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Addressing Greenhouse Gas Intensive Agricultural Trajectories in Developing Nations: Exploring Better Approaches for Achieving Sustainable and Low-Emission Agricultural Practices

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Abstract

The escalating frequency and severity of extreme weather events, exacerbated by global temperature rise and rapid climate change, pose significant challenges, particularly for developing countries. This paper aims to explore strategies for developing nations to steer clear of greenhouse gas (GHG) intensive agricultural practices, given the pressing need to increase food production for a growing global population. Analyzing established research, case studies, and policy frameworks, the study identifies four prevalent global agricultural systems: Green Revolution (GR), Climate Smart Agriculture (CSA), Agroecology, and Regenerative Agriculture (RA). The focus is on how these systems can be adapted to address climate change impacts while concurrently curbing GHG emissions. The research delves into the opportunities, challenges, and barriers associated with implementing these agricultural approaches in developing countries. Additionally, it compares the suitability of the four strategies for fostering climate-friendly agricultural systems in these regions. Emphasizing a qualitative approach, the paper acknowledges a limitation in the absence of significant quantitative discussions. Nonetheless, it underscores the necessity for developing nations to adopt sustainable agricultural paths, offering examples of approaches already embraced for mitigating environmental impact. This study contributes valuable insights to the global discourse on sustainable agriculture and climate resilience in the context of developing countries.

Key words: Climate Change, Developing Countries, GHG emission, Green Revolution (GR), Climate Smart Agriculture (CSA), Agroecology, Regenerative Agriculture (RA).

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Introduction

The frequency, intensity, length, and severity of severe climate events have grown dramatically as a consequence of global temperature rise and fast climate change (Thornton et al., 2014; Pörtneret al., 2022). Floods, hurricanes, and heatwaves, for example, have caused 91% of all natural disasters in the previous ten years, with the frequency of such disasters rising by more than 35% throughout the 1990s. Catastrophic disasters have killed approximately 410,000 individuals in thelast ten years, the vast majority of whom died in low- and lower-middle-income countries (IFRC, 2020). If the current rate of global temperature increase is not reduced by 2% as agreed in Paris Agreement, and greenhouse gases (GHG) are not reduced to levels that trees, soil, and oceans cannaturally absorb, more terrible climate change disasters will occur on Earth (Satoh et al., 2022; Schleussner et al., 2022). On the other side, the world's population is rapidly increasing, rising from 2 billion in 1950 to more than 8 billion in 2022 (McLean, 2022). As a consequence, agricultural production must be considerably increased to supply food and nourishment for this rising population which made agriculture one of the greatest contributors to GHG. Agriculture, forestry, and other land use account for 24% of total global greenhouse gas emissions, according to the IPCC (IPCC, 2014). As a consequence, increasing agricultural productivity on the one handand reducing agricultural emissions on the other have become a global concern (Pörtner, 2022).The challenge is even greater for developing countries because almost 80% of the world's people live in underdeveloped and developing countries and regions, and many of these countries do nothave enough resources, infrastructure and technical facilities to reduce emissions from agricultureby ensuring their food security (Satoh et al., 2022). However, these nations must identify feasiblesolutions that promote sustainable agricultural paths while limiting their impact to global warmingand climate change.

This paper aims to explore the strategies and approaches that developing countries can adopt to best avoid greenhouse gas intensive agricultural practices. By examining existing research, case studies, and policy frameworks, this paper found four agricultural systems namely Green Revolution (GR), Climate Smart Agriculture (CSA), Agroecology and Regenerative Agriculture (RA) which are practiced globally. This paper will discuss how developing countries can adapt to climate change through these four methods of agricultural management and how they can reduce GHG emissions while continuing to increase production. In addition, this paper will also show theopportunities, challenges and barriers that developing countries face in implementing these four approaches. Furthermore, a comparison of which of these four strategies is most suited for climate-friendly agricultural systems in developing nations will be explored. Finally, several agricultural approaches that developing nations have already embraced for sustainable agriculture will be addressed as examples. Above all, since this research takes a qualitative approach, there is no significant quantitative discussion, which might be regarded as a shortcoming of this work.

METHODOLOGY

To write this paper, I have followed qualitative method purely. First, I have conducted an extensive review of existing academic literature, research papers, gray literature, and publications related to climate change impacts on agriculture, greenhouse gas emissions, and sustainable agricultural practices in developing countries. Second, I have summarized key findings and identified gaps in the literature regarding the strategies and approaches employed by developing countries to mitigate greenhouse gas-intensive agricultural practices. Afterwards, I have discussed some case studies from developing countries that have implemented the Green Revolution (GR), Climate Smart Agriculture (CSA), Agroecology, and Regenerative Agriculture (RA). Finally, I have analyzed these case studies to understand the contextual factors, challenges, and successes in adopting these agricultural systems highlighting the impact on greenhouse gas emissions and climate resilience.

