Journal of Environmental and Agricultural Studies
ISSN: 2710-1401
DOI: 10.32996/jeas
Journal Homepage: www.al-kindipublisher.com/index.php/jeas

JEAS
AL-KINDI CENTER FOR RESEARCH AND DEVELOPMENT

| RESEARCH ARTICLE

Advancement of Climate Adaptation, Resilience-Building, and Sustainability (CARS) Model in Agriculture in Developing Countries

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| ABSTRACT
Global Climate Change (GCC) and its responses are already changing how food is produced, processed, and consumed. The agriculture sector's recent history of hardships and challenges brought about by GCC has posed a significant danger to people's ability to acquire food, particularly in developing countries. Today, GCC impacts are already being felt across the globe, especially in remote and rural communities where vulnerability is high, adaptation capacity is limited, and resources are scarce. Therefore, finding sustainable, practical, and cutting-edge solutions to the challenges of GCC is essential. The United Nations 2030 agenda on sustainability aims to reshape the world's society by achieving a number of broad sustainable development goals (SDGs), which call for significant structural changes in society as well as profound transformations in policy, the economy, technology, and science. More specifically, agenda 2030 emphasizes the creation and effective application of models, technology innovations, and strategies that call for the full participation of all parties, including local and indigenous people and their experiences, traditions, and cultural practices. However, despite providing clear examples of sustainable lifestyles within their ecological environment, particularly in the equitable distribution of resources among community members, indigenous and local people's voices, knowledge, and concerns have remained underrepresented in the climate change and sustainability discourse. Thus, this paper advances the climate adaptation, resilience-building, and sustainability (CARS) model in agriculture in developing countries. The CARS model is meant for policymakers and hinges on integrating scientific knowledge with indigenous and local ecological knowledge (ILEK) in the climate change adaptation and sustainability discourse. This theoretical model supports the notion that an understanding of the indigenous and local ecological knowledge systems is critical to opening up an environment that supports community-based efforts to adapt to GCC by giving them options and engaging them in finding innovative, sustainable, and effective strategies to adapt to the impacts emanating from GCC. The ultimate goal of this model is to promote positive co-management and regional development through sustainability and climate change adaptation while generating a forum for discussion among indigenous and local communities and the relevant stakeholders.

| KEYWORDS
Climate change, adaptation, resilience, sustainability, agriculture, indigenous, local ecological knowledge, scientific knowledge, developing country

| ARTICLE INFORMATION
ACCEPTED: 20 July 2023 **PUBLISHED:** 02 August 2023 **DOI:** 10.32996/jeas.2023.4.2.5

1. Introduction
In many developing countries, the agriculture sector still remains the backbone of socioeconomic progress, and to this day, the sector still remains critical for food security since it generates the bulk of the world's food that people consume. Food security, in particular, is a severe concern for many people across the developing world, particularly those in rural and remote communities in Sub-Saharan Africa, Southeast Asia, and Latin America. Today, the world continues to face enormous challenges of having and securing adequate food that is healthful, safe, and nutritionally dense, particularly in many underdeveloped countries of Asia and

sub-Saharan Africa (Stern, 2007; FAO, 2008; Arora, 2019). And this challenge is likely going to be exacerbated by the frequency, intensity, and magnitude of global warming and climate change-related catastrophes (Beddington et al., 2010; Shafiee-Jood & Cai, 2016; Yohannes, 2016; OECD & FAO, 2017; Allen et al., 2018; IPCC, 2022).

According to the United Nations Framework Convention on Climate Change (UNFCC, 1992), global climate change (GCC) refers to:

> *"a change of the climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and is, in addition to natural climate variability observed over comparable periods."*

The challenge of providing enough food for all in unpredictable climate is likely going to be exacerbated by the current projected increase in the world's population, estimated at 9 billion people by the year 2050, as well as the rapid acceleration in worldwide calorie intake, estimated at 60% between 2000 and 2050 due to the expansion of income sources in many countries, particularly in Asia, as well as rising demands for land, food, and fuels, all of which will necessitate additional investments (World Bank, 2022). With agriculture accounting for an estimated 29% of GDP in developing countries and employing nearly 60% of the population, the effects of global warming and a changing climatic system on agriculture will have significant ramifications for jobs, food production, and the overall economy of all countries, particularly countries like Bangladesh, Malawi, etc., with agriculture-based economies (Yohannes, 2016; Arora, 2019; FAO, 2019).

Furthermore, the constant fluctuation in the weather system, notably the constant high temperatures, has resulted in an increase in drought, flood, and bushfire disasters throughout the world (Arora, 2019; IPCC, 2022). Natural catastrophes alone generated economic losses of USD 225 billion around the world in 2018. This is according to the annual report of the weather pattern (Arora, 2019). 'Climate and Catastrophe Insight' and losses due to natural disasters have exceeded USD 200 billion every year since 2016 (Arora, 2019, World Bank, 2022). These effects are expected to have long-term and short-term consequences for the world, particularly for impoverished and vulnerable people IPCC, 2022; World Bank, 2022). The expected short-term impacts or consequences will be those directly related to the frequency and severity of weather systems. At the same time, the long-term effects will be induced by precipitation patterns and a temperature shift (IPCC, 2021).

In recent years, the need to address the aforementioned GCC threats has compelled many scholars, scientists, governments, international organizations, and stakeholders around the world to return to the drawing board and devise mechanisms that can address current global environmental issues such as sustainable economic growth and environmental wellbeing as a whole, resulting in the emergency of global sustainability pathways or models such as 'Sustainable Development, 'Climate Smart Agriculture and Climate Compatible Development (CCD) (UNFCC, 1992; FAO, 2008, Mallick et al., 2012). As a global and driving concept of the twentieth and twenty-first centuries, sustainable development (SD) seeks to promote a balance between economic growth, social development, and, above all, environmental sustainability in all sectors and countries around the world (UNFCCC, 1992; Dernbach, 1998; Cerin, 2006; Puthenkalam and Chathanatt, 2016). Numerous governments throughout the world have accepted the ideas of sustainable development (SD) to such a degree that it has had a tremendous influence on many national, regional, and international agreements, policies, and initiatives. The primary purpose of SD is to eliminate the former pattern of economic development in which the relevance of the environment was overlooked or ignored, or not fully taken into account when embarking on massive development projects around the world (UNFCCC, 1992; Dernbach, 2003; Stoddart, 2011; Puthenkalam and Chathanatt, 2016). The ultimate goal of contemporary sustainability models such as Climate Compatible Development (CCD), which is the model this research paper is utilizing in advancing the climate adaptation, resilience-building, and sustainability (CARS) model in agriculture in developing countries, has been to achieve a balance between developmental and environmental needs (Blackford et al., 2011; Mallick et al. 2012). The CCD model seeks to ensure that development occurs without harming our environment and that global warming is slowed. It also seeks governments, particularly those in developing countries, to develop policies that would not only withstand the pressures of a changing climate through adaptation and mitigation strategies but also ensure to it that there is a balance between developmental needs and environmental needs (Mitchell and Maxwell, 2010; Blackford et al. 2011; Mallick et al. 2012). Furthermore, acknowledging that the agriculture sector is a source of livelihood for the majority of the world population and plays an important role in global warming resulting from greenhouse gas (GHG) emissions has further led to the emergency and need to find workable and effective solutions in agriculture that sees to it that mitigation and adaptation measures are met in, especially a continuously changing climate. According to the United Nations Food and Agriculture Organization (FAO, 2017);

> *"adapting to these changes by investing in and adopting innovative sustainable farming methods will be critical to farmers' livelihoods and their ability to meet the needs of a growing population."*

This means that there is a crucial need to identify, formulate and implement effective strategies that can help the local, indigenous, and vulnerable communities across the globe to mitigate and adapt to climate risks. And it is in this vein that the engagement of all key stakeholders, including the voices, knowledge, and experiences of the local and indigenous people in climate policy formation and implementation and in climate adaptation is critical (Nyong et al. 2007; Anik and Khan, 2012; Tengo et al.,2014; Makondo and Thomas, 2018; Kerr et al., 2018; Camila et al., 2019).

1.1 Methodology

This paper has adopted a desktop research methodology based on a systematic literature review of already published reports, statistical and graphical analysis of climate change data, indigenous and local ecological knowledge, and previous original research surveys that the researcher and other researchers have carried out on climate change, agriculture, and indigenous and local ecological knowledge. The choice of this research methodology emanates from the current economic meltdown and the COVID-19 crisis that has made it impossible to travel and conduct research activities in other places far away from home. Furthermore, because of the nature of the current research, which seeks to advance a new theoretical model (CARS Model), it was seen fit that analyzing primary literature in a systematic manner on the current research topic will provide credible background insights on the issue being studied at the same time increases the credibility and of primary data research analysis.

1.2 Problem Statement

For many decades, the formulation and implementation of the many mechanisms or rather solutions to the GCC crisis have been solely and primarily based on scientific knowledge, with little regard for indigenous and local ecological knowledge (ILEK), and have primarily focused on mitigation (reducing or lessening and possibly stabilizing, the impacts of GHG emissions trapped in the atmosphere) (UNFCCC 1992; Nyong et al.,2007; Makondo & Thomas, 2018; Sakapaji, 2021). However, worldwide attempts to combat GCC through scientific mitigation and adaptation techniques have faced both political and economic difficulties, particularly in developing countries (Cambray et al., 2013). Furthermore, research investigations on the efficiency of current models or processes in combating GCC have also demonstrated that it is difficult for developing countries to successfully adopt and use modern techniques, mechanisms, models, and technologies specifically for adaptation and resilience-building purposes because of their mostly aligned to the top-down approach and have little or nothing to do with the local ecological knowledge system (Nyong et al., 2007; Zondiwe, 2010; Nakashima et al., 2012; BCAS, 2012; Sakapaji, 2018; Makondo and Thomas, 2018).

