmers to gradually build a resilient, regenerative agricultural system that enhances both productivity and environmental stewardship.

Higher Budget

For small-scale farms with access to a wealthy budget, transitioning to a regenerative agriculture system involves adopting advanced practices and technologies that ensure sustainability, efficiency, and productivity. The following steps outline a comprehensive strategy for making a full-scale transition to regenerative agriculture, focusing on crops, livestock, apiculture, water management, and energy systems [Table.16].

Table 16: Transitioning a small-scale farm to a regenerative agriculture system on a wealthy budget

Step	Action	Implementation	Complementary Elements	Cost Approximation (IQD)	Cost Approximation (USD)
1	**Implementing a Full-Scale Transition to Regenerative Agriculture**	Transition the farm to fully regenerative practices by adopting no-till farming and agroforestry. These methods improve soil health, increase biodiversity, and enhance long-term crop yields.	No-till farming and agroforestry build resilient soils and diverse ecosystems, reducing the need for chemical inputs and improving environmental sustainability. These practices enhance farm productivity and carbon sequestration.	No-Till Equipment and Tools: 5,000,000 - 10,000,000	3,300 - 6,600
				Agroforestry Planting and Maintenance: 10,000,000 - 20,000,000	6,600 - 13,200
2	**Moving to a Fully Integrated Livestock System**	Develop a fully integrated livestock system with organic certification and holistic management practices. This system focuses on animal welfare, environmental sustainability, and high-quality organic products.	A fully integrated livestock system enhances soil health, reduces external inputs, and produces high-quality, organic products. Holistic management practices ensure a balanced and productive farm ecosystem.	Organic Certification Process: 2,000,000 - 5,000,000	1,300 - 3,300
				Holistic Management Infrastructure: 10,000,000 - 20,000,000	6,600 - 13,200

Step	Action	Implementation	Complementary Elements	Cost Approximation (IQD)	Cost Approximation (USD)
3	**Expanding into Organic Honey Production**	Expand apiculture operations to produce organic honey, supported by advanced hive management and processing facilities. This aligns with the farm’s regenerative goals and improves honey quality.	Organic honey production adds value to the farm’s products, supports sustainability, and aligns with regenerative principles. Advanced hive management ensures healthy, productive bee colonies.	Hive Management Technology: 3,000,000 - 6,000,000	2,000 - 4,000
				Organic Honey Processing Facility: 10,000,000 - 20,000,000	6,600 - 13,200
4	**Transitioning to a Fully Automated Water Management System**	Implement a fully automated water management system with sensors and automated irrigation. This ensures efficient water use, reduces waste, and enhances crop and livestock productivity.	Automated water management conserves water, reduces labor, and supports sustainability goals. The system’s real-time monitoring optimizes water use, benefiting both crops and livestock.	Automated Irrigation and Sensor Systems: 10,000,000 - 20,000,000	6,600 - 13,200
				Water Recycling and Harvesting Infrastructure: 10,000,000 - 20,000,000	6,600 - 13,200

Step	Action	Implementation	Complementary Elements	Cost Approximation (IQD)	Cost Approximation (USD)
5	**Investing in a Complete Off-Grid Renewable Energy System**	Transition the farm to a fully off-grid renewable energy system using solar, wind, and biogas. This ensures sustainable and independent power for all farm operations, with potential surplus energy sold back to the grid.	An off-grid renewable energy system eliminates reliance on fossil fuels, supports waste management through biogas production, and reduces the farm's carbon footprint. The system provides energy security and sustainability.	Solar and Wind Energy Systems: 20,000,000 - 40,000,000	13,200 - 26,400
				Biogas Plant Installation: 15,000,000 - 30,000,000	10,000 - 20,000
				Battery Storage Systems: 10,000,000 - 20,000,000	6,600 - 13,200

For small-scale farms with a wealthy budget, transitioning to a regenerative agriculture system involves the adoption of advanced, sustainable practices that enhance productivity, environmental stewardship, and long-term viability. Implementing a full-scale transition to regenerative practices, such as no-till farming and agroforestry, improves soil health and ecosystem diversity. Moving to a fully integrated livestock system with organic certification and holistic management practices ensures that livestock production is both profitable and sustainable. Expanding into organic honey production with advanced hive management and processing facilities adds value to the farm's apiculture operations. Transitioning to a fully automated water management system maximizes water efficiency, reducing waste and enhancing productivity. Finally, investing in a complete off-grid renewable energy system provides the farm with a sustainable, independent energy source that supports all farm operations and contributes to overall sustainability. These investments create a highly efficient, productive, and environmentally sustainable farming operation, fully aligned with the principles of regenerative agriculture. Each step is designed to complement the others, resulting in a cohesive and resilient agricultural system that is well-equipped to meet both current and future challenges.