GREENHOUSE GAS AND ITS IMPACTS ON CLIMATE CHANGE

Greenhouse gases (GHGs) are gases in the Earth's atmosphere that trap heat. They allow sunlight to enter the atmosphere freely but prevent some of the heat that the Earth would otherwise radiate back into space from escaping. This natural greenhouse effect is crucial for maintaining a habitable temperature on Earth. However, human activities, particularly the burning of fossil fuels and deforestation, have significantly increased the concentrations of certain greenhouse gases, leading to an enhanced greenhouse effect and contributing to climate change (Mikhaylov et al., 2020; Fant et al., 2016). The major greenhouse gases include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), fluorinated gases, and water vapor while water vapor is the most abundant greenhouse gas, its concentration is largely influenced by natural processes (Bruhwiler et al., 2021; Schneider et al., 2010). Human activities primarily drive the increased concentrations of carbon dioxide, methane, and nitrous oxide. The impacts of greenhouse gases on climate change are profound. As these gases accumulate in the atmosphere, they trap more heat, leading to a warming of the Earth's surface (Staniaszek et al., 2022; Zeebe et al., 2013). This warming is associated with a range of adverse effects, including **rising temperatures, melting ice, rising sea levels, extreme weather events, acidification, health risks and threats to agriculture (**Oreggioni et al., 2021**).** The following is an examination of the detrimental impacts of greenhouse gases on agriculture.

THE RELATIONSHIP BETWEEN AGRICULTURE AND GHG EMISSIONS

While agriculture provides food for about 8 billion people on Earth today, a study published in thejournal Nature in 2021 shows that the food production process for this huge population accounts for about 34% of anthropogenic GHG emissions (Crippa et al., 2021). Similarly, the IPCC's 5th Assessment Report reveals that agriculture, forestry, and other land uses account for 24% of worldwide GHG emissions. The following diagram will help us understand the above discussion.

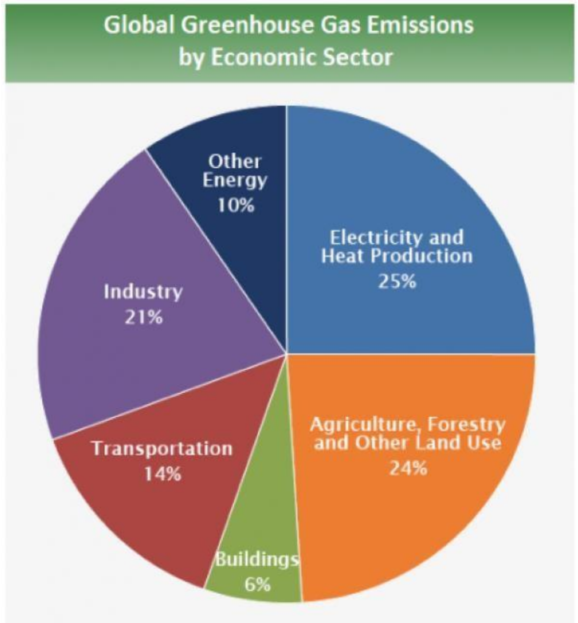

Figure 1shows the Global emissions by economic sector (IPCC, 2014).

At this stage we will discuss what types of GHG emissions releases from the agricultural sector and how and from what sources. The major sources of GHG emissions from agriculture are livestock farming, crop production, and land use change (Duxbury, 1994). One of the primary sources of greenhouse gas emissions in the agricultural sector is animal farming. About 32% of allagricultural emissions are caused by methane released during enteric fermentation in ruminant animals including cattle, sheep, and goats (UNEP, 2020). Methane and nitrous oxide (N2O) are released into the air during the breakdown of manure. GHG emissions are exacerbated by the cattleindustry's use of fossil fuels for transportation, heating, and cooling. Second, fertilizer usage and rice paddies produce GHGs (Rojas-Downing et al., 2017). Nitrogen fertilizers boost agricultural yields but it emits N2O which is a powerful GHG with 298 times the warming potential of carbondioxide (Smith et al., 2014). Thirdly, deforestation which is a result of the conversion of forestland into agricultural land releases carbon dioxide into the atmosphere. Natural ecosystems absorb lesscarbon as forest cover decreases. Land-use change also results in emissions of other GHGs, such as methane and N2O. Lastly, CO2 emissions are caused by the use of energy in agriculture. This includes running machines, watering systems, and processing centers (Molotoks et al., 2021).

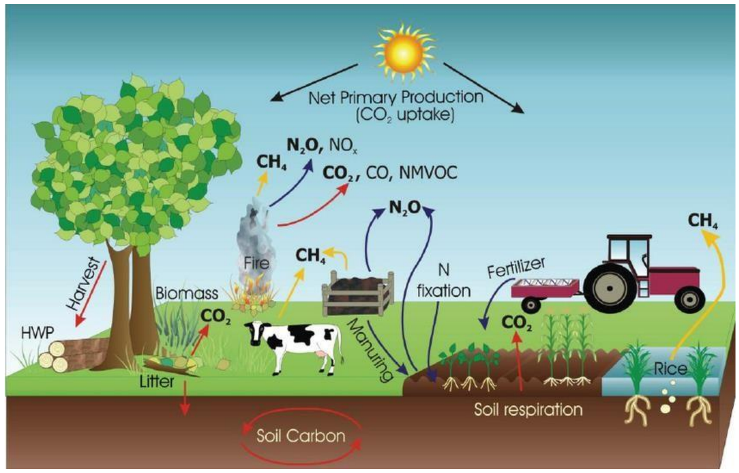

Figure 2 shows the primary sources of greenhouse gas emissions, sinks, and processes in managedecosystems that are associated with on-farm agricultural activities (MacLeod et al., 2015).

