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Climate Smart Agriculture and Mitigation Techniques for Sustainable Resilient Farming in Middle East Region

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Abstract
Purpose: With increasing demand for food production and population rise globally and in the middle east region, transformation of agriculture sector to balance the climate change impacts and adaptation are very critical. The present study attempts to examine the advancements and developments underway in the agriculture sector in the middle east region especially in view of the climate change challenges.
Methodology: A descriptive study was followed by referring to various resources is done considering the important factors contribution to climate change. Literature from scientific published studies, information published in international organizations, technical reports are reviewed extensively to present the study outcomes.
Findings: Agriculture is very important for economic growth and GDP. Middle east region is witnessed with multiple challenges, high temperatures, occurrence of extreme weather events limiting the food production capacity, in addition to climate change impacts. Currently climate smart agriculture practices, approaches and techniques through international partnership can only address the challenges eventually contributing towards climate change adaptation.
Research implications: The concept of climate smart agriculture is less progressively understood in the middle east region due to many factors. Not much empirical studies are done by researchers to explore the prospects of climate smart agriculture techniques in the middle east while substantial work research in this area is done in African continent.
Originality/value: The present study gains significance to the research community, government sectors and agrarian community in the middle east and GCC countries to understand the potential scope needed to increase food production in the region by adapting to climate change. These findings would provide background information, for researchers to explore studies on mechanism to achieve sustainable resilient farming by adaptation to climate change challenges.

Keywords: Agriculture, Technology, Practice, Conservation, GCC, Temperature

1.0 Introduction

Climate Smart Agriculture (CSA) is the new concept substituting the conventional agriculture system followed from many centuries. Over the years, the conventional agriculture system has gone through significant change because of multiple challenges and pressures from population rise, exploitation of resources leading to degradation, industrialization, globalization, climate induced natural disasters such as famine, droughts, floods etc. misbalancing the supply and demand for food grains (Kremer, 1993).

Agriculture has become key sector for transforming economies, for maintaining food security and nutrition of a nation and a prime goal for developing nations to sustain economic status (Lin, 2018). China has experienced growth rate of GDP from $155 to $8123 during from 1978 to 2016 by accelerating agriculture production and transformation. Such transformations are more evident when technology, innovation is incorporated into the traditional system of farming modernizing the agriculture sector. Reasonably, the key for economic growth lies in modernization of agriculture from adopting technology and innovation together for achieving growth in economic status through increased income from agricultural production. In relation, the current state of agriculture is oriented towards industrialized economics which has moved away from subsistence agriculture system (Laborde et al, 2019).

The potential challenges prevailing locally, regionally, and globally should be addressed more systematically in consultations with governance and policies. In the present phase, agriculture sector is surrounded with mounting global challenges that are prominently posing risk to sustenance and progress of the sector (Chouchane & Boly, 2017). On the other hand, agriculture sector is also affected by paramount challenges like, increasing global population and distribution patterns, reduction in food grain production, inefficient channels from production to consumption, poor governance and management are all leading to significant gaps in today's agriculture sector. Further to this effect, the increasing incidence of famines, droughts, floods, unseasonal monsoons, temperature changes etc. the consequences of climate change phenomena has escalated the agriculture crisis to alarming levels in every economy (Bernadaux, 2021). Figuratively, the COVID-19 pandemic too has impacted the agriculture particularly to the downstream operations involving postproduction processing and marketing business.