5.2.8 Medium-Scale Farms

Low Budget

For medium-scale farms with a limited budget, transitioning to a regenerative agriculture system involves gradually adopting sustainable practices that enhance soil health, improve livestock management, support biodiversity, and increase energy efficiency. The following steps outline a practical and cost-effective approach to initiating this transition [Table.17].

Table 17: Transitioning a medium-scale farm to a regenerative agriculture system on a low budget (FAO and World Bank).

Step	Action	Implementation	Complementary Elements	Cost Approximation (IQD)	Cost Approximation (USD)
1	**Introducing Regenerative Practices in Crop Management**	Begin transitioning to regenerative agriculture by implementing crop rotation, cover cropping, and organic fertilizers. These practices enhance soil health, biodiversity, and reduce chemical input dependency.	Crop rotation and cover cropping improve soil structure, increase water retention, and build healthy soils. Organic fertilizers enhance long-term fertility, reducing the need for synthetic inputs.	Crop Rotation and Cover Cropping Seeds: 300,000 - 600,000 per hectare	200 - 400 per hectare
				Organic Fertilizers: 200,000 - 400,000 per hectare	130 - 260 per hectare
2	**Implementing Rotational Grazing and Improving Animal Welfare**	Enhance pasture management and animal welfare by adopting rotational grazing practices. This improves pasture health, reduces soil compaction, and provides better nutrition for livestock.	Rotational grazing prevents overgrazing, improves pasture quality, and enhances animal welfare. Better management leads to healthier livestock and improved productivity.	Fencing and Infrastructure for Rotational Grazing: 500,000 - 1,000,000 per hectare	330 - 660 per hectare
				Pasture Improvement (seeds, soil amendments): 200,000 - 400,000 per hectare	130 - 260 per hectare

3	**Increasing Native Plantings and Transitioning to Organic Beekeeping**	Support bee populations and enhance honey production by increasing native plantings and adopting organic beekeeping practices. This enhances biodiversity and aligns with regenerative agriculture principles.	Native plantings support biodiversity and improve pollination, leading to higher crop yields. Organic beekeeping enhances bee health and productivity, producing higher-quality honey.	Native Plant Seeds and Seedlings: 200,000 - 400,000 per hectare	130 - 260 per hectare
				Organic Beekeeping Supplies: 100,000 - 200,000 per hive	65 - 130 per hive
4	**Transitioning to More Efficient Irrigation Systems**	Improve water use efficiency by adopting drip or sprinkler irrigation systems. These systems reduce water waste, lower costs, and enhance crop productivity, making the farm more resilient to water scarcity.	Efficient irrigation systems optimize water use, improving crop health and yield. Soil moisture sensors further enhance water management, making the farm more sustainable in arid conditions.	Drip Irrigation Installation: 500,000 - 1,000,000 per hectare	330 - 660 per hectare
				Soil Moisture Sensors: 200,000 - 400,000 per set	130 - 260 per set
5	**Incorporating Renewable Energy Sources into Farm Operations**	Begin integrating renewable energy sources, such as solar and wind power, into farm operations. This reduces reliance on grid electricity, lowers energy costs, and aligns with the farm’s sustainability goals.	Renewable energy reduces the farm's carbon footprint and operational costs, providing a reliable power source. Over time, expanding these systems can make the farm energy self-sufficient.	Initial Solar Panel Installation: 1,000,000 - 2,000,000	660 - 1,300
				Small Wind Turbines (optional): 3,000,000 - 5,000,000	2,000 - 3,300

For medium-scale farms with a low budget, transitioning to a regenerative agriculture system involves a series of gradual, cost-effective changes that improve sustainability, efficiency, and productivity. Introducing regenerative practices in crop management, such as crop rotation, cover cropping, and organic fertilizers, enhances soil health and reduces dependency on chemical inputs. Implementing rotational grazing and improving animal welfare through better pasture management supports healthier, more productive livestock. Increasing native plantings and transitioning to organic beekeeping practices enhance biodiversity and improve honey production. Transitioning to more efficient irrigation systems optimizes water use, conserving resources and improving crop yields. Finally, incorporating renewable energy sources, such as solar and wind, into farm operations reduces energy costs and supports the farm's long-term sustainability goals. These steps create a foundation for a resilient, sustainable farming system that can grow and adapt over time, ensuring both environmental stewardship and economic viability. Each component of the transition is designed to complement the others, resulting in a cohesive and efficient agricultural operation.