On the other hand, Climate change is disrupting agricultural production globally. Studies have shown that shifting temperature and rainfall patterns affect the timing of agricultural activities (Lipper et al., 2014). The Intergovernmental Panel on Climate Change (IPCC) warns that rising temperatures could significantly reduce yields of major crops like wheat, rice, and maize (BeznerKerr et al., 20212). Extreme weather events, including droughts and floods, have become more frequent and intense, leading to a 9% to 10% decrease in global cereal production (Lesk et al., 2016). Climate change has also expanded the range of pests and diseases, affecting crop quality and yield. Water scarcity caused by climate change is projected to decrease global irrigated crop yields by 6% by 2050 (He & Rosa, 2023). Additionally, climate change alters the suitability of crops in their current regions, necessitating changes in farming practices and land use. Livestock production is impacted through heat stress, reduced pasture productivity, and increased disease exposure (Campbell, 2017). In such severe conditions, developing nations must, on the one hand, cut greenhouse gas emissions from agriculture. On the other side, more productive agriculture is required for the food security of its enormous population. The next chapter covers the difficultiesthat developing nations face in this area.

CHALLENGES OF BALANCING FOOD SECURITY AND CLIMATE-FRIENDLY AGRICULTURE FOR DEVELOPING COUNTRIES

Although, the total number of developing nations is debatable, the United Nations, on the other hand, classifies 152 nations and regions as developing economies based on a variety of characteristics such as income levels, human development indicators, and economic vulnerability(United Nations Conference on Trade and Development, 2021). According to 2021 estimates, thisenormous territory of the developing world is home to over 6.3 billion people, or 80% of the world's population (United Nations Conference on Trade and Development, 2021). This population will increase in the coming days. By 2050, the world's population could rise to 9.7 billion (United Nations, 2019). Therefore, agricultural production must be increased to ensure food security for this large population (Rojas-

Downing et al., 2017). However, in order to increase agricultural production using conventional methods, deforestation will increase the amount of agricultural land, chemical fertilizer use will increase at a faster rate, and animal husbandry will need to increase in order to meet the demand for milk and protein (Rojas-Downing et al., 2017). As a result, anthropogenic greenhouse gas emissions will rise, which will have a negative impact on the climate (Kalt et al., 2021). Consequently, extreme weather events such as droughts, floods, and hurricanes can destroy crops, reduce yields, and lead to food shortages. Furthermore, due to climate change, millions were already experiencing food insecurity in 2019. In addition, the predicted decline in global crop production is between 2% and 6% per decade (Little, 2019). By 2050, it was predicted in 2019 that food prices would increase by 80% (Flavelle, 2019). This will likely result in an increase in food insecurity, which will disproportionately affect low-income communities. On the other hand, for many developing countries, agriculture is an essential part of the economy. According to the World Bank, 4% of the global GDP and 25% of the GDP of some least developing countries comes from the agricultural sector (The World Bank, 2023).

Under such circumstances, developing countries face significant challenges in reducing greenhouse gas emissions from agriculture due to various economic, social and environmental reasons, while maintaining food security and economic prosperity. Some of these challenges are discussed below. First, limited resources and technology: Most poor nations lack the resources and sophisticated technologies required to minimize agricultural GHG emissions. Ogle et al. (2014) showed that underdeveloped nations lack access to better seeds, fertilizers, and irrigation infrastructure, which hinders low-emission farming methods. Secondly, many developing nations continue to rely on traditional agricultural practices that contribute to greenhouse gas (GHG) emissions, such as crop residue burning and inefficient irrigation. According to a study conducted by Amjath-Babu et al. (2020), the low adoption rates of sustainable land management practices in developing countries can be attributed to their reliance on traditional agricultural practices. Additionally, a research by Sova et al. (2019) found that a lack of policy support has made it difficult to implement successful climate change mitigation strategies in the agriculture sector in developing nations due to weak governance structures and limited policy support. Finally, it can be said that reducing greenhouse gas emissions from agriculture in developing nations is a complex and interconnected problem. However, I will discuss below how developing nations can reduce their agricultural greenhouse gas emissions. We will begin by discussing four agricultural theories such as 1. Regenerative Agriculture 2. Agroecology 3 Climate Smart Agriculture and 4 Green Revolution. Later, I will propose additional policies to reduce agricultural greenhouse gas emissions. I will conclude by demonstrating, through a series of case studies, that many developing nations have already taken steps to reduce detrimental greenhouse gas emissions from agriculture.

GREEN REVOLUTION (GR)

First we will discuss about green revolution. GR refers to a period of agricultural innovation and development that occurred predominantly in developing countries between the 1940s and the 1960s. Among other technological advances, this revolution was marked by the introduction of high-yielding crop varieties (HYVs), the expansion of irrigation infrastructure, and the use of chemical fertilizers and pesticides (Armanda et al., 2019). Within 5 years following the introduction of HYVs and the development of chemical fertilizers, herbicides, and insecticides toboost growth, yields of maize, rice, and wheat grew by 40% (Morvaridi, 2012). GR was initiated

in reaction to increasing hunger and food insecurity in many regions of the globe, notably Asia and Africa. By expanding food production, the objective was to enhance agricultural productivityand decrease poverty. The introduction of high-yielding varieties (HYVs) of basic crops such as rice, wheat, and maize was a crucial invention of GR. These crops were developed with the goal of having shorter stems, stronger roots, and larger yields than conventional types. They were alsomore resistant to pests and disease, as well as more tolerant of drought and other environmental challenges (Thenkabail, 2010).