1.1 Theoretical Background and Significance of Study

The world population is expected reach 10 billion by the year 2050 (World Food Summit, 1996), as per population prediction reports and to provide food security and nutrition, the current food production should rise from 2.1 billion tons to 3 billion tons (Ranganathan, Waite, Searchinger and Hanson 2018). Further estimates from FAO, the demand for agriculture will increase by 50% by 2050. To achieve the target, with the 38% of the world land available for agriculture, of which 1/3rd for grain crops, such situation leads to competition for resources, disproportionate exploitation of land can lead to land degradation, inconsistent farming practices etc., (Gilbert, 2012) all of those accumulating greenhouse gas emissions from agriculture and forestry (UNCC 2021). Moreover, as agriculture including forestry and other land use are contributing to 24% of global greenhouse gas emissions of which 11% is from carbon dioxide (EPA, 2021), it is anticipated that further emissions from agriculture sector will be very detrimental in catalyzing the global warming potential. On the contrary, to increase agriculture production to accommodate the rising population with limited cultivable land available with minimum resource usage is essential to reduce the emissions from agriculture to mitigate climate change impacts (Lynch et al, 2021). Despite such measures, every country has to keep tap on sustainable land management practices consistently to achieve climate resilience from farming.

In the middle east, 28% (84 million) of the total population (296 million) depend on agriculture, but it accounts to only 13% of the GDP. Agriculture in this region can play significant role in the future if appropriate initiatives are identified. Emphasizing sustainable farming practices and techniques will transform agriculture in the middle east region to be more resilient to global warming and climate change impacts. In this setting, need of the hour is to adopt climate smart agriculture (CSA) approach which is an innovate integrated approach to sustain croplands, livestock, forests, and landscapes in conjunction with climate change concerns (Bernadaux, 2021).

1.2 Objectives and Development of Study

The CSA approach is heavily promoted by all agrarian economies with support from global organizations such as food and agriculture organization (FAO), united nation frame convention on climate change (UNFCCC), international institute of sustainable development (IISD) who provide impetus to this initiative for mitigating climate change impacts from agriculture sector alone. Fundamentally the consequences of climate change are felt profoundly on agriculture sector in developing nations, combined with demographic problems, expansion of desertification and land degradation in many nations especially in most of the middle east countries (FAO, 2022). Hence, the most affordable way of managing to balance the gap, is by adopting proper land use management and land use for agriculture by practicing CSA techniques. Therefore, this study purposedly intends to examine the climate smart agriculture approach and diverse measures taken in middle east countries towards adapting climate change effects on agriculture, further, to understand how different innovative agriculture methods under the CSA is augmenting sustainable resilient farming in the region to the climate change phenomena.

2.0 Literature Review

2.1 Describing Climate Smart Agriculture

The modern agriculture currently echoing under climate smart agriculture (CSA) which is basically a practice towards climate consciousness agriculture. More structured definitions state “Climate smart agriculture (CSA) is an approach for transforming and reorienting agriculture development under the new realities of climate change” (Lipper et al, 2014). The widely known definition given by FAO tells “Climate-smart agriculture (CSA) is an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support the development and ensure food security in a changing climate” in addition to many similar definitions by different researchers.

2.2 Conceptualizing of CSA in Diversified Economies

Agriculture sector globally is one of potential sources for emission of greenhouse gases, according to FAO reports the emissions from the sector has reached 9.3 billion tons in 2018 (FAOSTAT, 2020). To sustainably manage the complexities surrounding, economies have attempted to adopt smart agriculture techniques such as vertical farming, streamline supply chain etc. to decarbonize the sector from the increasing emissions (Soofi et al, 2022). Analysis from Partey et al, 2018 indicates the prospects of CSA technologies and techniques in developing counties like West Africa through agroforestry, soil conservation etc. The CSA approach in sub-Saharan Africa among small farming households too is gaining more promising results (Kombat et al, 2021). Studies done on smallholder farms in Tanzania adopted CSA technologies adopting better crop and land management measures for resilience to climate change (Kurgat et al, 2020). While the factors influencing the adoption of CSA technologies are spread across climate related and demographic patterns which tend to vary among nations (Tran et al, 2020). However, Williams et al (2015) contradicts the CSA as regional specific

governed by locally prevailing weather and land management practices, and on larger scale needs support from government, planners, researchers. Mizik (2021) reports from his review on small scale farms indicate better water and crop management methods are widely followed techniques under CSA to achieve economic and environmental benefits.