Higher Budget

For medium-scale farms with a wealthy budget, transitioning to a regenerative agriculture system involves adopting advanced practices and technologies that ensure the farm's long-term sustainability, productivity, and profitability. The following steps outline a comprehensive approach to implementing high-level regenerative practices across crop management, livestock systems, apiculture, water management, and energy infrastructure [Table.18].

Table 18: Transitioning a medium-scale farm to a regenerative agriculture system on a wealthy budget (FAO and World Bank).

Step	Action	Implementation	Complementary Elements	Cost Approximation (IQD)	Cost Approximation (USD)
1	**Fully Transitioning to Regenerative Agriculture with Advanced Practices**	Fully transition to regenerative agriculture by incorporating advanced practices like permaculture and biodynamic farming. These methods create self-sustaining ecosystems, enhancing biodiversity and soil health.	Permaculture and biodynamic farming create resilient farm ecosystems, reduce external input reliance, and increase productivity. They support biodiversity and long-term soil health.	Permaculture Design and Implementation: 10,000,000 - 20,000,000	6,600 - 13,200
				Biodynamic Preparations and Equipment: 5,000,000 - 10,000,000	3,300 - 6,600
2	**Developing a Comprehensive Regenerative Livestock System**	Implement a comprehensive regenerative livestock system with enhanced grazing techniques, organic feed production, and holistic management practices, ensuring animal welfare and environmental sustainability.	A comprehensive system improves soil health, pasture productivity, and animal welfare. Organic feed production reduces reliance on external inputs, creating a synergistic relationship between crops and livestock.	Mob Grazing Infrastructure: 10,000,000 - 20,000,000	6,600 - 13,200
				Organic Feed Production: 5,000,000 - 10,000,000	3,300 - 6,600
3	**Establishing a Fully Organic Apiculture Operation**	Establish a fully organic apiculture operation with advanced processing and marketing capabilities, ensuring high-quality organic honey production and supporting the farm's regenerative goals.	An organic apiculture operation produces premium honey, enhancing farm profitability. Advanced processing and marketing ensure control over production quality and access to high-value markets.	Organic Hive Management and Monitoring Systems: 5,000,000 - 10,000,000	3,300 - 6,600
				Honey Processing Facility: 15,000,000 - 30,000,000	10,000 - 20,000

				Marketing Development: 5,000,000 - 10,000,000	3,300 - 6,600
4	**Transitioning to a Sophisticated Water Management System**	Implement a sophisticated water management system including water recycling, desalination, and real-time monitoring, ensuring efficient and sustainable water use on the farm.	A sophisticated system enhances water resilience, reduces reliance on external sources, and ensures efficient and sustainable water use, even in challenging conditions.	Water Recycling Systems: 10,000,000 - 20,000,000	6,600 - 13,200
				Desalination Units: 20,000,000 - 40,000,000	13,200 - 26,400
				Real-Time Monitoring Tools: 5,000,000 - 10,000,000	3,300 - 6,600
5	**Investing in Large-Scale Renewable Energy Infrastructure**	Invest in a large-scale renewable energy infrastructure that powers all farm activities, ensuring energy independence and sustainability. This infrastructure should include solar, wind, and biogas energy sources.	A large-scale renewable energy infrastructure reduces the farm's carbon footprint, lowers energy costs, and ensures a reliable power supply. Surplus energy can be sold back to the grid for additional income.	Solar Panels and Wind Turbines: 30,000,000 - 60,000,000	20,000 - 40,000
				Biogas Plant Installation: 15,000,000 - 30,000,000	10,000 - 20,000
				Battery Storage Systems: 10,000,000 - 20,000,000	6,600 - 13,200