GREEN REVOLUTION: PREVENTER OR FACILITATOR OF CLIMATE FRIENDLY AGRICULTURAL DEVELOPMENT IN DEVELOPING COUNTRIES

It is possible to claim that GR was both a preventer and a facilitator of climate-friendly agriculturaldevelopment, depending on how it is viewed and implemented. On the one hand, the reliance of the Green Revolution on chemical fertilizers and pesticides, as well as monoculture farming, led to a decline in soil health, water resources, and biodiversity (Pingali, 2012). This caused the environment to deteriorate, which had an adverse effect on climate change. In this sense, GR prevented the growth of climate-friendly agriculture because it put production above sustainability and had a detrimental effect on the environment (Osborne & Beerling, 2006). In contrast, GR alsopaved the way for the development of new agricultural technologies and practices that could be adapted to promote climate-friendly agricultural development. For instance, the development of high-yielding crop varieties permitted more efficient land use, thereby reducing the need for additional deforestation and fostering sustainable land management (Stevensonet al., 2013).Similarly, the use of irrigation infrastructure contributed to the conservation of water resources and the promotion of water efficiency, a crucial aspect of climate-friendly agricultural development. In addition, GR gave farmers and agricultural scientists the opportunity to experiment with new practices and technologies that prioritize sustainability and climate change mitigation (Thenkabail, 2010). This includes, among other things, the promotion of agroforestry, conservation agriculture, and organic cultivation. These practices can be adapted and implementedto promote sustainable agricultural development that mitigates the effects of climate change by expanding on the legacy of GR (Harwood, 2020).

CLIMATE SMART AGRICULTURE (CSA)

CSA is the approach most recently emphasized by the Food and Agriculture Organization of the United Nations to introduce climate-friendly agricultural systems in developing countries. CSA refers to agricultural techniques and systems that boost production and resilience while lowering greenhouse gas emissions and other environmental consequences in a sustainable manner. CSA aspires to incorporate and implement the concepts of sustainable agriculture as well as adaptationand mitigation to climate change (Campbell, 2017). As terminology, CSA was first discussed in 2010 at a conference on food security and climate change organized by the Food and Agriculture Organization (FAO) of the United Nations (Sarker et al., 2019).

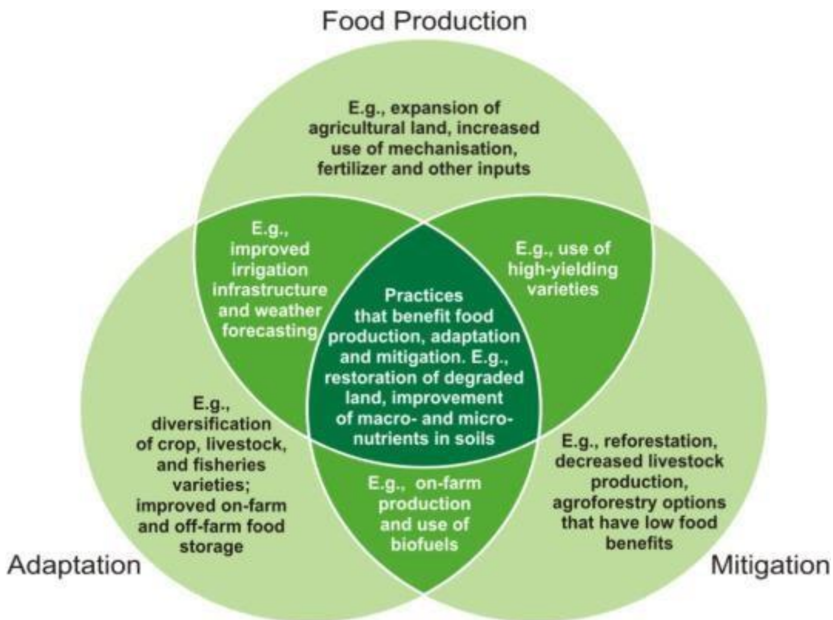

Figure 3 shows how CSA is promising adaptation, mitigation and production enhancement of agriculture **(**Dovie, 2019).

According to FAO, three fundamental pillars of CSA that are often referred to as "Triple Win" areensuring sustainable growth in agricultural production and revenue, promoting adaptive and resilience capacity of agriculture and food security systems to the effects of climate change, and reducing GHG emissions from agricultural production (Campbell, 2017). Drought-resistant crop varieties, optimizing irrigation systems, conservation agriculture methods such as low tillage andcover crops, and integrating livestock with crop production in sustainable ways are examples of climate-smart agricultural practices (Lipper et al., 2017). Furthermore, using renewable energy and better managing manure and other organic waste might help decrease greenhouse gas emissions linked with agricultural production.