In the last two decades, the United Nations has been pushing and focusing discussions more on sustainability pathways with emphasis on the formulation and successful implementation of policies and models that require the full participation of all stakeholders, including local and indigenous people and their experiences, traditions, and local ecological knowledge practices. More so, many researchers, academicians, international boards, NGOs, and other stakeholders have emphasized the need to understand the local ecological system through indigenous and local ecological knowledge (ILEK) and integrate this knowledge with science if any meaningful adaptation that enhances the resilience of a people is to bear fruit (Nyong et al., 2007; Anik and Khan, 2012; Tengo et al., 2014; Makondo and Thomas, 2018; Kerr et al. 2018; Camila et al., 2019; Sakapaji, 2021). However, despite this push, the voices, knowledge, and concerns of both the indigenous and local people have remained underrepresented in the climate and sustainability discourse even when these people have demonstrated vivid examples of sustainable lifestyles within their ecological environment, in particular, the equitable distribution of resources among community members and the many conservation and sustainable pathways practiced (Berks, 1999; Makondo & Thomas, 2018; Sakapaji; 2021).

It is from the aforementioned background that this paper advances the climate adaptation, resilience, and sustainability (CARS) model in agriculture in developing countries. The CARS model is meant for policymakers in developing countries and hinges on integrating scientific knowledge with indigenous and local knowledge (ILEK) in the climate change adaptation discourse. The model supports a bottom-up approach and hinges on the notion that an understanding of the indigenous and local ecological knowledge systems and how policies may affect the adaptability capacity of the local and indigenous people is critical to opening up an environment that supports community-based efforts to adapt to GCC by giving them options and engaging them in finding innovative, sustainable, and effective strategies to adapt to climate change impacts.

2. Scientific Evidence Supporting a Global Climate Change

The earth's climate has been changing for hundreds of thousands of years; however, from the 20th century until now and especially the beginning of the industrial revolution and into the early 21st century, evidence has shown that during this period, humans have played a huge role in changing or modifying of the earth's climate. Piacentini and Mujumdar (2009) and Rohila et al. (2017) have indicated that from the beginning of the millennium (the year 1000), the most variable that characterizes the climate is the ambient temperature which fluctuates scantly diminishing at a rate of -0.02 ÅãC/century up to around 1900 and after that increases all of a sudden, at a rate of +0.57 ÅãC/century. The main reason for this sharp increase in the ambient temperature over the years has been linked to the greenhouse gas (GHG) emission in the atmosphere, which includes a type of particular matter named black carbon (IPCC, 2013).

For thousands of years up until the start of the mechanical transformation (industrial revolution), the GHGs have advanced in our atmosphere in terms of concentration; in any case, with the increment in population coupled with the ceaseless utilization of fossil fuels, the increase in deforestation and the advancement in food production and other related issues have exacerbated the issue of GHG outflows significantly (Yohannes, 2016).

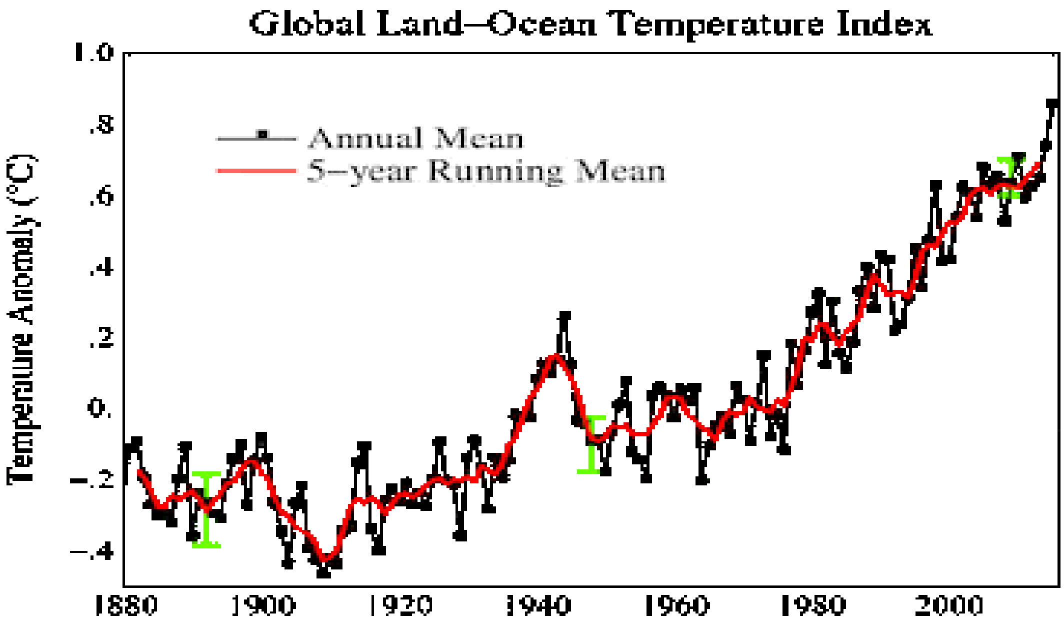

Figure. 1 Global Land-Ocean Temperature Index
Source: NASA, 2018

In addition, taking into account the anthropogenic factor, scientists have observed a clear pattern between greenhouse emissions and the temperature increase since the 1980s. Today there is clear evidence that since 1880 as shown in the graph below (Figure 1), anthropogenic factors are driving mostly the observed changes (NASA, 2018; IPCC, 2013). The lean towards anthropogenic factors as the culprit in the increase in global greenhouse gases have been specifically observed in the increase in carbon dioxide (CO2) in the atmosphere, which is at 421ppm as of May 2022 compared to two centuries ago when it was only 280ppm (NOAA, Global Monitoring Laboratory, 2022).

Figure 2 shows the monthly mean carbon dioxide measured at Mauna Loa Observatory, Hawaii, the longest record of direct measurements of CO2 in the atmosphere. Monitoring was Initiated by C. David Keeling of the Scripps Institution of Oceanography in March of 1958 at a NOAA weather station. NOAA started its own independent and complementary CO2 measurements in May of 1974 (NOAA Global Monitoring Laboratory, Scripps Institute of Oceanography at the University of California San Diego).

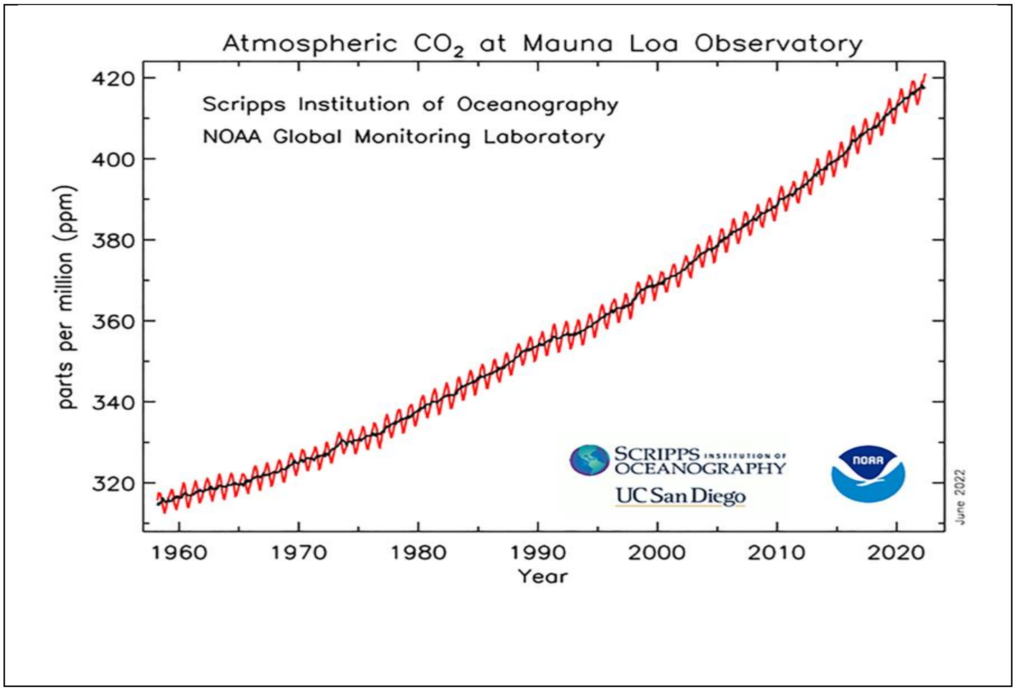

Figure: 2 Atmospheric CO2
Source: NOAA Global Monitoring Laboratory

From the start of the industrial revolution, the oceans have seen an increment in water levels of around 20cm, and this drift is anticipated to extend to between 0.26 cm (the least esteem within the idealistic RCP2.6 situation) and 0.98 cm (within the cynical RCP8.5 situation) by 2100 (IPCC, 2013). Frieler et al. (2016) from the Potsdam Institute for climate change impact research (PIK) in Germany have predicted that:

> *"Even if greenhouse gas emissions were stopped today, sea level would continue to rise for centuries, with the long-term sea-level commitment of a 2°C warmer world significantly exceeding 2 meters." Researchers of this Institute propose that the sea level could rise even more than 130 cm by 2100 (PIK, 2016; IPCC, 2018).*

An analysis of world data on these types of events like sea rise has concluded and indicated that statistical analysis, climate modeling, and physical reasoning of the observed information emphatically show that a few sorts of extraordinary occasions, most outstandingly heatwaves, and precipitation extremes, will enormously increase in a warming climate, and this increment is evident today (Coumou and Restore, 2012; Rohila, 2017; Arora, 2019; World Bank, 2022). The higher the temperatures, the higher the chances of new diseases, especially in higher latitudes and altitudes, as in the case of Dengue Fever (Liu- Helmersson et al., 2014). Van der Leun, Piacentini and de Gruijl (2008) and Piacentini, Della Ceca and Ipi. a (2018) have indicated that even if solar radiation is the main cause of skin cancer, an increase in ambient temperature can also produce a higher number of cases related to skin cancer by considering the statistical analysis of Skin Cancer Surveys in the USA. Sea level rise has caused massive flooding in low-altitude coastal zones forcing a large number of people to migrate from the coastal areas into the mainland, as in the case of Pakistan in 2022 and Bangladesh, specifically in the Ganges Delta (Karim and Nimura, 2008; Sakapaji, 2018). Furthermore, the migration of thousands of people from the mid-east and other areas of North Africa and sub-Saharan Africa to areas of Europe can be said to be partly due to the instability in these regions, but the drying (drought) of many parts of these regions due to climate variability has partially been associated with this large movement of people to Europe (Kelley et al. 2015; Sakapaji, 2018).