For medium-scale farms with a wealthy budget, transitioning to a regenerative agriculture system involves the adoption of advanced practices and infrastructure that ensure long-term sustainability, productivity, and profitability. Fully transitioning to regenerative agriculture with practices like permaculture and biodynamic farming creates a self-sustaining, resilient farm ecosystem. Developing a comprehensive regenerative livestock system with enhanced grazing, organic feed, and holistic management practices supports animal welfare and environmental sustainability. Establishing a fully organic apiculture operation with advanced processing and marketing capabilities allows the farm to produce high-quality organic honey and other bee products for premium markets. Transitioning to a sophisticated water management system that includes water recycling and desalination ensures a sustainable and efficient water supply. Finally, investing in large-scale renewable energy infrastructure provides the farm with energy independence and supports all farm operations with clean, sustainable power. These investments create a highly efficient, productive, and environmentally sustainable farming operation, fully aligned with the principles of regenerative agriculture. Each step in the transition is designed to complement the others, resulting in a cohesive and resilient agricultural system that maximizes both environmental stewardship and economic viability.

5.2.9 Large-Scale Farms

Low Budget

For large-scale farms with a limited budget, transitioning to a regenerative agriculture system involves gradually adopting practices that focus on improving soil health, enhancing livestock management, supporting apiculture, optimizing water use, and integrating renewable energy. The following steps provide a strategic approach to initiating this transition in a cost-effective manner [Table.19].

Table 19: Transitioning a large-scale farm to a regenerative agriculture system on a low budget (FAO and World Bank).

Step	**Action**	**Implementation**	**Complementary Elements**	**Cost Approximation (IQD)**	**Cost Approximation (USD)**
1	**Focusing on Soil Health, Crop Diversity, and Organic Inputs**	Begin by assessing soil health and enhancing it through crop rotation, intercropping, and the use of organic inputs like compost and manure.	These practices build resilient soils, reduce dependency on chemical inputs, and improve long-term productivity, enhancing water retention and nutrient availability for crops.	Soil Health Assessment and Organic Inputs: 2,000,000 - 4,000,000	1,300 - 2,600
				Crop Rotation and Intercropping Seeds: 1,000,000 - 2,000,000	660 - 1,300
2	**Improving Livestock Management Through Better Grazing Practices**	Implement rotational grazing to prevent overgrazing and improve pasture health. Supplement with natural feed options like farm-produced hay or silage.	Better grazing practices enhance soil health, prevent erosion, and support pasture productivity, while natural feed options improve livestock health and reduce external input dependency.	Rotational Grazing Infrastructure: 3,000,000 - 6,000,000	2,000 - 4,000
				Natural Feed Production: 1,000,000 - 2,000,000	660 - 1,300

3	**Expanding the Apiary and Transitioning to Organic Practices**	Gradually increase the number of hives and transition to organic beekeeping methods. Enhance bee forage by planting native flowering species.	Expanding the apiary improves pollination, leading to higher crop yields. Organic beekeeping enhances bee health and supports the production of high-quality, premium honey.	Additional Hives and Equipment: 3,000,000 - 5,000,000	2,000 - 3,300
				Organic Beekeeping Supplies: 1,000,000 - 2,000,000	660 - 1,300
4	**Transitioning to Water-Efficient Systems and Implementing Water Conservation Strategies**	Install drip irrigation systems and implement water conservation strategies such as mulching, contour plowing, and rainwater harvesting.	Efficient water management practices reduce water use, lower costs, and improve crop health by maintaining consistent moisture levels. Conservation strategies increase drought resilience.	Drip Irrigation Systems: 4,000,000 - 8,000,000	2,600 - 5,300
				Water Conservation Infrastructure: 3,000,000 - 6,000,000	2,000 - 4,000
5	**Gradually Integrating Renewable Energy Sources**	Begin with a small solar power system for critical operations and expand capacity over time. Consider adding wind turbines to diversify energy sources.	Integrating renewable energy reduces carbon footprint, lowers energy costs, and ensures a reliable power supply, aiming for full energy independence.	Initial Solar Power Installation: 5,000,000 - 10,000,000	3,300 - 6,600
				Small Wind Turbines (optional): 10,000,000 - 20,000,000	6,600 - 13,200

