

Harvesting Sustainable Agriculture with Climate Finance: Review

Manpreet Kaur Makkar^{1,*}, Basit Ali Bhat², Nitin Gupta¹, Anuj Vaid¹

¹Mittal School of Business, Lovely Professional University, Punjab, India

²Gulzar Group of Institutes, Punjab Technical University, Punjab, India

*Corresponding author: mkaur4989@ymail.com

Abstract. This study presents an in-depth analysis of climate finance within the agricultural sector and its pivotal role in fostering sustainability in agrarian economies. It investigates the availability, accessibility, challenges, and effective utilization of climate finance. Climate finance emerges as a critical resource for establishing funding mechanisms and incentives that support sustainable agricultural practices, bolstering resilience and mitigating greenhouse gas emissions. Secondary sources, including books, journals, articles, policy documents, and reports, provide the data for this research. The findings of this study underscore a vital revelation: private investors play a crucial role in augmenting climate finance, thereby facilitating the transition to sustainable agriculture. It is evident that their participation significantly enhances the financial support available to farmers and agricultural stakeholders. Furthermore, the study reveals that a combined effort from both government and private investors has yielded considerable progress in advancing climate finance investment within India's agricultural sector. This collaborative approach has proven instrumental in addressing the challenges faced by those seeking climate finance in agriculture. It has effectively increased awareness, streamlined application processes, and strengthened institutional support, ultimately driving the adoption of sustainable practices. The implications of this research extend to policymakers, agricultural institutions, and financial organizations, highlighting the pivotal role of private investors in improving climate finance accessibility. The future scope of this research suggests that the effective utilization of climate finance has the potential to catalyse the widespread adoption of sustainable agricultural practices. The study emphasizes the importance of channelling climate finance through a variety of stakeholders to maximize its utility and make use of all available resources and instruments.

Keywords: Climate Finance, Climate change, Mitigation, Adoption, Sustainable Agriculture, SDG's and India

1. Introduction

The challenges posed by climate change are daunting, but the opportunities for revolutionary transformation and sustainable growth are equally vast, and it is up to people of planet to seize them with courage and conviction (Balint et al., 2017; VijayaVenkataRaman, *et al.*, 2012). The ability of stewards to handle the urgent and complicated challenge of climate change, as well as to innovate and establish a new instrument for transformation towards sustainability, will characterize the twenty-first century (Sterr & Ott, 2004; Levin, 2012). Climate change is a complex and urgent global challenge that requires funds and innovations to address the systemic issues at hand (Kivimaa & Kern, 2016). Financial instruments have the potential to play a significant role in addressing climate change by mobilizing capital, incentivizing low-carbon investment, and promoting sustainable practices (Linnerooth-Bayer & Hochrainer-Stigler, 2014; Dikau & Volz, 2019).

While Human activities are the primary source of greenhouse gas emissions, particularly burning fossil fuels for energy, transportation, industrial processes and agriculture (Yoro & Daramola, 2020; Engdaw, 2020). Hence to effectively address climate change, it is important to focus on every factor that contributes to greenhouse gas emissions particularly agriculture as it has not received the same level of attention as other sectors such as energy, transportation, and industry (Yoro & Daramola, 2020; Pamučar et al., 2021). Many industries contribute to greenhouse gas emissions (Lynch et al., 2021), and achieving net zero emissions would be unattainable unless all of these industries received significant attention. IPCC, (2018) has stressed upon giving optimum attention to sustainable agricultural practices. The agriculture industry is one of the major contributors to the effects of global warming (Al-Ghussain, 2018) through livestock, fertilisers, crop-residue, irrigation of ground water, over-tilling of soil, and monoculture farming (Lynch et al., 2021). Additionally, transpiration, airborne particles (dust, soot), precipitation, wind, etc (Paustian et al., 2016). According to the Greenhouse Gas Working Group (2010) report, agriculture accounts for between 6 and 8 percent of the radiative forcing associated with greenhouse gases (GHGs) such as methane and nitrous oxide in developed nations like Canada and the United States which are not dependent on agriculture. Animal husbandry, manure management, and agricultural soils contribute about 5% of total global methane (CH₄) emissions and 84% of total global nitrous oxide (N₂O) emissions (Lynch et al., 2021). At the same time, climate change has affected the availability of water, animal growth and milk production, feed crop and forage farming, reproduction, and biodiversity. Drought, rising temperatures, and greenhouse gases have a severe impact on the agriculture industry. (Zwane, 2019; Davis, 2023).