3.0 Methodology

3.1 Framework Approach

The present study is structured on descriptive in nature and the focus revolves around the concept of CSA, a principal mechanism to remain resilient to climate change impacts on agriculture. The study closely looks the this established concept in different geographic and demographic pattern with reference to uncontrolled variables such as temperature, climate change, population dispersion and density, land use and condition. However, these variables are observed holistically to realize the importance of the study, but the parameters associated with these variables are not examined over time scale critically to signify the relationship with the CSA approach.

3.2 Methods and Data Analysis

The sources and data required for conducting the study is followed by adopting by integrating literature review and collecting information from secondary sources according to descriptions of Halcomb and Hickman (2015). Information pertaining to the study subject are taken from reference organizations, websites, web portals, published scientific and technical report documents from global organizations etc. are used for interpreting concepts underpinning the objectives of the study. Also, scientific studies by various researchers published in journals, books, scientific articles are extensively reviewed and considered as highlighted by (Johnston, 2014).

The study focuses on the middle east region (figure 1) since the region has not significantly explored the futuristic trends in agriculture and the growing disparity between food demand and increasing population, hence CSA in this region would be vital mitigation initiative to ensure the growth of agriculture remains resilient to the future climate change challenges. In this context, the authors have attempted to study the prominence of employing CSA techniques followed by the middle east countries to overcome the bigger challenges.

4.0 Findings and Discussion

4.1 Middle East Geography and Geomorphology

Middle east region is a group of countries located touching the southeast Asia and African continent towards west and Europe to the north. The region does not have any definite number of countries but ranges from 15 to 18 based on transcontinental boundary (Figure 1). The largest of them is kingdom of Saudi Arabia and smallest is Kingdom of Bahrain in terms of geographical area. Most of the middle east countries are characterized as arid and semi-arid regions with limited plant cover Galun and Garty (2001) having an average precipitation between 300 to 800 mm with summer rains and in winter rains 200 to 500 mm (FAO). The region periodically experiences dust, sandstorms mostly between May to September.

Figure 1: Middle east region, composition countries and geographical area[1].

4.2 Climate Smart Agriculture- Genesis

CSA concept was first introduced by FAO in 2009, to emphasize food security and agriculture mitigation in developing countries, and later developed in 2010 to include practices, policies. The necessity for creating such as approach to mitigate and adapt to climate change is an outcome of negotiations on international climate change under UNFCCC. In 2013, FAO then released CSA source books for practicing in agriculture.

4.2 *Agriculture Amidst a Challenging Crisis in Middle East*

Agriculture in the middle east region is surmounted with many challenges, prominent among them are the increasing population and urbanization which has reached 70% and expected to reach 329 billion by the year 2050. Moreover, there are no correct figures available on percentage of cultivable land particular for the middle east countries, but only 15% of the land is suitable for farming. About 2/3rds of the population is habituated in areas having insufficient water resources which can hardly support cultivation. Soil salinity in the arid and semi-arid region are perennial problems and profoundly observed in the middle east region due to scare and disperse rainfall through the year. As a result, most of region especially the GCC countries heavily rely on food imports from other countries, in addition the climate change extreme events such as prolong spell of dry weather, dust storms, high temperatures etc. have further worsened the cultivation efforts thereby widening the gap between food production, supply and demand. To overcome these shortcomings, sustainable development approaches are prioritized by some countries in the region, such as UAE, Saudi Arabia by adopting improvised resource conservation strategies. In addition, these countries have also taken better pest and disease management measures, water management measures due to inadequate ground water resources etc.