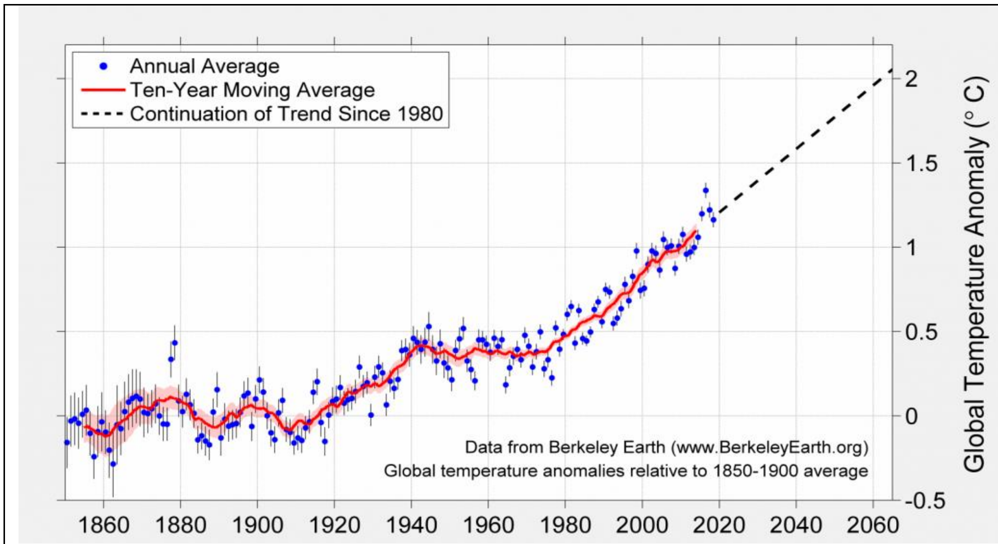

Figure: 3 Long-term Trend of the Earth's Surface Temperature
Source: Berkeley Earth.Org

Though understanding the features of specific years is fascinating, global warming is ultimately about the long-term history of the Earth's climate. The graph in figure 3 depicts a ten-year moving average of the Earth's surface temperature compared to the average temperature from 1850 to 1900. Since 1980, the general trend has been +0.19 °C/decade (+0.34 °F/decade) and has altered slightly. We may construct a fair prediction of how the near-future climate may develop if the factors driving global warming continue at their current rate by continuing this pattern. As indicated in figure 3, some recent years have experienced temperatures that are more than 1 °C (1.8 °F) higher than the average temperature from 1850-1900, which is commonly used to approximate the pre-industrial climate. The Paris Agreement on Climate Change intends to keep global temperature rises well below 2 degrees Celsius (3.6 degrees Fahrenheit) and encourages countries to strive for warming of no more than 1.5 degrees Celsius (2.7 degrees Fahrenheit). Therefore, at the present pace of change, the Earth's long-term average temperature will be 1.5 °C (2.7 °F) higher than the 1850-1900 average by 2035 and 2 °C (3.6 °F) higher by 2060. The rising concentration of greenhouse gases in the atmosphere as a result of human activity is the direct cause of the current global warming. If the Paris Agreement's objective of no more than 1.5 degrees Celsius (2.7 degrees Fahrenheit) warming is to be met, considerable progress in decreasing greenhouse gas emissions must be made quickly.

As discussed above, the most compelling evidence of a changing climate by scientists has been the long-term data relating atmosphere CO2 levels and global temperature. Other changes that strongly indicate a changing climate have been those to do with sea level rise, the expanse of ice, the fossil record, and the distribution of species. In addition to these, we have evidence from visual impacts of climate change across the globe, such as the melting of glaciers, super storms, worsening droughts, increasing tornados, and extreme floods like the 2022 devastating floods in Pakistan, Nigeria, South Sudan, and many parts of the globe. Climate variability thus will contribute to existing long-term natural issues, such as groundwater consumption and soil debasement, which can influence food security and agribusiness generation frameworks. Mora et al. (2018) have found traceable proof of the impacts of GHG emissions in 467 pathways, such as human well-being, water, food, economy, infrastructure, and security. These impacts run from warming, heat waves, precipitation, dry spell, surges, fires, storms, sea-level rise, and changes in land cover and sea chemistry. These discoveries highlight the truth that GHG emissions pose a wide range of threats to humans by triggering existing hazards to which humans are already vulnerable.

3. The Duo Relationship between Agriculture (a Driver of Climate Change) and Climate Change

Over the last two decades, there has been mounting evidence that the agriculture sector is responsible for the majority of worldwide deforestation and is partially to blame for the current fluctuation in climate (Geist & Lamnin, 2002; Stern, 2007; Gibbs et al., 2010; Kissinger et al.,2012; Thornton & Lipper, 2014; Yohannes, 2016; Rohila et al., 2017; Kerr et al., 2018). According to current estimates, agricultural deforestation has occurred at a pace of over 13 million hectors per year during the previous 50 years, accounting for around 30% of the potential area cover of subtropical, temperate, and tropical forests (Rohila et al., 2017; Yohannes, 2016; FAO, 2016; 2019). Today, approximately 40% of the world's land is utilized for agriculture, with farmland accounting for 1.5 billion hectares or 12% of the total global land area. It should be recognized, however, that not only have agricultural methods increased and escalated over time, but they have also impacted the ecosystem (Rohila et al., 2017). There is an overwhelming consensus today that the agriculture sector is one of the largest sources of greenhouse gas (GHG) emissions due to agricultural activities such as land-use change and land cover transformation, which have tremendously contributed to global weather variability (FAO, 2014a; Yohannes, 2016). According to Thornton and Lipper (2014) and the US Environmental Protection Agency (2021), the agriculture sector generates around 24% to 30% of anthropogenic GHG emissions, with three quarters happening in developing countries, and this percentage is expected to climb to more than 80% by 2050. According to MA (2005b), between 1969 and 2000, there was a rise in the consumption of agroecosystem services across the world, owing to the constant increase in population growth, which doubled to 6 billion people in 2000, and the increased requirement to feed this rising population. This also meant that the usage of machinery, pesticides, fertilizers, and irrigation operations had increased, resulting in continuous environmental damage (Rohila et al., 2017). Thornton and Lipper (2014) and Rohila et al. (2017) have furthermore indicated that increased agricultural activity over the years has resulted in the deterioration of about 40% of the world's agricultural land, as well as numerous hazards and damage to many agroecosystems services.

Yohannes (2016) also shows that there was a considerable rise in GHG emissions from 2001 to 2011 (14%), which was caused by an increase in overall agricultural production. GHG emissions from agriculture, for example, accounted for one-third of total emissions in Ethiopia as of 2015 (Yohannes, 2016). Furthermore, as the world's population continues to expand, so will the need for food, implying that overall GHG emissions from the agriculture sector will rise over time. This means that the erratic weather conditions we are currently experiencing will worsen, and life will be extremely difficult, particularly for many people in underdeveloped nations. Agriculture's continual negative environmental consequences may be traced back to the world's continuous agricultural expansion, and these negative effects are multidirectional and complicated. It is today acknowledged by many stakeholders that; the negative effects of agricultural operations will not only have a bad influence on the general functioning of the natural environment but will also likely have a detrimental impact on human health. According to some researchers, the negative effects of agricultural operations will not only have a negative influence on the general functioning of the natural environment but will also likely have an impact on resource allocation or other items such as fuels and fibers (Chapin et al., 2000; Yohannes, 2016; Huylenbroeck et al., 2007; Arora, 2019; Sakapaji, 2021).

Furthermore, some studies have shown that agricultural expansion and intensification not only cause land degradation and desertification but also have the potential to cause poverty and hunger due to lower productivity (Wood et al., 2000; Altieri & Koohafkan, 2008; Conway, 2012a; Pingali, 2012; FAO, 2016e; FAO, 2019). The crucial element to remember is that methane (CH4) enteric fermentation accounts for more than one-third of agricultural GHG emissions, with rice paddies accounting for 12%. Farming accounts for the majority of global methane and nitrous oxide discharges (Yohannes, 2016). The outflows from methane are created by enteric fermentation amid the stomach-related digestion of ruminant creatures and by rice development. Nitrous oxide outflows, on the other hand, come primarily from the application of nitrogen-based fertilizers and creature fertilizer administration. Sad to mention that GHG's expulsion by the world woodland has fallen within the final two decades from 2.8 Gt every year to an evaluated 1.8 Gt in 2014.36 In any case, a 2019 FAO report shows that the Amazon rainforest, which is one of the biggest forests in carbon sequestration is losing its capacity to sequester carbon dioxide connecting this failure to an expanding rate of biomass mortality. This should worry us all because if this lack of sequestering carbon dioxide by the Amazon Forest continues, the fight against climate change will prove to be more difficult.