In case of developing nations, (especially agrarian economies) agriculture is one of the highest carbon emitters among the other sectors of the economy. But, still, the prominence of improving the agriculture sector is negligible as compared to the energy or transportation. In India, 65 percent of population lives in rural areas and 47 percent of the population is dependent on agriculture for their livelihood as per the report published by the Ministry of Finance and Press Information Bureau (PIB, Jan 2023). India's agriculture contribution to GDP (20.19%) is significantly more than the global average (6.4%). Thus, rural economic development and promoting sustainable agriculture are crucial for the country's holistic growth. Agriculture, being the second largest contributor to carbon footprints and third to the GDP necessitates the transition of agricultural operations from a carbon-intensive to an environmentally friendly and cost-effective mode.

This can be achieved through advancement of technology, the establishment of operational systems, and the precise application of available financial resources (green agriculture finance). To achieve sustainable development of the country, contribution of financial resources plays crucial role. But conversely the agenda in the current budget of India in greening agriculture witnesses a reduction of roughly 17% in the funding for Management of Natural Resources (under the Department of Agriculture Research and Education) compared to last year's estimate. This department comprises Natural Resource Management Institutes, including Agro-Forestry Research and Climate Resilient Agriculture Initiative.

Global food security necessitates the development and adoption of innovative technologies that contribute to addressing the challenges of achieving Sustainable agriculture, i.e., a farming approach that aims to meet the needs of the current generation without jeopardizing future generations' ability to meet their own needs. For instance, nanotechnology has the potential to help to agricultural sustainability by enhancing efficiency and lowering the environmental impact of pesticides and seed priming (Wang et al., 2022; Pereira et al., 2021). Furthermore, organic farming and conservation tillage can promote soil health by increasing the quantity, diversity, and activity of microorganisms (Tahat et al., 2020). These activities contribute to more efficient agricultural systems by combining environmental, social, and economic elements to build a more resilient and efficient food production system. It also assists the farmer community in ensuring the agricultural sector's long-term profitability while also safeguarding the environment and promoting food security.

These factors motivate the authors to identify the challenges and opportunities in promoting sustainable agricultural practices via climate or green finance in developing nations like India. To determine the efficacy and value of climate and green finance on the transition to sustainable farming methods. The study aims at analysing the availability, accessibility as well as the use of climate-related finance within the sector of agriculture. It also focuses on available climate-smart methods, sustainable farming techniques, and resilient systems for agriculture. It aims to pinpoint the challenges and obstacles that farmers face when trying to access climate-related finance. Additionally, to study the role of financial sector, policies of government as well as international initiatives for encouraging sustainable agriculture.

2. Background

Agriculture plays a crucial role in driving economic growth, particularly in developing countries where it contributes significantly to the global agricultural value (FAO 2013). This sector serves as a source of employment and livelihood for 2.5 billion individuals, often including vulnerable populations living in poverty. However, agricultural activities also account for a significant portion of global greenhouse gas (GHG) emissions, including carbon dioxide, nitrous oxide, and methane, which rise alongside increased agricultural production. Several factors contribute to this upward trend in emissions, including the global population doubling from 3.7 billion in 1970 to over 7 billion in 2014 (UN 2014), the adoption of emission-intensive practices like intensive tillage, stubble burning, and excessive fertilizer use, and the growing affluence and meat consumption leading to an increase in ruminant livestock. According to Bennetzen, Smith, and Porter (2016), the developing regions of South and Southeast Asia, as well as Central and South America, are responsible for approximately 80% of global agriculture-related emissions. Consequently, the agricultural sector presents a targeted and impactful opportunity to mitigate emissions within these regions by promoting the adoption of sustainable agricultural practices.