Another potential challenge these countries would eventually suffer from the climate change is from the rising sea levels globally, predicted to rise by 0.1 to 0.3 meters by 2050 can cause low lying countries in the middle east region to lose portion of their coastal lands that can disrupt

[1] Worldatlas.com. https://www.worldatlas.com/articles/which-are-the-middle-eastern-countries.html

fishing communities and their livelihood. These disturbance on coastal geology can lead to saltwater intrusion from surface and subsurface aquifers altering the soil physico-chemical characteristics making it detrimental for coastal farming (Waha et al, 2017). Despite, the impeding problems impacting the agriculture sector, there is great potential and scope for the middle east region to adopt farming practices that are climate responsive and resilient to the changes. Some countries have made national frameworks for reducing emissions from agriculture and shifted to cultivating crops that are climate resistant, practicing better water management through sensor technology etc.

4.3 CSA- Measures towards Emission Reduction and Climate Resilient Mechanism

Climate change is impacting and impacted by agriculture from the emissions from cultivation and livestock. To neutralize the emissions and protect the agriculture invariably from the impact of climate change, the sector should strike a balance between the production, mitigation, and adaptation by following practices which can mitigate the impact, adopt approaches for land, water use and have access to institutional arrangement for enabling environmental protection (Figure 2).

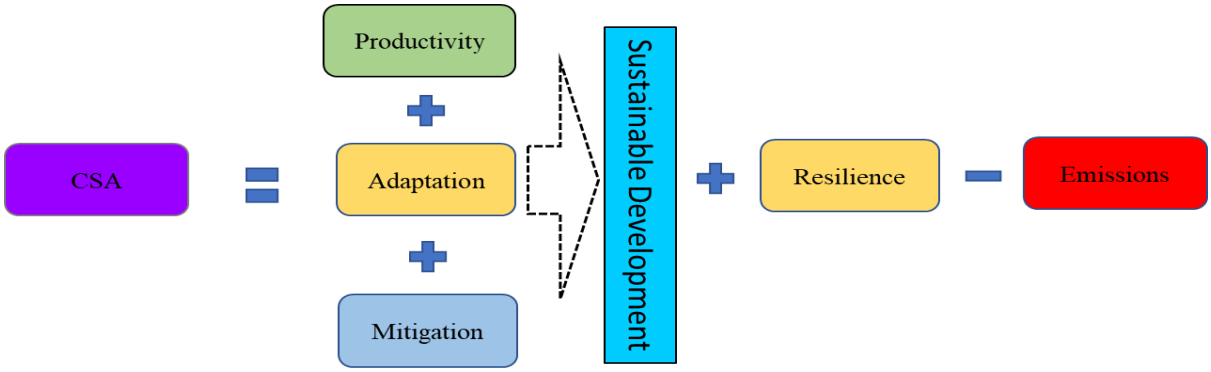

Figure 2: Comprehensive approach of climate smart agriculture for resilience to climate change. [2]

Though CSA leads to proactive measures for adopting sustainable means of farming, subjectively the mechanism also addresses the problem of food security, distribution, develops interlinkages between agriculture, poverty and climate change significant to the context of middle east region. However, to achieve the holistic objective of CSA, intending nations must adopt combination of practices, approaches and technologies that are feasible to mitigate and adapt agriculture to the changing climate patterns (Table 1).

Table 1: Climate smart agriculture thematic areas

Practices	soil management, crop production, water management, livestock management, agroforestry, energy management
Approaches	landscape management, alternative farming methods, capacity development, diversification
Technologies	mulching, intercropping, organic manure, minimum tillage, crop rotation, intercropping, biological control, organic herbicides, nuclear isotope, drip irrigation, check dams, contour bunds, micro irrigation, zero grazing, rotational grazing, fodder intercrops, solar power systems, sensor technology, vertical farming, hydroponics, aquaponics, strip cropping, crop rotation, mixed cropping, mixed farming

[2] Adapted from: How is it different? | Climate-Smart Agriculture Guide (csa.guide)

To further facilitate and adopt climate resilient initiatives especially in developing nations, financial funding for investing on agricultural technology, technical support and guidance are very crucial to build at micro to macro farming level. There are multiple and diverse funding opportunities available for adaptation and mitigation for different sectors for the farming communities in the middle east to choose for adopting the climate response agriculture measures. For middle east nations to classify with CSA framework, should make arrangement to adopt practices, approaches, and technologies for optimizing food production, follow measures to mitigate emissions and adaptation at various levels (Figure 3).