For large-scale farms with a low budget, transitioning to a regenerative agriculture system involves gradually adopting sustainable practices that focus on improving soil health, enhancing livestock management, supporting apiculture, optimizing water use, and integrating renewable energy. Starting with a focus on soil health, crop diversity, and organic inputs builds the foundation for a resilient and productive farming system. Implementing better grazing practices and incorporating natural feed options improve livestock health and sustainability. Expanding the apiary and transitioning to organic practices support biodiversity, enhance crop pollination, and improve honey production. Transitioning to water-efficient systems and implementing water conservation strategies ensures sustainable water use, reducing waste and improving crop yields. Gradually integrating renewable energy sources reduces dependence on non-renewable power, lowers energy costs, and supports the farm's long-term sustainability goals. These steps create a foundation for a resilient, sustainable farming system that can grow and adapt over time, ensuring both environmental stewardship and economic viability. Each component of the transition is designed to complement the others, resulting in a cohesive and efficient agricultural operation.

Wealthy Budget

For large-scale farms with a wealthy budget, transitioning to a regenerative agriculture system involves implementing cutting-edge technologies and sustainable practices across all areas of the farm. The following steps provide a detailed strategy to fully integrate advanced regenerative practices into crop management, livestock systems, apiculture, water management, and energy infrastructure [Table.20].

Table 20: Transitioning a large-scale farm to a regenerative agriculture system on a wealthy budget (FAO and World Bank).

Step	Action	Implementation	Complementary Elements	Cost Approximation (IQD)	Cost Approximation (USD)
1	**Fully Transitioning to an Integrated Regenerative Crop System**	Implement a complete transition using precision agriculture, no-till farming, and agroforestry. Utilize GPS-guided equipment, drones, and satellite imagery to optimize input use and monitor crop health. Integrate agroforestry by planting trees and shrubs within crop fields to enhance biodiversity and improve microclimates.	This integrated approach enhances crop productivity, reduces environmental impact, and ensures long-term soil health. Advanced technologies and sustainable practices create a resilient agricultural system.	Precision Agriculture Tools: 20,000,000 - 40,000,000	13,200 - 26,400
				No-Till and Agroforestry Infrastructure: 15,000,000 - 30,000,000	10,000 - 20,000
2	**Developing a Complete Regenerative Livestock System**	Achieve organic certification, implement advanced grazing management practices like holistic planned grazing, and produce high-value organic products. Invest in infrastructure such as mobile fencing, water systems, and climate-controlled shelters.	This system improves animal welfare, enhances soil fertility, and produces premium products that can command higher market prices. Advanced grazing management contributes to carbon sequestration and overall farm sustainability.	Organic Certification and Infrastructure: 20,000,000 - 40,000,000	13,200 - 26,400
				High-Value Product Development: 10,000,000 - 20,000,000	6,600 - 13,200

3	**Expanding to a Large-Scale, Organic Apiculture Operation**	Scale up the apiculture operation by increasing the number of hives, transitioning to organic practices, and building state-of-the-art facilities for honey processing. Develop a marketing strategy targeting premium markets.	Enhances farm biodiversity and crop pollination while producing high-quality organic honey. Advanced processing facilities ensure consistency and quality, supporting premium product markets.	Hive Expansion and Organic Management: 10,000,000 - 20,000,000	6,600 - 13,200
				Processing and Packaging Facilities: 20,000,000 - 40,000,000	13,200 - 26,400
				Marketing and Distribution: 10,000,000 - 20,000,000	6,600 - 13,200
4	**Investing in a Fully Integrated Water Management System**	Develop an advanced irrigation system, implement water recycling technologies, and install desalination units. Use real-time monitoring tools to manage water use efficiently.	Maximizes water use efficiency, reduces waste, and ensures a sustainable water supply. Advanced technologies support high productivity while conserving critical water resources.	Advanced Irrigation Systems: 20,000,000 - 40,000,000	13,200 - 26,400
				Water Recycling and Desalination Units: 30,000,000 - 60,000,000	20,000 - 40,000
				Real-Time Monitoring and Management Tools:	6,600 - 13,200