ADAPTATION AND MITIGATION METHODS OF CSA

CSA emphasizes the importance of adaptation strategies to mitigate the effects of climate change.Some key adaptation strategies include crop diversification and the use of drought-resistant varieties to reduce crop failure risks and decrease reliance on a single crop. Improved water management techniques like drip irrigation, rainwater harvesting, and soil moisture conservation help farmers adapt to changing rainfall patterns and conserve water (Adamides, 2020). Soil conservation practices such as conservation tillage, crop rotation, and cover cropping prevent soil erosion, retain moisture, and enhance fertility. Furthermore, early warning systems and climate monitoring aid in preparing for extreme weather events and making informed agricultural decisions. Moreover, agroforestry, another effective CSA adaptation method, involves the use of trees to provide shade which reduce wind, improve soil health, conserve water, and promote biodiversity (Campbell, 2017).

Mitigation plays a crucial role in CSA to address the impacts of climate change. Here are some examples of mitigation methods in CSA. Conservation agriculture is an important approach that reduces tillage and improves soil health, employing practices such as minimal soil disturbance, crop rotation, cover crops, and crop residues to reduce greenhouse gas emissions from agriculturalactivities. The use of renewable energy, such as solar, wind, and biogas, helps minimize agricultural emissions by utilizing solar pumps for irrigation and utilizing biogas from animal waste for cooking and lighting (Campbell, 2017). Livestock production is a significant source of greenhouse gas emissions, and CSA practices like improved manure management, feed supplements, and dietary changes for animals can help reduce emissions in this sector. Additionally, agroforestry is a recommended mitigation strategy in CSA, as it contributes to carbonsequestration by trees, which absorb and store carbon dioxide in their biomass and soil (Kurgat etal., 2020).

CSA'S METHOD OF INCREASING AGRICULTURAL PRODUCTION

To begin with, improved crop management strategies such as early planting, efficient fertilizer management, and weed control may boost crop yields and quality. Similarly, agricultural production may be increased by utilizing better seeds that are adapted to local environments (Kurgat et al., 2020). Integrated crop-livestock systems which involve the integration of crop andlivestock production systems can increase soil fertility, reduce crop pest and disease pressure which consequently provide additional sources of income from livestock production (Campbell, 2017). . Furthermore, conservation agriculture and proper water management techniques can helpincrease crop yields. Moreover, effective post-harvest management techniques such as proper storage and handling can help reduce post-harvest losses and improve food quality and safety (Adamides, 2020).

CSA AND DEVELOPING COUNTRIES: TRIPLE WINS FOR WHOM?

Despite the potential benefits of CSA in terms of climate change and food security, civil society organizations, activists and organizations working on farmers' rights internationally have been strongly opposed to it. They complain that the initiative undermines agroecological solutions to climate change and agricultural issues (CIDSE, 2015). It also creates opportunities for a greenwashing in agribusiness for governments and large multinational food companies because CSA may be used as a marketing tool by them to promote their green credentials without making substantive changes to their practices (Anderson, 2014). They also allege that marginal and smallholders farmers of developing nations will suffer as a result of this initiative as they will notbe able to afford the huge technology, market access and high investment that adaptation of this initiative will require (Karlsson et al., 2018) As a result, this initiative will disempower small farmers of developing countries (CIDSE, 2015). In addition, one of the criticisms of CSA is that it focuses too much on technology-based solutions in climate change mitigation and adaptation, such as improved seeds, fertilizers and irrigation systems, but ignores other sustainability issues such as sustainable land management, water management, biodiversity conservation and issues ofsocial justice are also overlooked (Newell & Taylor, 2018). Above all, critics say, CSA lacks a participatory approach because it is a top-down and techno centric approach with little input fromlocal farmers in solving agro-centric problems. Such an approach will create a lack of ownership among the stakeholders who are truly affected by climate change and food security, which will hinder the implementation of such initiatives (Taylor, 2018).

AGROECOLOGY

Agroecology is one of the some significant sustainable and climate-friendly agricultural systems that are widely discussed in contrast to traditional and industrialized agricultural systems. Agroecology is a scientific discipline and approach that focuses on understanding the ecological processes that govern agricultural systems, and using that knowledge to design sustainable and resilient farming practices. It is an interdisciplinary discipline that incorporates concepts from ecology, agronomy, sociology, and economics and others (Kremsa, 2021). Dalgaard et al. (2003)define agroecology as the study of plant, animal, human, and environmental interactions within agricultural systems. Agroecology originated in the early 20th century when farmers and scientists realized industrialized agriculture had detrimental environmental and social effects. The current discipline of agroecology began in the 1980s as a reaction to the detrimental effects of the Green Revolution, which encouraged high-input, monoculture-based farming (Gliessman, 2018). Today,organizations such as the Food and Agriculture Organization of the United Nations (FAO) recognize agroecology as an essential method for achieving sustainable agriculture (Loconto & Fouilleux, 2019).