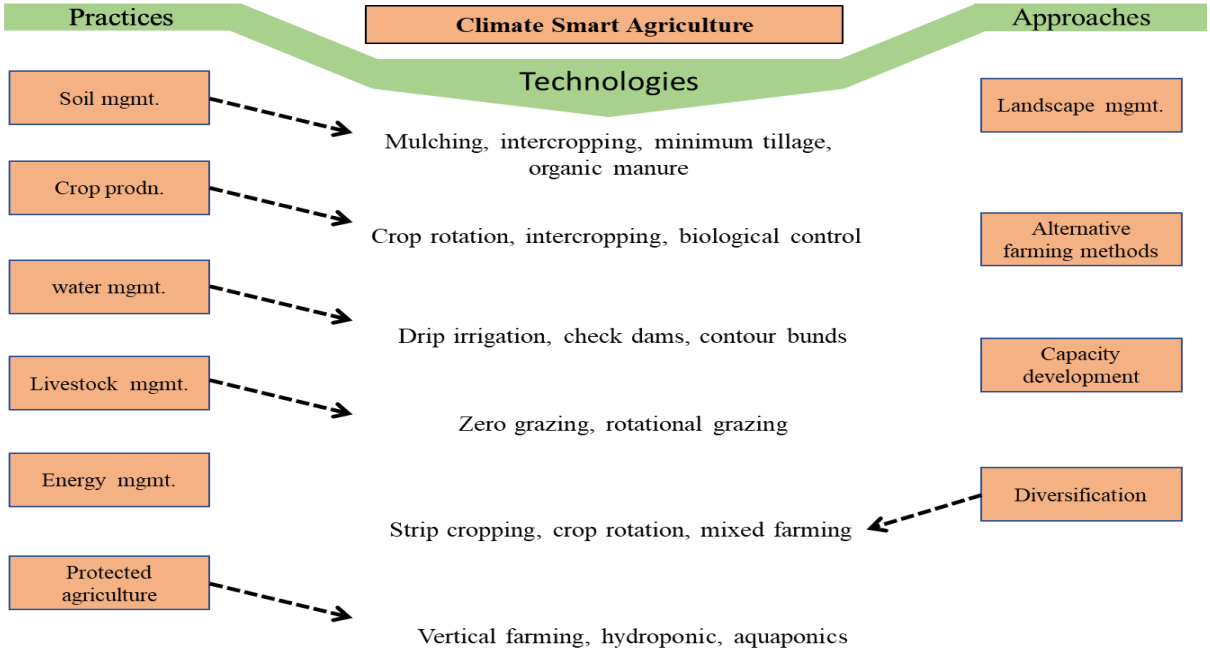

Figure 3: Different practices, approaches and technologies classified under climate smart agriculture. [3]

4.4 Climate Smart Technology (CST)- Small Sustainable Initiatives

4.4.1 Vertical Farming

Towards this path, UAE in the GCC countries have adopted protected agriculture technology through initiating vertical farming for growing mainly vegetable, herbs and leafy greens in indoor environment. Succeeding this, Saudi Arabia has embarked on vertical farming market among other countries in the GCC region, growing crops in indoor and outdoor environment under hydroponics, aeroponics, and aquaponics mechanism. Better water and energy management practices are being employed in vertical indoor farming to recycle unused water in crop production (Mathews, 2021). The state of Kuwait in the GCC has also recently unveiled the first vertical indoor farming following the UAE and Saudi Arabia to cultivate herbs and leafy greens. While Qatar in partnership with Finland and Russia have also ventured into vertical indoor farming to grow leafy greens and exotic fruits. These small-scale climate smart technological initiatives can address local food security and can also reduce energy and resources consumption.