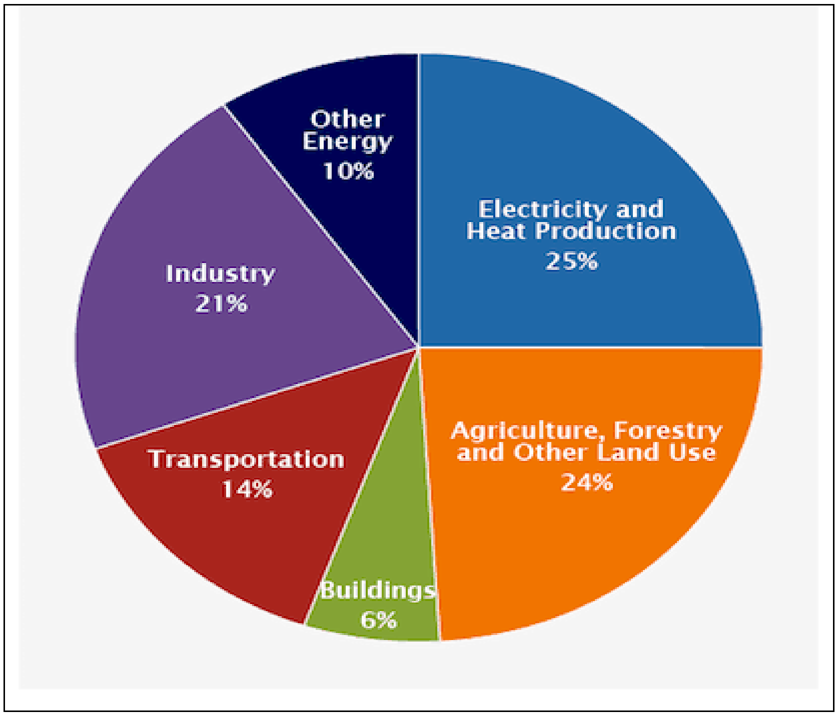

Figure: 4 GHG emissions from the agricultural sector compared to other sectors
Source: US Environmental Protection Agency, 2021

It is worth emphasizing that the disturbance to the socioeconomic and environmental systems is already occurring sooner than anticipated (Arora, 2019; IPCC, 2021). The negative impacts emanating from a changing climate due to the activities in the agriculture sector will have drastic changes in the way food is produced. Changing temperatures, precipitation averages, and unpredictable or more varied extreme climates are likely to alter agricultural yields, health, physical safety, and earnings, ultimately leading to higher poverty levels and impeding paths to current and future development levels, particularly in developing countries (Nelson et al., 2010; Vermeulen et al., 2012). These repercussions are more likely to harm the most visible sectors of the economy in many nations, including agriculture, energy, forestry, and the majority of coastal zones in both the developed and developing worlds (Stern, 2007; FAO, 2008; FAO, 2016; Yohannes, 2016). Most likely, the aforementioned consequences will afflict underdeveloped countries due to their incapacity to efficiently absorb the resulting shocks.

Today the window of opportunity to formulate the right policies by governments around the globe to fight GCC and promote sustainable development, particularly in the agriculture sector, is closing, but this does not mean that nothing can be done to alter the course at which our climate is changing. It is, therefore, upon all nations to change the current trend on emissions if we are to reverse the current rise in global temperature and protect our environment and protect the current and future developmental programs that can alleviate the poverty levels rampant in the world. Thus, unless something substantial and tangible in terms of robust, sustainable agricultural policies and strategies is encouraged and implemented quickly, global climatic conditions will continue to change, impacting the very fabric of economic development (agriculture) in many developing countries and exacerbating the already poor conditions that are prevalent in these countries. It is from this background that this research paper endorses the notion that, in order to effectively and sustainably address both the impacts of agriculture in terms of global GHG emissions and the impacts on agriculture as a result of a changing climate, the integration of local and indigenous knowledge (ILEK) with scientific knowledge is critical, especially at the local and community level and also given the fact that the world's population is growing (projected to reach 9 billion by 2050) and will require a constant and continuous supply of not only nutritious food but most importantly sustainable food.

4. Relevance and Potential of ILEK in Climate Change Adaptation, Resilience Building, and Sustainability in Agriculture

Indigenous and local people all over the globe have always adapted to climate variability by employing their local ecological knowledge. These coping techniques have existed for centuries and are embedded in their cultures, and have, in the past, greatly aided them in adapting to a changing environment. Because this information is deeply established in the people's local norms and culture, it has been seen to have the potential to improve people's capacity to build effective adaptation responses to GCC. And this knowledge is what is being referred to in this paper as indigenous and local ecological knowledge (ILEK). According to Nakashima et al. (2012), ILEK can be defined as;

> *"Knowledge and know-how that is linked to a specific location and comprises both old and new knowledge innovations that the local people have acquired over time through the interaction and co-existing with their local ecological environment and which they keep on constantly adjusting to adapt and suit a changing environment."*

This knowledge is particularly important at the local and community level, and it is believed to play a significant role in enhancing a community's resilience and capacity building, as well as responding to ecological and climate change within a certain threshold (Nyong et al., 2007; Klein et al., 2014; Audefroy and Sanchez, 2017). ILEK has also been seen to be effective in contributing and constructing social capital that may sustain and improve social life and the local economy, especially in a changing environment (Berkes et al., 2000; Ngong et al., 2007; Audefroy & Sanchez, 2017; Makondo & Thomas, 2018). Recent studies around the globe have indicated that ILEK practices can be the cheapest way to solve environmental problems and promote sustainable development, particularly in the agriculture sector and natural resource conservation and management (Nyong et al., 2007; Zondiwe, 2010; Anik and Khan, 2012; Nakashima et al., 2012; Onrubia, 2015; Audefroy & Sanchez, 2017; Makondo and Thomas, 2018). Furthermore, ILEK on natural ecosystems has also been seen to enable indigenous and local people to adapt their behaviors in animal husbandry, water, land, agriculture, forestry, and natural systems, allowing them to create resilience in a changing climate (Audefroy & Sanchez, 2017).

The following are some instances of how ILEK can be relevant in improving the resilience and adaptability capability of local people in agriculture in various regions across the globe. Farmers in Nepal's hills have devised several agroforestry processes or models to combat landslides, high rates of soil erosion, and frequent drought (ICIMOD, 2007b). Farmers in the Tarai area of Northern India and Northern Nepal have implemented time- and cost-effective techniques to prevent recurring floods by erecting Bamboo huts. Smallholder farmers in southern Bangladesh have used Bamboo trees to build what they are calling floating gardens where they plant their crops in times of severe floods and in places where the sea level rise has enormously engulfed much of the land, including their farms. The three examples presented here illustrate how ILEK may assist various communities in efficiently adapting to and remaining robust to the effects of climate change (ICIMOD, 2007b). Agroforestry is one of the important themes being debated today in the sustainability and climate change discourse, as well as in the balance of food crops and forests. For years, some indigenous smallholder farmers in the Sahel and in central Zambia have planted their crops alongside common trees such as Baobab, Acacia, and Msango (Faidherbia albida) trees since these plants are known to thrive in a variety of ecological and climatic situations in particularly arid regions (Nyong et al. 2007).

Today, experts and scientists have recognized the value and function these trees can play in agriculture in the region and are now pushing communities across the Sahel to plant these trees alongside their fields rather than cutting them down and are working towards developing more robust drought resistance trees to be used for the same and of course with knowledge learned from these local and indigenous people of these areas (Nyong et al., 2007; Sakapaji, 2021). This is one clear example of how integrating ILEK and science may improve the resilience of many disadvantaged local people, particularly those in developing countries. Furthermore, indigenous and local people in Malawi (Zondiwe, 2010) and the Sahel (Nyong et al., 2007) have for generations evolved complex methods of predicting, gathering, and interpreting meteorological conditions, and for decades, these have proven to be effective at adapting to a changing environment. In the same vein, farmers in both locations (Malawi and the Sahel) have been able to utilize their knowledge of meteorological conditions to make decisions such as when to plant, when to harvest, and when to prepare the land for the following agricultural season depending on the local weather conditions observed (Nyong et al., 2007; Zondiwe, 2010; Makondo & Thomas, 2018).

From the case studies given above, it can be concluded that ILEK is extremely significant, especially in this day and era where environmental sustainability is a critical issue across all sectors. Thus, it can be said that incorporating or rather integrating ILEK into developmental and climate policy is especially critical at this time, and governments, particularly those in developing countries, must take this seriously as it should be the starting point to achieving sustainable development (Smith and Lenhart, 1996; Bardati, 2019, Camila et al., 2019). Furthermore, local knowledge and coping techniques must be preserved and reinforced or integrated with scientific knowledge; otherwise, local people's adaptive ability may be impaired when local understanding of the environment is lost (Pandey et al., 2017). Strengthening and expanding on these local and indigenous skills also increases the likelihood that adaptation measures will be implemented since it fosters greater community ownership and engagement in the process (Sakapaji, 2021). Furthermore, ILEK can also be used in understanding climate change patterns and impacts at the local level, where scientifically quantitative data analysis such as mapping and climate models have difficulties in clearly assessing or projecting future climate risks and impacts (Klein et al., 2014). In order to understand the different and multiple risks and impacts of climate change, we need good data with a temporal depth which requires having good records of past climate information. This is actually true and important when understanding climate patterns with wide spatial coverage and at global scales. However, this data is not always available, as can be seen from even our more basic meteorological data, which is sometimes very incomplete, and sometimes also the spatial distribution of meteorological stations and knowledge is also very uneven across the world (more in western countries than in the global south) (Klein et al., 2014). Thus, even though these global scales and climatic models are very relevant to understanding general patterns in terms of climate change, they are often insufficient to detect all the impacts of climate change, especially when we look at very local scales.