METHODS OF AGROECOLOGY IN ADAPTATION AND MITIGATING GHG FROM AGRICULTURE

Agroecology is a scientific strategy for planning and managing agricultural systems that are resilient, sustainable, and socially equitable, rather than a particular farming technique. As a result, there is no one-size-fits-all method for agro ecological farming since it is dependent on the local conditions, resources, and demands of the population in the area. (Wezel et al., 2009). However, there are some general principles that are often associated with agro ecological farming. Some of them are discussed below. Soil health: Agro ecological farming places a strong emphasis on the value of healthy soil and makes use of techniques to maintain and enhance soil fertility, includingcover crops, crop rotation, and the use of organic fertilizers. Low reliance on external inputs: In order to achieve sustainable production, agro ecological farming attempts to decrease reliance onexternal inputs like synthetic fertilizers, pesticides, and genetically modified organisms (GMOs) (Kremsa, 2021). Instead, it empowers local communities to engage in agricultural system decision- making and management by integrating local knowledge into agricultural practices which promotes social justice, community resilience, and ecological sustainability (Timmermann & Félix, 2015). Biodiversity: Agro ecological systems optimize above- and below-ground biodiversity to boost ecological resilience, natural pest management, and soil fertility (Wanger et al., 2020). Decreased energy use: Agro ecological methods including decreased tillage, diverse cropping systems, and intercropping minimize agricultural energy inputs and GHG emissions fromfossil fuels (Altieri & Nicholls, 2012).

AGROECOLOGY: REDUCING FOOD WASTE AND CHANGING DIET FOR REDUCING GHG EMISSION

Food waste accounts for 6% of global GHG emissions (Ritchie, 2020). According to World Bank,1/3 of food produced globally is either lost or wasted (The World Bank, 2021). One of the many ways agroecology says to reduce GHG emissions is to prevent food waste and change our diet. The figure below shows the huge amount of food we waste.

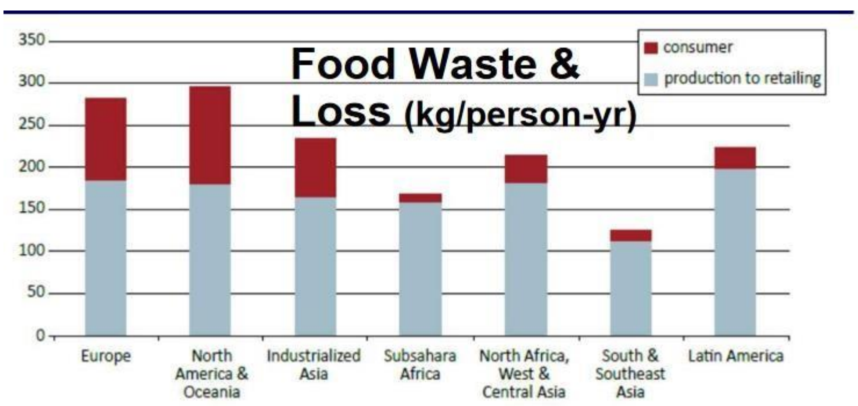

Figure 4.3. Per capita food losses and waste at the consumption and pre-consumption stages in different world regions. Source: Gustavsson et al (2011)

Figure 5 shows the global food waste and loss per year per person (Gustavsson et al., 2011)

Similar data we get from the study of FAO. FAO reported that approximately 1.3 billion kilogramsof food were lost or squandered globally in 2007, which equates to about one-third of the food produced for human consumption at the time. Food losses and waste deprive the impoverished ofaccess to food in developing regions, significantly deplete resources like land, water, and fossil fuels, and increase the GHG emissions associated with food production (Munesue et al., 2015). Therefore, tackling food loss and waste is essential for achieving climate objectives and loweringenvironmental stress (The World Bank, 2021).

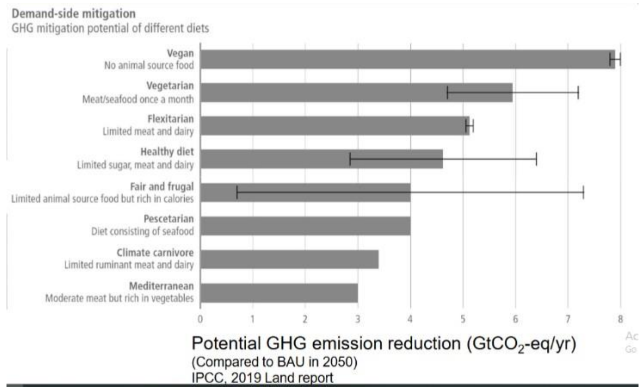

Figure 6: reveals the potential GHGs emission reduction of different diets ((IPCC, 2019)

With this figure we can see that a vegan can help reduce CO2 by about 8 GT per year and a vegetarian by about 6 GT per year. So Developing nations can help reduce global GHGs by cuttingout excess animal meat from their livestock management.

CHALLENGES FOR DEVELOPING COUNTRIES IN ADOPTING AGROECOLOGY

Many developing countries have adopted agroecology to reduce GHG emissions from agriculture,and many are planning to do so. But in this case, developing countries in general face the following challenges. First, the adoption of agroecology demands supportive policies, research funding, incentives, and institutional frameworks. Comprehensive policies that emphasize and encourage agroecology may be lacking in developing nations. Second, agro ecological approaches sometimesinvolve early investments and a longer transition period, which may be difficult for poor farmers in developing countries who lack land, water, seeds, and other resources (Timmermann & Félix, 2015). Third, agroecology demands ecological knowledge and advanced agricultural practices. Farmers may lack knowledge and technical abilities to undertake agro ecological methods. This knowledge gap needs training and extended programs. Agroecology may involve lowering dependency on these external inputs, which may be difficult without local contributions or supporting policies. Addressing these challenges requires a multi-dimensional approach that includes capacity building, policy support, infrastructure development, and market access, along with active involvement and empowerment of local communities (Wanger et al., 2020).