				10,000,000 - 20,000,000	
5	**Creating a Completely Self-Sufficient Renewable Energy System**	Install a comprehensive renewable energy system, including solar panels, wind turbines, and a biogas plant. Integrate with high-capacity battery storage and design the system to generate surplus energy for sale.	Eliminates reliance on external energy sources, reduces operational costs, and supports long-term sustainability. The system provides stable and reliable energy for all operations, with the potential for additional revenue from surplus energy sales.	Solar Panels and Wind Turbines: 40,000,000 - 80,000,000	26,400 - 52,800
				Biogas Plant and Battery Storage: 30,000,000 - 60,000,000	20,000 - 40,000

For large-scale farms with a wealthy budget, transitioning to a regenerative agriculture system involves the adoption of advanced technologies and sustainable practices across all aspects of farm operations. Fully transitioning to an integrated regenerative crop system with precision agriculture, no-till farming, and agroforestry improves soil health, enhances biodiversity, and maximizes productivity. Developing a complete regenerative livestock system with organic certification, advanced grazing management, and high-value products ensures sustainability and profitability. Expanding to a large-scale organic apiculture operation with state-of-the-art facilities supports biodiversity, enhances pollination, and produces high-quality organic honey. Investing in a fully integrated water management system with advanced irrigation, recycling, and desalination technologies ensures efficient and sustainable water use. Finally, creating a completely self-sufficient renewable energy system provides the farm with reliable, sustainable power, reducing costs and supporting long-term environmental goals. These investments create a highly efficient, productive, and environmentally sustainable farming operation, fully aligned with the principles of regenerative agriculture. Each component of the transition is designed to complement the others, resulting in a cohesive and resilient agricultural system capable of thriving in both current and future conditions.

5.3 Implementation Strategy; From Blueprint to Action: The Potential of the "National Green Belt Project"

The National Green Belt Project in Iraq is a monumental environmental and socio-economic initiative designed to combat the advancing desertification threatening Iraq's fertile lands and urban centers (Abdulridha & Alkarawy, 2022). Proposed by Dr. Hassan Al-Janabi in 2012 the objective is to prevent further desert encroachment and mitigate the effects of climate change, which have severely impacted Iraq's environment and agriculture (Al-Janabi, 2012). The project seeks to plant over 200 million trees across at least 3,000 square kilometers. These trees are carefully selected for their ability to withstand Iraq's harsh desert conditions, including extreme drought and high temperatures. The project is not solely environmental; it also aims to boost Iraq's socio-economic landscape by creating job opportunities, particularly in rural areas, and fostering new communities in previously uninhabited regions. This initiative is expected to generate significant employment and stimulate local economies, particularly in areas most affected by environmental degradation (Al-Janabi, 2012).

As of 2024, the National Green Belt Project in Iraq, initially proposed to combat desertification, is unfortunately facing significant challenges and has not progressed as originally planned. Key issues include a lack of sustained funding, bureaucratic inefficiencies, and poor policy implementation. Although substantial sums were initially allocated to the project, these funds have not been effectively utilized, leading to incomplete or abandoned sections of the Green Belt. The broader environmental crisis in Iraq has exacerbated the situation, including increased dust storms and a rapidly advancing desert, which the Green Belt was supposed to mitigate research highlights the socio-economic benefits of implementing this green belt program. The creation of over 85,000 farms would not only provide livelihoods for half a million people but also contribute to Iraq's food security and environmental sustainability. Furthermore, integrating renewable energy sources such as solar and biomass, along with recycling domestic water, is proposed to enhance the sustainability of these communities (Abdulhameed et al., 2024). Dividing the project into ten sections, each spanning 52.5 km, and completing the planting over five years would be feasible. Additionally, intercropping with high-tolerance crops like barley is recommended to further enhance soil stability and productivity. It is essential to monitor climatic conditions, particularly rainfall, to adapt the irrigation strategy as necessary (Abdulhameed et al., 2024).