It can therefore be said that our current knowledge and methods to understand climate change are insufficient to thoroughly understand the climate change impacts and its cascading effects on ecosystems and human populations (Klein et al., 2014). This is yet another reason why ILEK is extremely relevant to understand climate change and the reason why there has been increasing recognition of ILEK as an important tool in the climate change and sustainability discourse (Agrawal, 1995; Berks, 1999; Nyong et al., 2007; Klein et al., 2014; Makondo & Thomas, 2018; Sakapaji, 2021). In addition, this recognition has also been partly attributed to indigenous peoples and local communities' long-term interaction with their environment, and their economies and livelihoods are essentially based on the use and management of natural resources (Agrawal, 1995; Berks, 1999; Nyong et al., 2007; Klein et al., 2014). Indigenous and local people have also developed a very complex and detailed knowledge system that allows them to identify changes in their environment. Lastly, not only does ILEK allows indigenous and local people to identify the effects of climate change at the local scale, but it also allows them to derive interpretations of connections between different elements that are relevant to understanding changes in climate (Klein et al., 2014). As already pointed out, in recent years, there has been increasing support from the scientific community for the integration of ILEK into the climate change and sustainability discourse. The growing interest from the scientific community in indigenous and local ecological knowledge to understanding climate change can be well illustrated when we look at the number of publications on the topic in the last two decades or so, especially in regions such as Asia, West and East Africa, Canada and the Himalayas (Nyong et al., 2007; Marin 2010; Anik & Khan, 2012; Klein et al., 2014; Pandey et al., 2017; Makondo & Thomas, 2018).

However, despite this huge support and recognition of ILEK, many of the mechanisms or solutions for adapting to and combating the projected climate change impacts have been solely or primarily based on scientific knowledge, ignoring ILEK, and have primarily focused on mitigation (reducing, lessening, and possibly stabilizing the impacts of GHG emissions trapped in the atmosphere) (Nyong et al., 2007; Makondo & Thomas, 2018; Sakapaji, 2021). It is worth emphasizing that for more than a half-century, ILEK has been marginalized and ignored in mainstream literature, developmental policy formation, implementation, sustainability, and climate change discourse (Nyong et al., 2007; Makondo & Thomas, 2018). This is also due in part to ILEK's perceived irrelevance and a lack of knowledge of the possibilities that ILEK can provide for both climate change adaptation and sustainable development (Ngulube, 2002; Nyong et al., 2007; Anik and Khan, 2012; Makondo and Thomas, 2018; Sakapaji, 2021). Furthermore, several other academics and experts have voiced worry about how well ILEK can handle the rising pressures of a changing climate, particularly the unexpected character of recent climate change catastrophic occurrences (Cox 2000; Kameda and Nakanishi 2002; Turner and Clifton 2009; Valdivia et al., 2010; Naess, 2013). This has called into question the legitimacy and efficacy of ILEK in preserving and defending the lives and livelihood of people. Furthermore, other researchers have expressed grave worry about indigenous or ILEK's capacity to adjust to an increasingly random and unpredictable shift in weather patterns, which they feel will significantly impair indigenous and local peoples' ecological knowhow to adapt and nurture resilience (Turner and Clifton 2009, Valdivia et al. 2010), and Naess, 2013). This worry has resulted in a focus on more scientifically focused processes or remedies (mitigation options) to combat climate change, especially in the last two to three decades.

However, despite the push for scientifically based solutions to mitigate the effects of climate change, the 2018 IPCC special report on the impacts of 1.5°C above pre-industrial levels has indicated that even if we stop GHG emissions, the harm has already been done, as sea level rise and global warming, in particular, will continue to rise over centuries due to the earth's inertia system (IPCC, 2018). As a result, there is an urgent need for adaptation mechanisms and solutions that may successfully minimize the vulnerability associated with climate change, and ILEK can play a significant role in accomplishing this aim. Furthermore, during the last decade, a rising number of policymakers, researchers, and other stakeholders have forcefully advocated for the combination of mitigation and adaptation measures in the fight against climate change (Maxwell & Mitchel, 2010; Harmeling, 2011; BCAS & CDKN, 2012; Hagemann et al. 2012; Sakapaji, 2021). Nevertheless, recent studies have shown that while the integration of the two strategies of mitigation and adaptation might seem a viable option in the fight against climate change, the implementation process has proved difficult in many developing countries (Ayers & Kaur, 2010; Blackford et al. 2011; BCAS & CDKN, 2012; Sakapaji; 2018, 2021). Research studies on the effectiveness of integrating climate change strategies of mitigation and adaptation, particularly in Bangladesh, have shown that it is not easy for developing countries to successfully adopt the integration strategy, particularly in the agriculture sector (BCAS and CDKN, 2012; Sakapaji, 2021). Furthermore, these alien adaptation and mitigation mechanisms have been primarily associated with scientific knowledge and know-how, high implementation costs, and lengthy processes; procedures associated with the acquisition of funds for the same have focused more on scientific mitigation means rather than adaptation (Nyong et al., 2007; BCAS & CDKN, 2012; Anik & Khan, 2012; Sakapaji, 2018). Some studies have also revealed a persistent paucity of climate money to fund various scientific efforts or projects for climate change mitigation and adaptation, notably in many underdeveloped countries (BCAS and CDKN, 2012; Pingali, 2012; Sakapaji, 2021). Thus, where financing constraints prevent scientific investigations from progressing, ILEK practices emerge to cover the gaps. This is why many scholars are now pushing for ILEK and the possible integration with scientific knowledge because its locally tailored, cost-effective, and community-owned. It is also believed that ILEK can be relevant in addressing the effects of climate change within a certain threshold and contribute to improving the resilience and adaptability capacity of many rural, local, and indigenous people across the globe, particularly where this knowledge is integrated with science (Nyong et al., 2007; Moyo, 2010; Nakashima et al., 2012; Klein et al., 2014; Anik & Khan, 2012; Makondo & Thomas, 2018; Donatti et al., 2019; Sakapaji 2021;).

From this perspective, it is possible to assert that, despite the fact that ILEK has not been given the necessary platform as an invaluable and relevant source of knowledge, it can still be a relevant source of knowledge in the climate change adaptation, resilience-building and sustainability discourse, especially when integrated with scientific knowledge (Berkes, Colding, & Folk 2000; Nyong et al., 2007; Berkes, 2012; Klein et al 2014; Makondo & Thomas, 2018; Kerr et al., 2018; Sakapaji, 2021). It is also vital to emphasize and acknowledged that ILEK alone will not be sufficient to adapt to new climate scenarios or situations that are outside the scope of those previously encountered and that new strategies will be required. This is because the incremental adaptations through ILEK that were also previously installed or implemented may now be insufficient as the vulnerabilities and dangers of temperature fluctuation have risen, necessitating the implementation or transformation adaptation (far bigger and more expensive adaptations). Nevertheless, even with these transformation adaptation techniques, having knowledge of the local ecological system through ILEK will still be imperative if these initiatives are to enhance the adaptability capacity and resilience of people to climate change (Adesina & Elasha, 2007; Moyo, 2010; Nakashima et al., 2012; Awuor, 2013; Klein et al., 2014; Makondo & Thomas, 2018; Kerr et al., 2018; Bardati, 2019; Sakapaji, 2021). It is for this reason that this research paper is focused and pushing for the integration of ILEK and scientific knowledge through the climate adaptation, resilience building, and sustainability (CARS) model, which will be discussed shortly after the discussion of the synergies that exist between scientific knowledge and ILEK.

5. Synergies Between ILEK and Scientific knowledge

As previously indicated, there has been a growth in academic and scientific interest in ILEK, resulting in the establishment of a new reciprocal relationship between scientific knowledge and ILEK, which is strengthening the connection between the two bodies of knowledge through information sharing. However, there is still a long way to go until the two sets of knowledge (Scientific and ILEK) are fully integrated for successful natural resource management and policy creation (Berkes F., 1999; Nyong et al., 2007; Audefroy & Sanchez, 2017; Kohsaka & Rogel, 2019). To fully define and understand the two knowledge systems, we will seek to define them. Scientific knowledge is a knowledge system that has evolved and been solidified during the last 150 years. This knowledge is founded on a system of rules known as the scientific method, which was established to help us comprehend and interact with our natural world. The scientific method and procedure begin with making an observation, followed by creating predictions or hypotheses based on these observations and then testing these hypotheses. And this creates communicative knowledge with a minimal bilateral contribution to our knowledge advancement. Local ecological knowledge, also known as traditional knowledge or indigenous knowledge systems, refers to the knowledge practices and beliefs maintained by indigenous peoples and local communities across the world (Berks, 1999; Nakashima et al.,2012; Audefroy & Sanchez, 2017). The acquisition of this knowledge is a result of their long-term contact with their surroundings. Because of the diverse natures of these two knowledge systems, they also have very different features, and the following section highlights some of the most significant differences between these knowledge systems (Alexander et al., 2011; Berks, 1999; Audefroy & Sanchez, 2017).