Regenerative Agriculture (RA)

RA is one of several methods of reducing GHGs from agriculture in the developing world that is gaining global recognition. RA is a system that combines traditional agriculture with sustainable innovations (Gosnell et al., 2019). The Rodale Institute began using the term "regenerative agriculture" in the early 1980s, but it did not acquire widespread usage until the early to mid-2010s (Renature, 2021). RA is an approach to farming and land management that prioritizes improving soil health, increasing water retention, and promoting biodiversity, which can contribute to increased agricultural yields and more resilient farms (Gosnell et al., 2019). Its techniques includereducing tillage, planting cover crops, rotating crops, intercropping, integrating livestock into cropping systems, and utilizing natural fertilizers and insect control techniques (Schreefel et al., 2020). This agricultural system's primary objective is to produce enough nutritious food for the world's population and to improve the lives and livelihoods of farmers by sequestering carbon in the soil and reducing greenhouse gas emissions by regenerating climate-friendly agricultural systems. Another purpose is to restore endangered biodiversity and improve natural habitats. Oneof its goals is also to prevent further deforestation and grassland conversion by increasing productivity on existing agricultural land (McLennon et al., 2021).

DIFFERENCES BETWEEN TRADITIONAL AGRICULTURE AND RA AND HOW IT WORKS FOR REDUCING GREENHOUSEGAS EMISSION FROM AGRICULTURE.

The differences between RA and conventional farming systems and how it helps reduce greenhouse gas emissions in the climate are discussed below. In preparing this chart, data has beencollected from the research of McLennon et al., 2021, Renature, 2021, Schreefel et al., 2020 and Sahu & Das, 2020.

DIVERGENCES BETWEEN TRADITIONAL AGRICULTURE AND REGENERATIVE AGRICULTURE		
Criteria	**Traditional Agriculture**	**Regenerative Agriculture**
Soil health:	Traditional agricultural techniques including heavy tillage, monoculture crops, and industrial fertilizers and pesticides may damage soil health consequently.	Conversely, cover cropping, crop rotation, decreased tillage, and natural fertilizers increase soil health, fertility, and water retention in RA.

Biodiversity	Monoculture crops and insecticides and herbicides in traditional agriculture can endanger biodiversity and damage beneficial insects and wildlife.	Cover crops, intercropping, agroforestry, and other RA approaches promote biodiversity and conserveecosystem.
Carbon sequestration	By using fossil fuels for machinery andreleasing carbon dioxide from tilled soil, traditional agriculture may contribute to greenhouse gas emissions.	RA practices such as cover cropping, reduced tillage, and the use of perennial crops and agroforestry, which can store carbon in soil and biomass, can help sequester carbon.
Water management	Synthetic fertilizers and pesticides may cause soil erosion, nutrient runoff, andwater contamination in traditional agriculture.	Cover crops, decreased tillage, and natural fertilizers may prevent erosion, increase water infiltration, and safeguard water quality in RA.
Community benefits	Traditional agriculture may favor short-term profits for farmers and agribusinesses.	RA prioritizes community advantages includingfood security, biodiversity, and GHG reduction.

HOW AND TO WHAT EXTENT DEVELOPING COUNTRIES CAN MITIGATE GHG EMISSIONS FROM AGRICULTURAL SYSTEMS BY ADOPTING RA PRACTICES

The suitability of RA varies depending on the specific context of each developing country which include economic capabilities, natural diversity, and different soil composition which necessities customized farming approaches for maximizing productivity through regenerative practices (Schreefel et al., 2020). To enable developing countries to embrace regenerative agriculture, governments must initiate policy changes. It is crucial to develop comprehensive guidelines for farmers to adapt to this system (Sherwood & Uphoff, 2000). Encouraging farmers through incentive packages, providing complete information, technical support, and adequate resources areessential steps (Keshavarz & Sharafi, 2023). Additionally, creating a market that increases consumer demand for environmentally sustainable and ethically produced products is paramount.

These measures collectively support the adoption of regenerative agriculture practices in developing countries (Keshavarz & Sharafi, 2023).

On the other hand, implementing RA methods in developing countries presents several challenges.Firstly, significant financial investments are required for new technology, tools, and education, which may be difficult for nations with limited financial resources. Secondly, farmers may lack awareness, knowledge, and skills to effectively implement RA practices (McLennon et al., 2021).Moreover, the smaller farm sizes and labor-intensive techniques associated with RA can hinder scalability on a large commercial scale. Lastly, despite its growing popularity, there is a lack of comprehensive research on the long-term impacts and effectiveness of RA (Sherwood & Uphoff 2000). These challenges highlight that while RA offers potential benefits, its suitability and feasibility may vary across different farmers and regions, especially in developing countries withlimited resources and infrastructure (Lunn-Rockliffe et al., 2020).