Revitalizing Iraq's green belt through a regenerative agriculture approach requires a comprehensive strategy integrating food forests, efficient water use, community involvement, and supportive policies. This initiative will combat desertification, create job opportunities, stimulate the economy, and foster national unity. Incorporating food forests, which mimic natural ecosystems and include various plant layers, can significantly enhance biodiversity, soil health, and food security. Drought-resistant and heat-tolerant species, such as native date palms, along with the Um Rabia and IPA 99 wheat varieties, which have shown remarkable performance under supplemental irrigation, should be prioritized (Shideed et al., 2003). Efficient water use is crucial in Iraq's arid environment; advanced irrigation systems like trickle irrigation, which are significantly more efficient than traditional methods, should be employed (Dawood and Hamad, 1985). Alternative water sources, such as partially desalinated water from closed lakes, can further enhance sustainability (Janabi, 2012). However, the heart of the project would be community involvement. This approach mirrors the successful re-flooding of Iraq's southern marshes, where policies focused on sustainable livelihoods for the Marsh Arabs and integrated them into the restoration process (Jawad, 2021). Effective policy measures and government interventions are critical, necessitating the establishment of a specialized commission to coordinate and fund the project, incentivize efficient irrigation technologies, and promote renewable energy (Janabi, 2012). Pilot projects in various governorates should be conducted to refine methods before large-scale implementation, reducing risks and allowing for adjustments based on practical experiences (Janabi, 2012). Considering the many unstable factors explored in this chapter, the project should be rooted in sustainable development and grey system theory. Policy recommendations should ensure a close monitoring of all important metrics for the long-term implantation of the project, for example, there should be a list of all towns and villages within the NGB that could involve their community in the implementation of the NGB. This study and monitoring could be followed as for China's "Grain for Green" by subvention, ensuring a smooth transition that would benefit these communities in the long run. The policies should incentivize the diligence of the community involved and the government should be able to adapt to help with any obstacle met during the project, there should be a call to the citizens of Iraq to participate and the international community to boost the project. Everyone would greatly benefit from this policy-led regenerative agriculture. Planting a food forest that would combat the desert expansion would create a strong base for any follow-up with the modalities of regenerative agriculture such as apiculture, aquaculture, livestock, new crops … The state and any stockholder would enjoy a direct economic benefit from the agricultural sector and the decrease of the desert storms and climate change destructive costs.

As highlighted in this thesis, regenerative agricultural models are virtually limitless, with each farm potentially developing its unique approach. The key, according to General Systems Theory (GST), is to design a viable model that considers all relevant factors, from labor and politics to crop selection and water availability. The goal is not to create a universal model for arid regions but to foster a mindset that seeks the best solution tailored to the specific context and scale of the project. The NGB initiative offers a national framework to address significant challenges and inspire arid environments globally. For this thesis, I conducted a straightforward calculation of crop choices on the NGB scale, serving as an example of the potential yield. Although I recognize the absence of certain specific metrics, this exercise demonstrates what could be achieved with optimal decisions. The model remains adaptable, capable of incorporating new elements like renewable energy, livestock, or apiculture with updated data. The table below presents a simplified estimate of yields for a regenerative agriculture project on a national scale in Iraq [Table.21].

Table 21: Potential of a simple dual crop system yield for National Green Belt. Source: FAO (2024)

Crop Type	Area/Number of Trees	Average Yield per Unit	Total Estimated Yield
Date Palms (Halawy, Zahdi variety)	15 million trees	On average 80 kg per tree per year	1,200,000 tons
Wheat (Um Rabia and IPA 99 Varieties)	1,500 km² (150,000 hectares)	3.5 tons per hectare	525,000 tons
Olive tree (Kalamata, Kalamata, Arbequina)	10 million trees	On average 16.32 kg/tree/year	163,200 tons

6. Conclusion

Regenerative agriculture, focused on renewing and restoring ecosystems, offers a model for combating environmental degradation by promoting a balanced interaction with nature. However, its success depends on resisting profit-driven pressures that could undermine its potential. The concept of living soil emphasizes maintaining a vibrant, biodiverse ecosystem, challenging conventional farming's extractive nature by treating soil as a living entity requiring care. True sustainability requires reevaluating production and consumption patterns to reduce exploitation and achieve ecological balance, particularly in arid regions where intensive farming exacerbates degradation. Effective management in these areas must prioritize resilience over short-term gains. Rural communities, often marginalized, suffer most under intensive agricultural models, facing social and economic disparities that undermine their livelihoods. Equitable development recognizing rural contributions is crucial for sustainable practices. Globally, the Global South bears the brunt of economic systems favoring wealthier nations, enduring environmental and economic exploitation perpetuated by unequal trade and agriculture practices. The legacy of historical exploitation continues, with neo-colonialism manifesting through global agribusiness dominance, controlling trade, resources, and agricultural development. These dynamics maintain inequalities and hinder sustainable, autonomous agricultural practices in the Global South, reflecting a broader pattern of economic control reminiscent of colonial influence. However, they caution that the adoption of regenerative agriculture on a wide scale is hindered by a lack of region-specific knowledge and empirical evidence supporting its long-term economic and environmental benefits. To address these gaps, the review recommends the implementation of long-term farming system trials to build a robust evidence base for RA practices.