While ILEK is seen as a holistic or integrated knowledge system, scientific knowledge is more reductionist; it chops reality into smaller, more examinable pieces. Furthermore, ILEK includes beliefs in certain symbolic dimensions, and it contains both physical and metaphysical parts of the universe. Scientific knowledge, contrastingly, is mostly restricted to observations in the physical world. These various knowledge systems are also somewhat varied in terms of how they are delivered. ILEK is based on oral transmission and frequently incorporates storytelling, whereas scientific information is mostly recorded and delivered in writing form (Alexander et al., 2011; Berks, Klein et al., 2014; 1999; Audefroy & Sanchez, 2017). ILEK is also particularly place-based and context-specific; therefore, it is appropriate to the reality and situation in which these local inhabitants live. While scientific information is at hand, it seeks to comprehend bigger-scale patterns or to discover universal truths. So, they're looking at small-scale trends to see if they can upscale this to higher sizes. Indigenous and Local ecological knowledge is predominantly empirical. It was formed through experiential learning, whereas scientific knowledge is based on far more controlled experiments. Finally, ILEK is heavily focused on the practical uses of this information. While scientific knowledge strives to comprehend the systems that underpin the patterns found in nature (Alexander et al., 2011; Berks, 1999; Audefroy & Sanchez, 2017).

Despite these distinctions, there are some similarities between these knowledge systems. As for their organizing principles, both of these knowledge systems acknowledge that the cosmos is connected and that there are links between living and nonliving phenomena that mutually impact each other. Furthermore, while they are both solid and well-rooted systems of knowledge, they are both dynamic, which means they are susceptible to continual change throughout time (Alexander et al., 2011; Berks, 1999; Audefroy & Sanchez, 2017). Furthermore, both of these knowledge systems share a set of values such as honesty, inquisitiveness, and tenacity. As a result, they are both honest and valid attempts to comprehend processes and occurrences in our universe. Although they utilize quite distinct methodologies and approaches, they share some abilities and procedures since they both rely on the detection of patterns in the natural world (Agrawal, 1995). In empirical observation in natural situations, we may draw conclusions and make predictions about the future. Finally, the aims of both of these knowledge systems, local ecological knowledge and scientific knowledge, are similar. They want to be able to comprehend patterns in plants, animals, and ecosystems, as well as the qualities of things and materials, so that we may draw conclusions and make predictions about what will happen in the future (Alexander et al., 2011; Berks, 1999; Klein et al.,2014; Audefroy & Sanchez, 2017)

Thus, despite their diversity, the two knowledge systems share some common ground. It is today becoming increasingly clear that efforts to encourage cross-pollination across different systems can really improve our knowledge of complicated phenomena and complex systems. One of these approaches is called the multiple evidence-based approach, which is based on the premise that different knowledge systems can generate useful and valid knowledge (Tengo et al., 2014). And by exploring the complementarity between these knowledge systems, we can have a more holistic (enriched picture) and integrated perception of complex phenomena such as climate change and sustainable development (Tengo et al., 2014). To sum it up, the multiple evidence-based approach does not only explore where the different knowledge systems converge. But it actually explores all of the synergies, complementarities, and contradictions between these knowledge systems, aiming to build this enriched picture. The idea is that by building this enriched picture, we can have an enhanced understanding of environmental conditions of environmental changes and also cause the relationships and social-ecological systems (Tengo et al., 2014). And this is important because it can widen the scope, depth, or value of a given assessment of a given complex problem. And it can also be the starting point for a future knowledge generation, even within knowledge systems, but also across knowledge systems either through cross-fertilization or co-production of knowledge (Tengo et al., 2014). Also, this enriched picture can provide the basis for identifying desirable future trajectories to the future.

It can furthermore be pointed out that the multiple evidence-based approach does more than only investigate where diverse knowledge systems converge. However, it genuinely investigates all of the synergies, complementarities, and tensions between various knowledge systems in order to construct this expanded picture (Tengo et al., 2014). The notion is that by constructing this fuller image, we may gain a better knowledge of environmental circumstances, as well as the causes of interactions and social-ecological systems. This is significant because it can broaden the breadth, depth, or value of a particular assessment of a difficult situation. It can also serve as a springboard for future knowledge development, both inside and between knowledge systems, through knowledge cross-pollination or co-production. This enriched image can also be used to suggest ideal future trajectories (Tengo et al., 2014). Today, there are multiple cases in the academic literature where this cross-fertilization of knowledge systems has resulted in a better understanding of complicated phenomena.

The first case that shows the multiple evidenced-based approach in play is research undertaken by Tomaselli et al. (2018), where they used qualitative research methods and participatory epidemiology techniques to document the local knowledge from resource users of the community of Iqaluktutiaq (Nunavut, Canada) to assess the health and population status and trends for muskoxen and caribou in the area. In their final analysis, they demonstrated that local knowledge may give highly unique and useful information on the health and dynamics of these communities, which apparently science could not do (Tomeselli et al., 2018). Thus, this case has demonstrated that local ecological information can be a valuable resource in understanding local species and designing successful management methods for these animal populations. Another example is the work of Klein et al. (2014), who conducted research on herders on the Tibetan Plateau, with a focus on local ecological knowledge and environmental change in this location. It was found that Tibetans who actively herd on a daily basis and are located at higher elevations were most likely to notice changes in seasonality, reported as a later start of summer and green-up and as delayed and shortened livestock milking season. This has fueled an ongoing scientific discussion in which various meteorological data and scientific information on the region pointed to seemingly contradictory outcomes. As an example, in this scenario, using the local expertise of herders who have historically occupied and managed this territory would be the best thing to do to fill up the gaps and the inconsistency that has been exhibited by scientific methodologies and tools such as the metrological stations (Klein et al., 2014). This study clearly demonstrates that local ecological knowledge can reveal counter-intuitive outcomes and help resolve apparent contradictions through its strengths in situations of high variability, its ability to integrate over a range of variables and time scales, and its operation outside of western scientific logic (Klein et al., 2014). This further contributes to a more complete understanding of the complex system that is the influence of climate change on these high-altitude locations of the Tibetan Plateau. It can thus be said that future climate change research and climate adaptation policy-making will benefit a lot from rigorous, contextual dialogue with observations, concentrating on observable biophysical phenomena impacted by temperature and precipitation and crucial to livelihoods.

6. The Model of Climate Adaptation, Resilience-building, and Sustainability (CARS) Model

The formulation of a new model (CARS model) for climate adaptation, resilience building, and sustainability is anchored on a number of factors, including the failures of climate-compatible development (CCD), a model that is built on the notion that development must be tailored toward minimizing the harm caused by climate impacts while maximizing the many human development opportunities presented by a low emission, more resilient, future' (Mitchell and Maxwell, 2010). CCD seeks to tackle issues to do with climate adaptation, mitigation, and development simultaneously. This conceptual model of CCD advances the notion that mitigation, adaptation, and development strategies can mutually coexist with each other to generate 'triple wins', which can support lower emissions, build resilience, and promote development simultaneously (Blackford et al., 2011). This conceptual model solely emphasizes creating synergies when the three strategies, which are mitigation, adaptation, and development, are integrated. CCD was, in its initial creation, seen as a useful model to improve cost-effectiveness given the limited financial resources currently available to balance adaptation, mitigation, and development demands (Klein et al., 2007; Ayers and Huq, 2009). However, this approach has proven difficult to implement in many developing countries such as Zambia and Bangladesh, where access to the funds meant for the implementation of the so-called CCD projects or programs has proven limited, scarce, and uncoordinated (BCAS, 2012; Sakapaji, 2018). The fact that many of the projects and mechanisms championed by the CCD model require huge sums of financial assistance from the international donor community, governments, NGOs, and the private sector makes it an incapable model of addressing the immediate climate change challenges the many developing countries are facing especially those in rural and remote communities. In addition, the success of a CCD project requires a multi-stakeholder, multi-sector, and the development of partnership between and among ministries in working together, something that is and has proven extremely difficult to achieve in many developing countries. Besides, the notion of inter-ministry and inter-sectors working together to achieve the tenets of CCD is very alien or rather nonexistent in most third-world countries (Mallick et al., 2012; BCAS, 2012; Sakapaji, 2018). Furthermore, CCD as a model for policymakers in developing countries, faces a lot of challenges, especially with interest groups such as fossil fuels companies and investors, making it even more impossible for its intended aims to be achieved (Fegenhauer, 2009; Sakapaji, 2018). For example, individuals and companies that represent a stake of shares in the national economy through their direct or indirect dealings in highly polluting industries such as fossil fuels and coal may resist change to clean energy initiatives as they feel that a sharp shift to clean energy will mean a defeat and a loss on their part making it impossible for the implementation of CCD programs and projects in such environments as the interest groups play a vital role in the running of the government. Such opposition has already been witnessed in both developed and developing countries (Sakapaji, 2018). In some countries, indigenous and local people have also refused to give way to CCD initiatives or programs due to some cultural or religious values placed on sites where a CCD program or project is earmarked (Sakapaji, 2018). Such cases are plenty across the developing world, where value is so much placed on religious and local cultural locations.

Figure: 5 The **Model of Climate-Compatible Development (CCD)**
Source: (Mitchell and Maxwell, 2010)

The lack of government capacity in most developing countries to respond to and implement CCD initiatives or programs is yet another cause for the formulation of a more useful climate model that can enhance adaptation, resilience, and sustainability, especially in the agriculture sector. In many developing countries, there is a common problem of lack of or limited educated manpower to be able to capably handle the issues associated with the implementation of CCD programs (BCAS, 2012, Mallick, 2012). CCD requires that all parties involved are fully aware of the surrounding issues and concerns, particularly those to do with the tradeoffs which have proved difficult to implement in many developing countries. Furthermore, in many developing countries, particularly in southern Africa and southeast and south Asia, where the researcher has first-hand information, the lack of educated human resources and capacity for both technology and infrastructure has proven even harder to successfully implement CCD programs. Lastly, the trade-off involved in the implementation of CCD projects has the potential to ignite tensions between groups of people within a given community if care is not taken in communicating the evidence and the actual expected outcomes of the project (Fegenhauer, 2009).