Currently, the concentration of agriculture is on adapting to climate change or adjusting for losses caused by natural disasters. This focus has overshadowed the larger context of cause for climate change. The expansion of agriculture, primarily driven by excessive use of fertilizers, over-tilling, monoculture farming, excessive use of ground water, irresponsibly use of energy, deforestation and land conversion, has emerged as a significant contributor to climate change, as it leads to increased carbon dioxide emissions and the reduction of carbon sinks (FAO, 2016). These practices exacerbate the global warming phenomenon. Moreover, inefficient irrigation techniques and poor water management practices in agriculture contribute to water scarcity and higher energy consumption, further intensifying greenhouse gas emissions (Valipour, 2014). The excessive use of chemical fertilizers and pesticides not only degrades soil quality but also releases nitrous oxide, a potent greenhouse gas, into the atmosphere (Kuehne, 2021).

Unsustainable monoculture practices, prevalent in many agricultural systems, have negative consequences for both the environment and crop production. Monocultures reduce biodiversity, creating an environment that is highly susceptible to pests and diseases, necessitating increased pesticide use (Hunt et al., 2019). These unsustainable practices lead to adverse environmental impacts such as soil erosion and nutrient runoff, which further exacerbate the effects of climate change (Gupta, 2019)

3. Research Design

This conceptual research study aims to outline the methodology and approach to be used in investigating the integration of climate finance into sustainable agriculture practices. The research will adopt a qualitative research approach to gain a comprehensive understanding of the integration of climate and green finance with sustainable agriculture practices. Data will be gathered from scholarly articles, books, and reports from reputable sources including policy documents, guidelines, and reports related to climate finance initiatives in the agricultural sector. This study will thematically analyse the content to understand the strategies, mechanisms, and challenges associated with integrating climate finance into sustainable agricultural practices.

4. Challenges for Sustainable Agriculture Practices in India

The challenges hindering India's adoption of sustainable agriculture practices are multifaceted and require urgent attention (Priyadarshini & Abhilash, 2020). Firstly, the country's heavy reliance on agriculture as the backbone of its economy and increasing population puts immense pressure on farmers to maximize yields. In their pursuit of higher productivity, farmers often resort to using chemical fertilizers, pesticides, and unsustainable farming techniques, which have detrimental effects on the environment and human health (Horrihan et al., 2002; Srivastava & Kesavachandran, 2019). The lack of awareness and knowledge about sustainable agriculture techniques among farmers presents a significant hurdle. Without adequate education and training, farmers struggle to adopt more environmentally favourable practices. (Economic Times, 2023). This knowledge gap needs to be addressed through extensive farmer education and training programs and the dissemination of information about sustainable practices (Brar et al., 2022).

In addition, limited access to essential resources poses a significant challenge. Advanced farming technologies (Mahmud, et al., 2021; Sahoo et al., 2021), irrigation facilities, and financial support are often inaccessible to many farmers, particularly those in remote areas. The high cost of adopting sustainable practices further exacerbates the problem (Sumane, et al., 2018). Critics argue

that unless adequate resources and financial assistance are provided, the adoption of sustainable agriculture practices will remain an elusive goal for many farmers.