The findings of this study underscore the critical importance of adopting regenerative agricultural practices as a pathway to revitalizing Iraq's agricultural sector. Unlike conventional agriculture, which often exacerbates environmental degradation and social inequities, regenerative agriculture presents a holistic and sustainable alternative that prioritizes the restoration of soil health, biodiversity, and community well-being. Through the implementation of practices such as no-till farming, crop rotation, and holistic grazing, regenerative agriculture has the potential to reverse the damage caused by decades of unsustainable agricultural methods and external economic pressures. Moreover, this thesis highlighted the economic viability of regenerative agriculture, particularly in fragile ecosystems like those in Iraq's arid regions. By demonstrating that regenerative practices can be both ecologically restorative and economically profitable, this research challenges the conventional wisdom that sustainability and profitability are mutually exclusive. The case of Iraq exemplifies how regenerative agriculture can foster resilience and sustainability, even in the face of significant socio-economic and environmental challenges. However, the successful implementation of regenerative agriculture in Iraq will require substantial policy support, investment in infrastructure, and a commitment to overcoming the systemic barriers identified in this research. The limitations of existing policy frameworks, including the lack of enforcement, bureaucratic inefficiencies, and the influence of global economic forces, must be addressed to create an enabling environment for regenerative practices to thrive. Additionally, the need for community involvement and the reclamation of traditional knowledge cannot be overstated. These elements are crucial for ensuring that regenerative agriculture is not only technically feasible but also culturally and socially accepted within the local context. The comparative analysis of agricultural systems and the examination of case studies from other regions, including the failed transition in Sri Lanka, provided valuable insights into the potential pitfalls and success factors associated with implementing regenerative agriculture.

These examples reinforced the importance of adopting a phased and well-researched approach, supported by stakeholder engagement and grounded in empirical evidence. The use of GST in this context proved to be a robust tool for managing uncertainties and developing adaptable strategies that can withstand the dynamic challenges of Iraq's agricultural landscape. This thesis advocates for a paradigm shift in how agricultural development is approached in Iraq and similar arid regions. Regenerative agriculture, supported by a strong theoretical and methodological framework, offers a viable solution for achieving long-term environmental sustainability, economic resilience, and social equity. The insights gained from this research contribute to the broader discourse on sustainable agriculture and provide a blueprint for policymakers, practitioners, and scholars committed to fostering a more sustainable and equitable future for Iraq's rural communities.

7.References

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BIOGRAPHY

Amar Ahmad Darwish was born in Firminy, France, on November 06, 1996. He has pursued a diverse and interdisciplinary educational path. He is currently enrolled in the Master in Agriculture and Environment (InterEN-Agro) program at the University of Zagreb, Croatia, (2022) where the language of instruction is English. Prior to this, he completed a Master of Science in Neuroscience and Biotechnology at the Holy Spirit University of Kaslik, Lebanon, (2019-2024) in collaboration with the Erasmus+ program, also in English. His academic foundation was laid with a Bachelor of Science in Life and Earth Sciences, specializing in Biology (2015-2019), from the same university. His secondary education culminated in a French Baccalaureate in Social Economy from Lycée Abdel Kader, Beirut, which he passed with distinction. Amar is fluent in English and French, possessing strong writing and speaking skills in both. He is also proficient in Arabic (spoken).

In addition to his formal education, Amar has a wealth of professional experience. He has worked as a guide for French hikers in Dalmatia, Croatia, under Hiking Trails d.o.o, and has been involved in research and development for a desert farm project in Iraq. He also served as the head of marketing at the Lebanese recycling association, Live-Love-Recycle, managing digital marketing and event coordination. Amar's background in biology is further reflected in his internship at Hospital Saint Raphaël in Baghdad, where he gained laboratory experience in microbiology and hematology. Amar is passionate about sustainability, having volunteered with Lebanese NGOs like Offrejoie and GreenVan, contributing to emergency response and sustainable agriculture projects. His personal interests include farming, acting, music, camping, and ecological initiatives.