It is from this background that this research paper advances the formulation of a new climate model other than CCD for policymakers in developing countries that can have the potential to successfully tackle the many climate change challenges in agriculture that pose a threat to the existence and livelihoods of the many poor people in these countries. Thus, the model of CCD has influenced the formulation of a new model that we are calling the climate adaptation, resilience, and sustainability (CARS) model in agriculture, as can be seen in figure 6. This model is anchored on the experiences, knowledge, and practices of the indigenous and local people and seeks to integrate such knowledge (ILEK) with scientific knowledge to effectively tackle climate change catastrophes at the local level and see to it that adaptation, resilience building, and development that is sustainable takes root.

The formulation of the CARS model is hinged on the premise that for any meaningful adaptation, resilience building, and development that is sustainable to take place, the understanding, inclusion, and integration of ILEK with scientific knowledge is crucial. It must be acknowledged that achieving sustainable development, particularly in developing countries, can be a difficult task, especially in this era of a changing and unpredictable climate. Therefore, it is imperative to formulate effective policies that see to it that GCC impacts are minimized or tackled through the integration of ILEK and scientific knowledge with a focus on enhancing sustainability and the resilience of the many vulnerable, poor people in developing countries. In this vein, policies meant to enhance adaptation and resilience building in agriculture must be meant to advance sustainable development through low-carbon development (LCD) and climate resilience development (IPCC, 2022). The formulation and successful enactment and implementation of policies that incorporate elements of ILEK with science coupled with Climate resilience development (CRD) and Low carbon development (LCD) are believed to be a cornerstone in the CARS model. Key to note is that the understanding and successful incorporation of effective elements of ILEK with science into policy that leads to effective adaptation, resilience building, and sustainable development is the bedrock of the CARS model.

6.1 The Model of Climate Adaptation, Resilience-Building, and Sustainability (CARS) in Agriculture for Developing Countries

The climate adaptation, resilience, and sustainability (CARS) model requires that the following five steps are followed to achieve and enhance adaptation, resilience, and sustainability, specifically in the agriculture sector.

1. Engaging the local or indigenous people themselves in identifying pressing climate change-related issues affecting them within their environment.
2. Rigorous research in identifying effective ILEK-based practices being utilized by the local or indigenous people for adaptation and resilience building.
3. Application of scientific knowledge to expand and build on the identified effective ILEK practices for an effective adaptation that ensures that resilience building and sustainable development are achieved and maintained in this era of a changing climate.

The above first three stages in the 'CARS' model are very critical in enhancing effective adaptation, resilience-building & sustainability efforts in the face of a Changing Climate. The last two stages in the CARS model involve governments in developing countries enacting and formulating developmental policies that are sustainable through climate-resilient development (CRD) and low-carbon development (LCD), which are the last two stages in the CARS model.

4. **Low Carbon Development (LCD):** This is a development that does not harm our environment, e.g. in agriculture, a shift from chemical fertilizer use to organic fertilizer or sustainable farming practices such as agroforestry and crop rotation.

5. **Climate Resilience Development (CRD):** This is a development that can help us adapt and increase resilience in the face of a changing climate, e.g., the development of early maturing crops or drought-resistant crops in agriculture that can withstand the pressures emanating from climate change impacts.

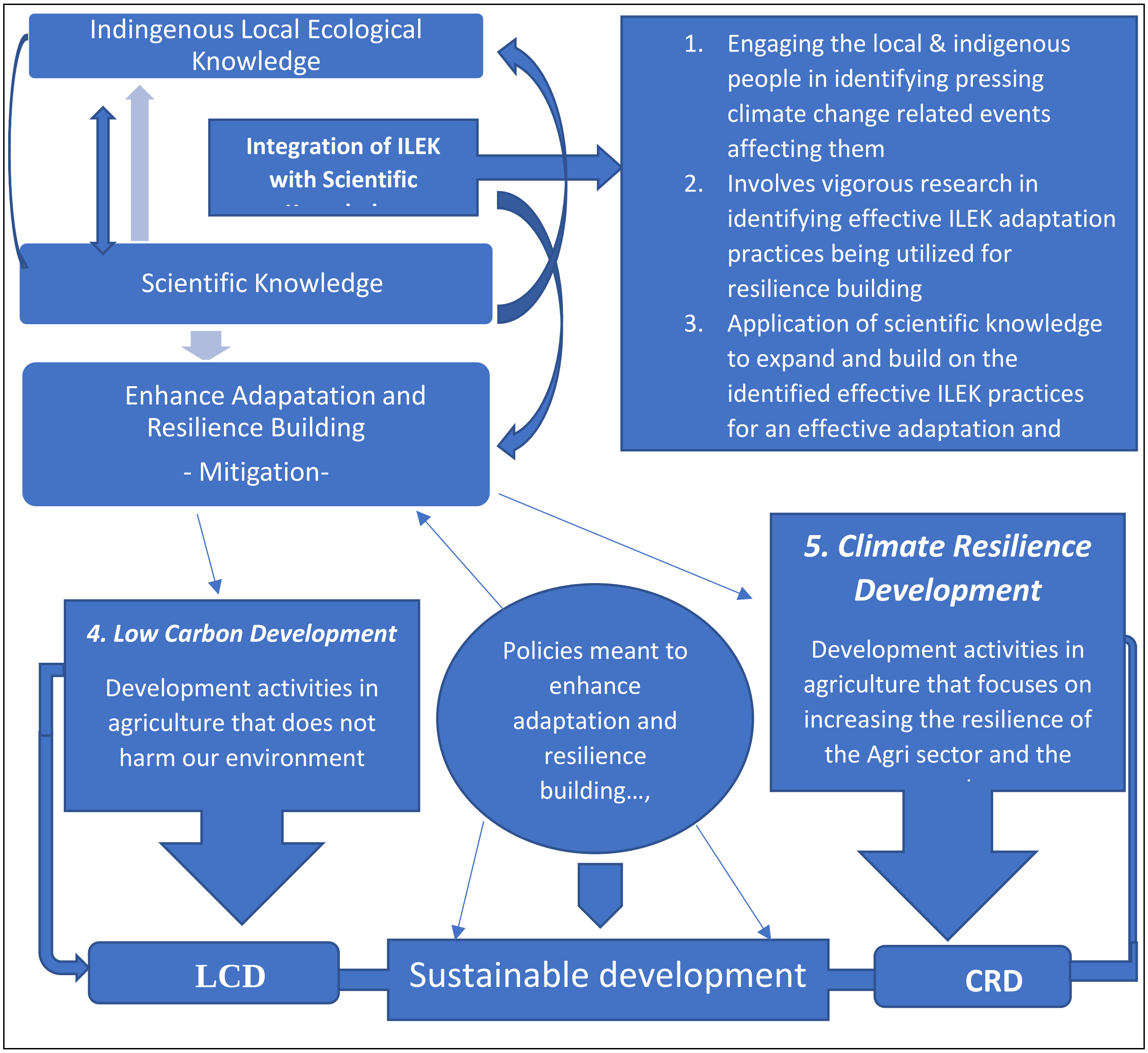

Figure: 6 The Model of Climate Adaptation, Resilience-Building, and Sustainability (CARS) in Agriculture for Developing Countries

As shown in the CARS model (figure: 6), there are two sustainable development pathways that policies must be aimed at in the agriculture sector, and these are Climate resilience development (CRD) and low carbon development (LCD). Climate resilience development (CRD) is a development that focuses on increasing the adaptation and resilience of people to impacts emanating from climate change (Blackford et al.,2011; Maxwell & Mitchell, 2010; Mallick et al., 2012). For example, in agriculture, climate resilience development could be the development of drought-resistant crops that can be grown in drought conditions brought about by climate change which in turn secures the food security of the people and that particular region. CRD centers on or rather focuses on the local and national scales and sometimes regional and can even have global implications. For example, if a country like Zambia or Bangladesh improves and increases its resilience to current and future risks and impacts emanating from climate change, such as droughts and floods, and puts emphasis on incorporating responses to climate change in its development strategy, there is likely going to be a risk reduction from climate-induced migration to cities or neighboring countries which will entail that the country and the whole region will be able to experience stability in the long run (Hagemann et al., 2012). On the other hand, low carbon development (LCD) involves the enactment and successful implementation of developmental policies by developing countries that do not harm our environment (Blackford et al.,2011; Maxwell & Mitchell, 2010; Mallick et al., 2012). Such development in the agriculture sector could involve a shift from the reliance on chemical fertilizers to organic fertilizers. While mitigation has often been viewed as a means to reduce emissions in developed countries in the far future, low carbon development

(LCD) addresses climate change issues relating to both developed and developing countries in the short and medium future (Maxwell & Mitchell, 2010). An example of this can be the need to mitigate emissions in the EU and the need to introduce widespread electricity using renewable resources in Africa. Climate-resilient development brings into place the development sphere and tackles issues that are both relevant to developed and developing nations. This is true in that many developed countries like the UK, which has now embarked on increasing the resilience of their water sector because of the increased droughts recorded in various parts of the country (Hagemann et al., 2012; Sakapaji, 2018). Low carbon development centers on a local, national, and global scale and benefits and functions cross-sectoral. Because of its development focus, low carbon development outcomes are more difficult to measure than emission reduction. Low carbon development's actual focus is on emitters who have development needs and agendas in mind. These can be both developed and developing nations. LCD approach is very broad in comparison to mitigation as it seeks to tackle both mitigation and development efforts. LCD brings out benefits for the long-term, medium-term, and in some instances, even for the short-term ones. For example, the introduction of renewable energy for the vulnerable and poor populations in developing countries will mean that emissions can be avoided in the long term in comparison to using fossil fuels, and for the short term and medium term, it would mean that the poor and the vulnerable populations of the poorest regions will have access to clean energy which will, in turn, improve their lifestyles or rather living conditions and which justifies the conditions set for development that are sustainable to take place (Hagemann et al., 2012; Sakapaji, 2018).