Furthermore, India's diverse climatic zones and fragmented land holdings make it difficult to implement standardized sustainable practices uniformly across the country (Azma et al., 2023; Bhardwaj et al., 2022). Critics contend that tailored approaches are needed to address the specific challenges and opportunities presented by each region, considering local environmental conditions and agricultural traditions (Lan and Yao, 2019). Socio-economic factors play a significant role in hindering the adoption of sustainable practices. Poverty, limited market opportunities, limited funds, and the need for immediate income often discourage farmers from investing in practices that may require initial investments or yield long-term benefits (Bhalerao et al., 2022). Critics argue that comprehensive policy support, including financial incentives and market reforms, should be implemented to alleviate these economic constraints and incentivize farmers to embrace sustainable agriculture.

5. Fuelling Sustainable Agriculture

The transformation of the agricultural landscape towards ecological sustainability has gained momentum through the utilization of financial instruments, marking a bold and innovative approach (Neumann, 2023). The integration of impactful financial mechanisms, such as impact investing, green bonds, and sustainable agriculture funds, has sparked a surge of capital directed towards the adoption of environmentally friendly farming practices (Lazaro et al., 2023). These novel financial instruments offer a distinctive avenue for directing investments into initiatives that promote crucial aspects of sustainable agriculture, including soil health, water conservation, biodiversity preservation, and the reduction of greenhouse gas emissions (Jayaraman et al., 2021). By facilitating access to affordable credit, grants, and financial incentives, farmers and agribusinesses are empowered to enhance their infrastructure, procure sustainable inputs, and undergo comprehensive training, thereby optimizing resource efficiency (Yao et al., 2022).

The interplay between finance and agriculture cultivates a symbiotic relationship that not only propels economic growth but also safeguards the environment, guaranteeing a thriving and resilient planet for future generations (Zinina & Olentsova, 2020). Through the ingenious utilization of financial instruments, sustainable agriculture manifests as a tangible reality, where profitability and ecological stewardship exist in harmonious alignment (Adegbite & Machethe, 2020).

To promote the widespread adoption of sustainable agriculture practices, policy interventions, capacity building, and financial support are essential (Piñeiro et al., 2021). Governments and relevant stakeholders should design and implement policies that incentivize and support the transition to sustainable practices (Pretty & Bharucha, 2018). *Capacity building programs* can provide farmers with the necessary knowledge and skills to adopt sustainable practices effectively (HN, 2018). Additionally, *financial support, both from public and private sources*, is crucial to invest in infrastructure, research and development, and farmer education to enable the adoption of sustainable agriculture practices at scale (Piñeiro et al., 2021). It also helps to support the high upfront costs associated with transitioning to sustainable agriculture, such as organic fertilizers, drip irrigation systems, and climate-resilient seeds, are often beyond the financial capacity of small and marginal farmers.

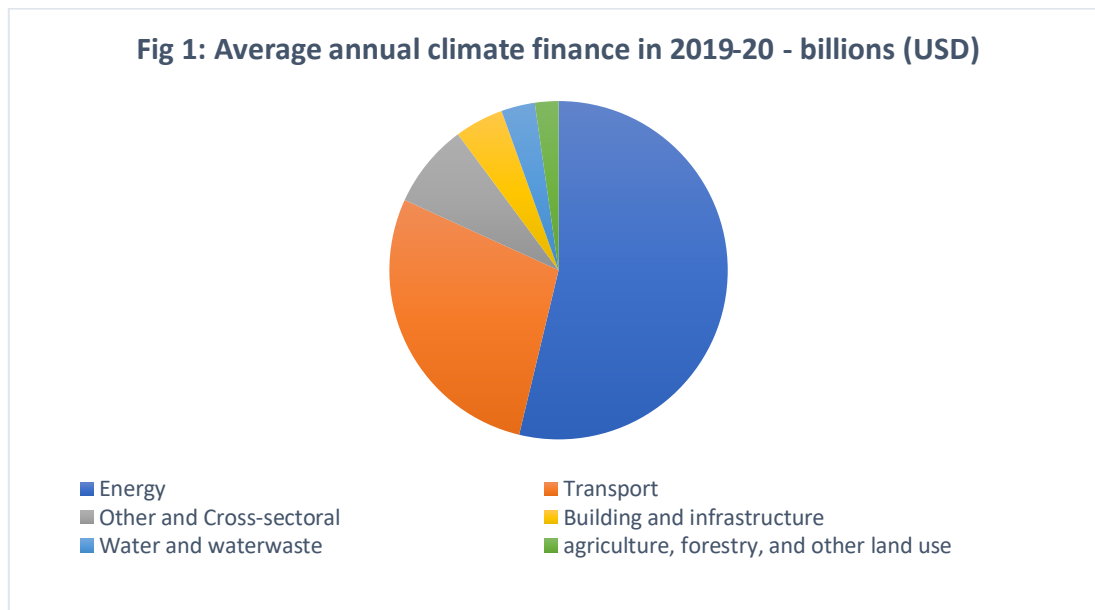
National and international organizations alike realize the significance of climate finance in agriculture, and contributed through these programs. The goal of these organizations is to help farmers adapt to the effects of climate change through the use of sustainable farming practices.