4.4.2 Soil Management

Another noteworthy breakthrough leading the CSA in the middle east region is from application of nuclear techniques for crop production. FAO in partnership with IAEA has

[3] Adapted from: www.ccafs.cgiar.org

provided technical support and guidance for farmers in Iraq, Jordan, Kuwait, Lebanon, Qatar, Saudi Arabia, Oman, UAE, Syria, and Yemen to grow crops and get increased yield in salt effected soil (Broussard, 2020).

4.4.3 Landscape Management

Soil scientists and engineers have discovered method for transforming unproductive desert land into fertile land suitable for growing crops through non-intrusive soil reclamation using liquid natural clay. The liquid natural clay, through small nano clay particles can turn the soils fertile to support plant growth. UAE in the GCC countries have started exploring this revolutionary technology to convert the vast desert unfertile lands for crop production.

4.5 Implications of CSA Initiatives in Mitigating Climate Change

The climate smart agriculture initiatives adopted in the GCC countries are representative measures to mitigate the impact of climate change in agriculture. The ways how those specific CST initiatives in the GCC countries are contributing to mitigating climate change are described in the table 2. Most importantly to prevent further intensification of climate change impacts, concentrated efforts towards adopting different measures recommended specifically for reducing, avoiding and removal of greenhouse gas emissions (GHGs) from agriculture practices should be emphasized in agrarian economies particularly in middle east countries (Table 2).

Table 2: Climate smart practices and technologies adopted in agriculture in the middle east region.

Practices	**Technology**	**Measure to mitigate climate change in agriculture sector**		
		Reduce GHG emissions	**Avoid GHG emissions**	**Remove GHG emissions**
Soil management	Mulching	✸		
	Intercropping			✸
	Organic manure	✸		
	Minimum tillage	✸		
Crop production	Crop rotation		✸	
	Intercropping	✸		
	Biological control		✸	
	Organic herbicides		✸	
	Nuclear isotope	✸		
Water management	Drip irrigation		✸	
	Check dams		✸	
	Contour bunds		✸	
	Micro irrigation		✸	
Livestock management	Zero grazing	✸		
	Rotational grazing		✸	
	Fodder intercrops	✸		
Energy management	Solar power systems		✸	
	Sensor detection	✸		
Protected agriculture	Vertical farming	✸		
	Hydroponics			✸
	Aquaponics			✸
Approaches				
Diversification	Strip cropping			✸
	Silviculture			✸
	Mixed cropping			✸
	Mixed farming			✸

In contrast, farmers having small land holdings are adopting crop rotation and soil conservation measures as most preferred CSA practices to large extent, whereas conservation agriculture, agroforestry, crop diversification, fertilizer management are less significantly practiced (Mizik, 2021), despite this, there are potential contributing factors influencing the extent to which the individual CSA practices are adopted by farming community in each region (Mutenje et al, 2019). Such measures should be established to reduce the GHGs alongside smart agriculture practices, approaches, and technologies to transform agriculture more adaptable to climate change. In contrast, the climate smart technologies followed in the GCC are beneficial to the local communities but also correspondingly facilitate in mitigating climate impact from agriculture (Table 3).

Table 3: Contribution of climate smart technologies to society and climate adaptation.