The formulated new model (CARS model) in this research paper has opened up a new paradigm that seeks to accommodate the voices and experiences of indigenous and local people. The CARS model has not only brought in a contemporary way of thinking and tackling emerging and future societal problems associated with climate change and development but has also bridged the knowledge gap that has been existing on the effectiveness of ILEK in addressing developmental and environmental problems of our time and those of the future. Furthermore, the CARS model provides the initial basis for enhancing innovative and effective ILEK-based practices through integration with scientific knowledge for effective adaptation, resilience building, and sustainability in agriculture in developing countries, something that is new and innovative. Besides, because of its emphasis on the collaboration and integration of ILEK and scientific knowledge, the CARS model has brought in a contemporary way of bridging the knowledge gap that has existed for decades between ILEK and scientific knowledge in addressing the human challenges of today and those of the future. Furthermore, the CARS model has the potential to be utilized in other developmental issues affecting developing countries as it is borne out of the notion and belief that it is the understanding of the local people's ecological system through their knowledge and experiences and integrating these with scientific knowledge that any meaningful climate adaptation or developmental agenda, especially at the local, national and regional levels would be successful. Furthermore, the conclusive findings from this study indicate and imply that ILEK must be treated with utmost importance just as Scientific knowledge as it has proven to help tackle past and emerging challenges faced by the local and indigenous people across the globe within a certain threshold. As such, policymakers in developing countries have the duty to enact, fund, and advance climate and developmental policies that encompasses the voices and experiences of the local and indigenous people. This is one sure way to effectively address today's and future climate and sustainability challenges. Lastly, the CARS model, as presented in this paper, is unique for developing countries as it is more locally oriented and ecologically centered and brings a sense of ownership in decision-making to the local and indigenous people in rural and remote places across the developing world.

It is today believed by many researchers that sustainable development goals cannot be fully met or attained if GCC impacts are not addressed, particularly in the agriculture sector in developing countries. This is the main reason why this research model (CARS Model) puts more emphasis on the integration of ILEK and scientific knowledge because only if the two are fully integrated at the local level can we be able to open up avenues for achieving the widely discussed sustainable development goals. Furthermore, it is hoped that by using this new model that seeks to link or integrate ILEK with scientific knowledge and possible replication of the acquired knowledge to other regions, a sustainable agriculture sector for all will be inevitable. It is the belief and understanding of the researchers that a successful implementation of the 'CARS' model, especially in agriculture in developing countries, can effectively enhance the adaptability capacity and resilience building of the many vulnerable and poor rural local communities across the developing world.

Many studies have today shown that the integration of ILEK and scientific knowledge approaches in planning, designing, and implementing policies on climate change and sustainable development has the potential to increase the adaptability capacity, resilience building, and sustainability efforts of any sector (Nyong et al.,2007; Berks, 2009; Thaman et al.,2013; Karki et al., 2017; Makondo & Thomas, 2018; Sakapaji, 2021). Thus, the integration of the two knowledge systems (ILEK and Science) requires that all of their unique and respective aspects are reconciled, and this can pave the way for a strong knowledge base that can effectively address emerging and future developmental and climate-related challenges (Nyong et al.,2007; Berks, 2009; Thaman et al.,2013, Klein et al. 2014; Makondo & Thomas, 2018; Sakapaji, 2021). According to Srinivasan (2004), the successful integration of these knowledge systems (ILEK and Scientific Knowledge) can have the following implications on the ground:

- an equitable, participatory approach

- knowledge exchanges
- collaborative processes
- mutually rewarding learning experiences
- problem-focused, demand-driven, and project- or pilot-based approaches
- building the capacity of all stakeholders
- public awareness
- a culture of continuity and sustainability
- periodic participatory assessment of targets and how well they have been achieved
- And outreach strategies, knowledge exchanges, and adaptation of technologies

It is from this background that the CARS model is inclined on the premise that for any meaningful development that is sustainable to take place from the local to national and from the regional to the global scales in this era of GCC, there must be policies in place that ensure that there is an equitable, participatory process that allows for knowledge sharing and experiences from those affected (local indigenous and rural people) and those spearheading policy formulation and implementation (government leaders & other stakeholders). The researcher believes that what developing countries need in a changing climate are policies that focus more on adaptation and resilience-building as the earth continues to warm, and climate change impacts will continue to increase in magnitude and intensity. To achieve this, developing countries must invest in research that ensures that the integration of ILEK with scientific knowledge is enhanced, as it is the cheapest way to a meaningful and effective adaptation and resilience-building in the face of GCC. Furthermore, the CARS model supports the idea that adaptation and resilience mechanisms to climate change through the integration of effective ILEK with Scientific knowledge should give way for the formulation of sustainable development policies that enhances the adaptation, mitigation, and resilience capacities of a people.

From the many ILEK case studies discussed in this research paper, it can be concluded that ILEK is very important, especially in this era where the sustainability of our environment is of utmost importance. As seen from the case studies discussed in this paper, ILEK has proved to be very much embedded in the functioning of many rural and indigenous communities across the globe. As such, the incorporation, collaboration integration, and advancement of such knowledge through the new and contemporary CARS model are crucial and key if we are to attain sustainability, especially in the agriculture sector. Furthermore, it must be noted that development that is sustainable cannot take place if the necessities such as water and food security are not achieved. With GCC, the sustainable development (SD) goals, especially goals number 1 and 2, which both seek to eradicate poverty and hunger, respectively, cannot be met if governments do not put in place policies that enhance people's adaptability capacity and resilience in the face of GCC. It must furthermore be noted that the CARS model is of the idea that if you cannot secure the immediate needs of the vulnerable poor people, which includes food and water, you cannot expect a development that is sustainable to take place. Securing these immediate needs requires that the local people are engaged in identifying the most pressing GCC challenges of their time. By identifying these pressing issues emanating from GCC through rigorous research and documenting the effective ILEK-based coping mechanisms or strategies and integrating them or building on them with scientific knowledge, an effective adaptation and resilience of the locals can surely be attained.

Developing countries are known to be reservoirs of vast ILEK practices that can effectively tackle the GCC challenges of our time (Berks et al., 2000; Nyong et al., 2007; Nakashima et al., 2012; Klein et al., 2014; Makondo & Thomas, 2018; Sakapaji, 2021). Thus, rigorous research on ILEK practices and the ultimate integration of this knowledge and practices with scientific knowledge is key and crucial. Achieving this will surely pave the way for sustainable developmental policies in the short, medium, and long term. It is the understanding of the researcher that if put into use by developing countries, the climate adaptation, resilience, and sustainability (CARS) model can successfully address many of the challenges emanating from a changing climate. The researcher, furthermore, believes and understands that sustainable development goals cannot be fully attained, especially in developing countries, if GCC impacts are not addressed, particularly in the agriculture sector. In this vein, the adoption and successful usage of this new model (CARS Model) in policy formulation by governments in developing countries will help ease climate change challenges that the vulnerable and poor rural communities are experiencing today and those of the future, especially in the agriculture sector.

7. Conclusion

This research paper sought to advance the climate adaptation, resilience-building, and sustainability (CARS) model in agriculture in developing countries which hinges on the integration of indigenous and local ecological knowledge (ILEK) and Scientific Knowledge. This paper adopted a desktop research methodology which was based on a systematic literature review of already published reports, statistical and graphical analysis of climate change data, indigenous and local ecological knowledge, and previous original research data surveys that the researcher and other researchers have carried out on climate change, agriculture, and indigenous and local ecological knowledge. The ultimate goal of this research study was to give policymakers and other stakeholders in agriculture, development, and climate change discourse a new paradigm or model where the acknowledgment, inclusion, and integration of vital elements of ILEK with scientific knowledge is prioritized, especially in responding to the challenges brought about by a changing climate. From the systematic literature review highlighted in this paper, results indicate that climate change is and will continue to have devastating impacts on the agriculture sector, and at the same time, the agriculture sector itself has and will continue to play a significant role in increasing the greenhouse gas (GHG) emissions. This duo relationship between climate change and agriculture is partly the cause of the current climate challenges we are facing today hence the need to find sustainable solutions as enshrined in the agenda 2030 that can see to it that emissions from the agriculture sector are cabbed, and a sustainable and resilient agriculture sector takes root. Despite some opposing views highlighting the ineffectiveness of ILEK in addressing current and future climate change-related catastrophes, and sustainability challenges, the findings of this research study through the new CARS model have indicated and demonstrated the value, relevance and role that ILEK can play in enhancing the adaptability, resilience, and sustainability capacity of a people to global climate change (GCC) impacts in agriculture in developing countries especially when integrated with scientific knowledge. The findings of this research paper also add value to the already existing research literature on how invaluable and effective some elements of ILEK can be in both the sustainability and climate change discourse. More importantly, the findings of this research paper have given policymakers, particularly in developing countries, a contemporary way of tackling the climate and sustainability challenges of today and those of the future through the new CARS model and its notion of integrating ILEK and scientific knowledge. However, its key to point out that since this new theoretical framework model (CARS model) has not yet been implemented anywhere on the globe, there is a need for future research to focus more on proving the effectiveness of this model in addressing what it claims to address in agriculture (climate change impacts and sustainability challenges).

Acknowledgment: Sincere appreciations go to Professor John Joseph Puthenkalam, who played a huge role in the guidance and formulation of the new theoretical model of climate adaptation, resilience-building, and sustainability (CARS Model), which is the pillar of this research paper.

Funding: This research received no external funding.
Conflicts of Interest: The authors declare no conflict of interest.
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Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors, and the reviewers.

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