Table No. 1: Organizations Supporting Agriculture towards Climate Change

Initiative	Focus Areas	Amount (USD)
National Adaptation Fund for Climate Change (NAFCC)	Climate-resilient agriculture, sustainable water management, soil conservation	\$200 million
National Bank for Agriculture and Rural Development (NABARD)	Promotion of climate-smart agriculture, renewable energy in agriculture, sustainable irrigation practices	\$500 million
Green Climate Fund (GCF)	Funding for projects on climate-resilient farming, sustainable land management, agroforestry, and water resource management	\$1.2 billion
International Fund for Agricultural Development (IFAD)	Support for smallholder farmers in adopting climate-resilient agricultural practices, improving water management, and sustainable livelihoods	\$150 million
World Bank	Investments in sustainable irrigation systems, climate-smart farming techniques, and agricultural research and development	\$800 million
International Climate Initiative (IKI) by Germany	Support for sustainable land management, climate-smart agriculture, and agricultural biodiversity conservation	\$100 million
United Nations Development Programme (UNDP)	Projects focused on sustainable agriculture, climate-smart farming, and capacity building for climate resilience in the agricultural sector	\$250 million

5.1 Status-quo of Climate Finance in Agriculture.

Though these organizations, some private institutions, and multiple government policies, are taking initiatives to support agriculture for climate change, still we are far behind the goal of attaining required finance to achieve sustainable agriculture and climate change mitigation (Khanna et al., 2022). As, these agencies, institutions, or government policies need more finance to deliver a successful result. According to the World Bank's Country Climate and Development Report (CCDIR, 2021), a country need 1.4% of its GDP by 2030 for climate action, whereas Lower Middle-Income Countries (LMIC) require 5.1% of their GDP, or \$190.58 billion in India's case. Furthermore, according to the Climate Policy Initiative, developing nations like India demand \$170 billion in green finance every year, but only receive \$47 billion (Khanna and Purkayastha, 2022). Therefore, apart from public sector, private sector investment is also required to overcome the effects of climate change.



Source: Climate Policy Initiative (2021)

The focus of the climate change fund is majorly on the energy and transportation sector, and agriculture being the second largest sector of carbon emissions has been overlooked. As described in the above chart, agriculture has faced the minimum allotment of funds of 2.2 percent of the pool. This could be due to lack of awareness among farmers, lack of R&D, or can be due to lack of financial instruments for fund channelization. But there is an urgent need of divergence of funds in the climate and green finance to the agriculture sector.