CST	Benefits	Mitigating climate change
Vertical farming	Continuous cultivation	Food stability
	Protection from adverse weather	Resource conservation
		Prevent erosion and degradation
	Less water consumption	Reduce water wastage
		Water conservation
	Less space use	No land degradation
		Prevents deforestation
		Protects biodiversity
	No chemicals and pesticides	Reduction in N_2O emissions
		Prevent soil degradation
		Protects water bodies from pollution
	Reduce transport cost	Reduction in CO_2 emissions
	Low energy consumption	Reduces GHGs emissions
Nuclear isotope	Crop and soil productivity	Reduces soil salination
		Food stability
	Reduce use of fertilizer	Reduction of N2O emissions
		Prevent soil degradation
		Control soil degradation
	Less water consumption	Water conservation
Liquid natural clay	Soil management	Reduce water consumption
		Prevent soil degradation
		Reduces soil erosion
	Energy conservation	Reduction in CO_2 emissions
		Reduction in N_2O emissions
	Crop and soil productivity	Food stability
		Food accessibility
		Reduces soil degradation

5.0 Conclusion

The study aimed to spot some light on the reviewing the efforts and measures adopted by developing countries in adapting to climate change. Focus was shed on highlighting the practices, approaches and technologies that are ensued to reduce the emissions of greenhouses gases from agriculture sector ensuring farming methods are resilient to climate change. Most of the middle east countries are in the dire consequences of climate change effecting agriculture production, on the other hand the growing population and demand for food production has become a biggest challenge currently. Despite these, lack of adequate water resources, presence of arid and semi-arid soils is deterring the region raising food production, while the GCC countries depend on food imports for meeting the requirements. Furthermore, with the rapid

pace of technology advancements and innovation, agriculture sector is plausible to fetch good prospects to agrarian economies, in this context CSA approach in the middle east region can address the food production challenges.

Currently this concept in the middle east is gaining more recognition recently, as some countries have started to adopt practices, approaches, and technologies to make agriculture more adaptable to the climate change impacts like droughts, high temperatures, floods, cyclones etc. Similarly, technology to cultivate crops in saline and arid soils are also taking a breakthrough in GCC countries with financial support and partnership collaboration with international institutes. Given this stand, adopting CSA approach is going to be very eminent to the middle east region to address the present and future challenges and for achieving sustainable resilient farming, a strategic roadmap and integrated approach is very essential for adapting to climate change.

5.1 Study Contribution- Practical and Managerial Implications

The most pressing problems that is maligning the globe is climate change and population explosion, this is also more evident in the middle east region. Forecasts on population rise in the middle east region and the demand for food production indicates the need to increase the agriculture production in the middle east region to be self-sufficient. Besides, with the occurrence of adverse weather conditions such as floods, dust, dry weather and arid soils, agriculture sector in the region should adopt strategies and try different sustainable cultivation practices that are appropriate to the prevailing weather regimes. New climate change adaptation approaches and technologies that are adopted by developed agrarian economies should be tried, tested, and applied by conducting feasibility analysis. Further, the agriculture sector in the region, needs immense support, guidance, and capacity development to farming communities to adopt practices, approaches and technologies that are indicative to sustainable and resilient to climate change. Moreover, the climate smart initiatives practiced in the GCC countries can be expanded to the other middle east countries to address the local food demand which can subsequently reduce the GHGs emissions. Besides, international organizations must extend technical support and guidance with collaboration from government to implement natural resources management measures especially to the farming communities in the middle east region to overcome resource scarcity.

5.2 Study Limitation and Future Scope

The study is conducted to understand the significance of climate smart agriculture and the different measures being followed to ensure that farming in the middle east region is coping with the climate change challenges. To achieve these objectives and present the outcomes from the study, there were certain inadequacies observed in gathering information on specific climate adaptation farming practices in the middle east countries, as there are very limited empirical research studies on this topic, while substantial research studies on African region. Further, not much progress towards climate smart agriculture techniques is observed to be followed in middle east and GCC countries except few instances. In addressing this gap, future studies should focus on identifying the specific farming practices followed with respect to every country in the middle east region and assess the potential reduction in emissions of GHGs from agriculture. Such studies will provide a comprehensive database to the government, decision makers and agriculturists to consistently evaluate and recommend sustainable cropping patterns.

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