WHICH OF THE FOUR AGRICULTURAL THEORIES (GR, AGROECOLOGY, RA, AND CSA) IS THE BEST FOR REDUCING GHG EMISSIONS FROM AGRICULTURE IN DEVELOPING NATIONS?

The best approach for reducing greenhouse gas emissions from agriculture in developing countrieswill depend on a variety of factors, including local environmental conditions, cultural practices, and economic constraints. However, based on current research and evidence, agroecology and regenerative agriculture appear to be the most promising approaches for achieving this goal (Francis et al., 1986; McLennon et al., 2021). These approaches prioritize soil health, biodiversity,and the use of ecological principles to design and manage agricultural systems. By promoting carbon sequestration and reducing greenhouse gas emissions from agriculture, they offer a sustainable and climate-friendly path forward for agriculture in developing countries (Kremsa, 2021). On the other hand, the Green Revolution and Climate Smart Agriculture (CSA) have also been promoted as ways to reduce greenhouse gas emissions from agriculture, they have been criticized for their reliance on chemical inputs and industrial farming practices (Newell & Taylor,2018; Osborne & Beerling, 2006). The use of chemical fertilizers and pesticides in the Green Revolution, for example, has contributed to soil degradation and water pollution. Similarly, while CSA promotes the use of climate-smart technologies, it does not necessarily prioritize soil health and biodiversity in the same way that agroecology and regenerative agriculture do (CIDSE, 2015and Pingali, 2012).

SOME POLICIES OF DEVELOPING NATIONS TO REDUCE GHG FROM AGRICULTURE

Despite various limitations, many developing countries have already taken some initiatives to reduce GHGs from agriculture. We will discuss it below. Brazil, Chile and Mexico have started practicing agroecology for their local farmers and indigenous peoples through their Global ForestCoalition (GFC) project. India started practicing agroecology through their Participatory Guarantee Systems (PGS) project. Through this project they are providing necessary training, investment and market facilities to hundreds of thousands of farmers to cultivate organic food through agroecology practices. The African country, Malawi, has also started practicing agroecology in four districts including the country's capital through their The Malawi Farmer-to- Farmer Agroecology project (or MAFFA) project and is also providing necessary training to farmers (FAO, n.d.).

On the other hand, FAO and the World Bank have taken various steps to help developing countriesadopt CSA to reduce GHG. The World Bank Group has decided to scale up the CAA as part of itsfirst Climate Change Action Plan, which was initially for 2016-2020 but has now been extended to 2021-2025. The World Bank has adopted the Climate- Smart Agriculture Investment Plans (CSAIPs) with ten countries including Bangladesh, Zimbabwe, Zambia, Lesotho, Mali, Burkina Faso, Ghana, Cote D'Ivoire, Morocco, and The Republic of Congo under its project and the initial investment is estimated at 2.5 billion US dollars. Already, each of these ten states has taken various initiatives to adopt CSA. Under this project, Brazil has already trained 20,025 beneficiaries to implement CSA on 378,513 hectares and expects to sequester 7.4 million CO2 over the next 10 years. Similarly, Pakistan is trying to adopt CSA in its Pakistan Punjab IrrigatedAgriculture Productivity Improvement Program. About 23500 hectares of land have been cultivated with low GHG systems involving about 5 million people and 11916 water projects have been improved (The World Bank, 2021). However, we will have to wait a little longer to know how much GHG emissions have been reduced from such climate-friendly agricultural practices indeveloping countries. However, we need to wait for some more scientific data and time to know how much GHG emissions have been reduced from such climate-friendly agricultural practices indeveloping countries and which of the above-discussed agricultural methods actually contribute more to reducing GHG emissions.

CONCLUSION

This paper first explored agriculture as one of the primary contributors to global warming and climate change, accounting for 24% of world greenhouse gas emissions. On the other hand, it highlighted that a more productive agricultural method is required to assure food and nutrition security for a rising population. In such a situation, it is paramount important to create an agricultural system that will expedite food security and economic growth while simultaneously aiding in climate change mitigation. As feasible as it is for developed nations to implement such a system, it is considerably more difficult for developing countries since most of them lack enough resources, trained labor, infrastructure, and technology. This study discussed GR, CSA, Agroecology, and Regenerative Agriculture techniques as alternatives to conventional agriculture. Among these four techniques, the Green Revolution has had a significant influence on developing nations' food production through the employment of sophisticated technology, equipment, and synthetic fertilizers, but at the same time it is increasing the agro-centric GHG emission. CSA model is an agricultural system that many people refer to as a "triple win" since it simultaneously enhances climate adaptation and mitigation while also improving productivity. However, this paper revealed that according to civil society and organizations working on farmers' rights, this triple win will not be a triple win for the marginal and smallholder farmers rather this triple win will greatly aid the large multinational agricultural industry and governments in a form of greenwashing. Moreover, Agroecology and Regenerative Agriculture can help reduce GHG emissions from agriculture while simultaneously ensuring food security in developing nations. However, the advanced technology, large infrastructure and finance required to adopt these two approaches are also challenging for many developing countries. Besides, different developing countries have adopted different approaches of these four models according to their context and conditions are also discussed in this paper as examples.

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