6. Channelization of Funds

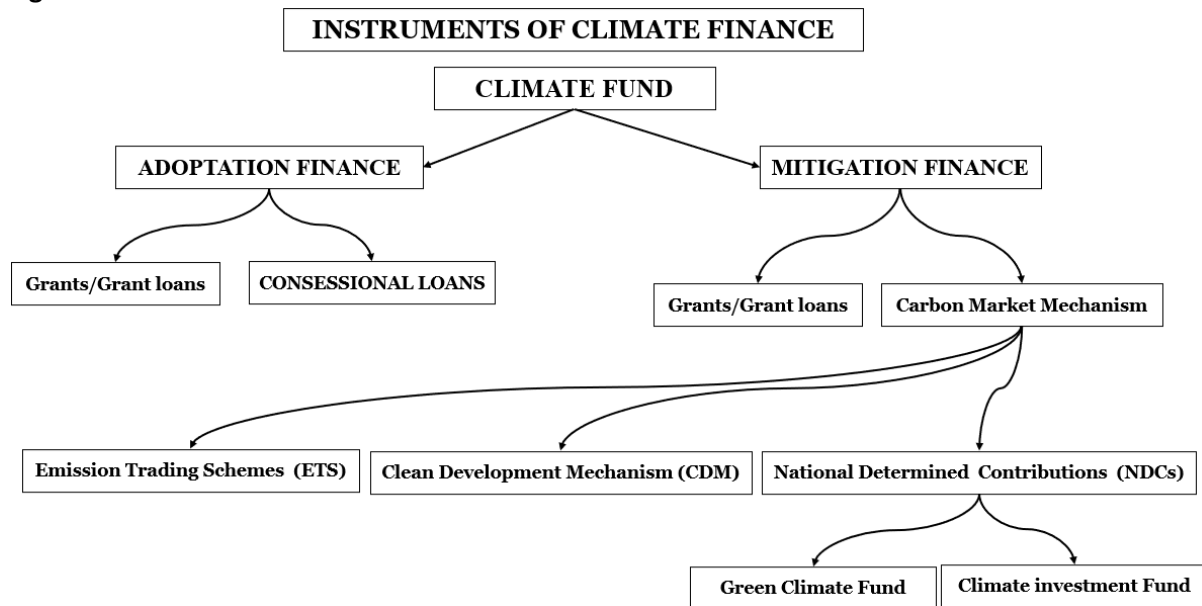
There are a variety of financing techniques that support sustainability among all sectors and environmental protection initiatives. Despite the fact that their names indicate different areas of concern, but they overlap due to their common aim of promoting the welfare of the community (Hee Jin Noh. 2018). As *Sustainable finance* focuses on the long-term welfare of the society through growth and development, the longevity of the natural resources through optimal utilisation, etc., similarly, *environmental, green, and climate finance* address similar issues, but with a concentration on distinct problem areas.

The climate finance is the financial tool that overlaps all the available options which helps deal with problems arising due to carbon emissions and effecting ecological balance, thus this study tries to address the aforementioned issue with the support of climate finance. Climate finance is categorized into two parts; Adaption and Mitigation finance. Adaption finance assists in dealing with present challenges caused by changing weather patterns, with a causal impact from melting glaciers and increasing sea levels. Whereas Mitigation finance helps to reduce the GHG emissions that effect climate, thus minimizing and controlling the change.

Agriculture requires climate finance to mitigate the effects and adapt to climate change; consequently. Thus, to address the issue financial instruments can be used, that comprise a vast array of financial mechanisms designed to mobilize funds and direct investments toward climate-friendly projects and initiatives, as well as the transition to a more sustainable and low-carbon future.

Various countries can effectively channel resources, incentivize sustainable practices, and foster the adoption of climate-smart agriculture by integrating climate finance instruments into agriculture. This integration is crucial for developing climate resilience, reducing greenhouse gas emissions, and ensuring the long-term viability of agricultural systems in the face of climate change (Bera et al., 2022; Vaidya and Bhardwaj, 2021).

Fig: 2



Source: Author's

6.1 Adoption Finance

The use of adoption finance as a climate finance instrument assists in easing the current effects of climate change, such as the cultivation of heat-resistant crops. It emphasizes current issues to ensure the survival of the agriculture industry. Because solutions to climate change take time to bear fruit, so it's difficult to make long-term plans without first attending to the here and now. Thus, through the provision of financial resources, adoption finance facilitates the transition of farmers towards sustainable farming practices. This includes the adoption of climate-smart agriculture such as precision farming, agroforestry, drip irrigation systems, use of biofertilizers, conservation agriculture, etc which optimize resource utilization, aids in water retention, improves soil structure and aeration (Blanco and Lal, 2008) thus reducing the variability due to weather conditions and raise the farmer system resilience against the climate change. Moreover, adoption finance enables farmers to access sustainable inputs like organic fertilizers, biopesticides, and disease-resistant seeds, encouraging the adoption of environmentally friendly practices and minimizing negative impacts on ecosystems and human health. This, in turn, leads to improvements in soil health, water quality, and biodiversity conservation.

Agriculture is highly susceptible to climate change impacts such as extreme weather events, changing precipitation patterns, and the spread of pests and diseases. Adoption finance can support investments in resilient infrastructure, early warning systems, and insurance schemes, enabling

farmers to adapt to these challenges (Lipper et al., 2014; Thornton et al., 2018). By strengthening the resilience of agricultural systems, adoption finance contributes to sustainable farming practices that can withstand climate uncertainties and ensure the continuity of food production (Lobell et al., 2014; Banerjee et al., 2021).

Additionally, adoption finance plays a critical role in supporting capacity building programs, training, and knowledge transfer initiatives, enhancing farmers' understanding of sustainable agricultural practices and enabling effective implementation. This empowers farmers with the necessary skills, techniques, and knowledge such as information on weather patterns, soil moisture, and other factors that can affect crop yields, thereby enhancing their resilience to climate change and improving agricultural productivity.

Furthermore, adoption finance contributes to the development of sustainable agriculture value chains by connecting farmers to buyers that prioritize environmentally friendly and socially responsible practices. By incorporating sustainability criteria, adoption finance stimulates market demand for sustainably produced agricultural products, benefiting farmers economically and incentivizing the adoption of sustainable practices throughout the value chain. Collectively, the effective utilization of adoption finance holds immense promise in fostering the transition towards sustainable agriculture, achieving environmental awareness, enhancing farmers' livelihoods, and securing a sustainable future for agriculture and world.

Table 2: Useability of Adoption finance

Activity	Sustainable Measures	Use of Grants	Use of Concessional Loans
Crop Residue	Promoting residue management techniques	Funding equipment	Providing low-interest loans/ Subsidizing credit
Livestock	Encouraging sustainable animal husbandry practices	Supporting infrastructure	Financing livestock upgrades
Fertilizers	Promoting organic and balanced fertilizer use	Subsidizing organic fertilizers	Offering low-interest loans
Over-tilling	Promoting conservation tillage practices	Providing training	Offering equipment loans
Monoculture Farming	Encouraging crop diversification and intercropping	Supporting crop rotation	Financing diversification/ Compensation schemes

(Source: Author's)

Note: Adoption finance is supported by a combination of public and private sources. Private organizations, foundations, non-governmental organizations (NGOs), and international institutions may also provide financial support for climate adoption finance

6.2 Mitigation Finance

Mitigation finance facilitates the adoption of practises that control, minimize, and reduce carbon emissions. As agricultural and livestock activities accounted for 5.3 billion tonnes of methane and nitrous oxide emissions in 2018, an increase of 14% since 2000 (FAO, 2018). Hence mitigation finance is an instrument of climate finance that has emerged as a promising approach to support sustainable agriculture in the face of climate change.

Several studies have highlighted the benefits of directing mitigation finance towards adoption of strategies that minimizes GHG emissions, like *efficient use of fertilizers* through precision

agriculture techniques that controls nitrous-oxide released into the atmosphere; *zero-tillage* that helps to improve the soil's health; *rice-water management* to control the methane emissions; *agroforestry* that absorbs CO₂ from air, prevents soil erosion and provides wildlife habitat; *renewable energy* sources like solar or wind energy thus reducing the burden on fossil fuels etc (Seymour et al., 2016; Béné et al., 2019). By allocating funds to these practices, mitigation finance enables farmers to increase productivity while simultaneously reducing greenhouse gas emissions.

Additionally, mitigation finance can play a pivotal role in promoting sustainable land use practices. Investments directed towards initiatives such as reforestation, afforestation, and sustainable land management can effectively mitigate climate change by sequestering carbon dioxide from the atmosphere (Dixon et al., 2019; De Figueiredo et al., 2021).

Furthermore, mitigation finance plays an essential function in facilitating the transmission of technology and capacity building within the agricultural sector. Research and development activities funded through mitigation finance enable the dissemination of innovative technologies and techniques that enhance agricultural productivity and reduce emissions (Osmond et al., 2017; Vermeulen et al., 2018). Investments in education and training programs supported by mitigation finance empower farmers with the necessary knowledge and skills to implement climate-smart practices effectively (Andersson et al., 2019). These initiatives are essential for ensuring the successful adoption and implementation of sustainable agricultural practices.

As global efforts to combat climate change intensify, investing in mitigation finance becomes imperative for achieving a sustainable and food-secure future. The provision of financial resources for climate-smart practices, technology transfer, renewable energy, capacity building, and sustainable land use has the potential to transform agricultural systems that reduces its carbon emissions thus controlling the climate change.

7. Private and Institutional investors

As stated above, solely public sector cannot defend the climate change effects, thus the support from private sector investors is needed. Private sector plays an important role to fill the gap between the required and available funds to fight against climate change (Khanna et al., 2022). Due to the agricultural sector's lack of attention (Khanna and Purkayastha, 2022), private investors are also investing in research and development for renewable energy sources, electric automobiles, and green buildings, among other things. As a result, to accommodate investor demand, the market provides a number of vehicles for investments in these areas, with green bonds being the most popular. These financial methods can also be used by the agriculture industry to encourage private investment.

Additionally, the huge gap exists in adaption and mitigation funds, as around 2.2 billion USD have been allotted to India out of which around 700 million USD is used for resilience agriculture i.e., for adapting to climate change. Thus, mitigating climate change is suffering a lag in demand and supply of funds. Thus, the possibility to cover the gap of public sector funds is through private sector funding.

Green bond being the widely accepted tool, supports projects with specific criteria of development that helps in reducing carbon emissions. Another tool to raise funds for environmental amelioration in market is *Green Schuldschein*- it is a hybrid of a loan and a bond that a large dairy company uses to finance the reduction of its environmental footprint (Friesland Campina, 2016). This tool

can be used as an alternative by the dairy companies to raise funds from the private investors to address issues related to the GHG emissions. Hence, these kinds of financial tools can attract capital from investors to mitigate the climate change

To establish the green financing system, China has formalized the sustainability-enhancing window guidance which will motivate financial institutions to increase *credit* for sustainable activities and reduce credit to polluting industries. This credit can be utilized by the farmers, being the part of supply-chain to adapt sustainable agriculture practices to adapt and mitigate climate change (Dikau and Voz, 2021). Social-Responsible investment (*sukuk*) by Islamic banking, can also be used as an instrument to finance organic agricultural activities. As this instrument helps to raise funds to support micro-finance and improve financial inclusion among farmers (Ghelich, 2019). *Resilience bond* is the tool that aids in climate adaptation by financing the investment in infrastructure or farming practices that build resilience against natural calamities and at the same time spread the risk among the investors (Cox, 2022). This market can be further enhanced through various innovative financial instruments, thus making the agriculture sector an asset class (Ouma, 2014; Veelen 2021).

7.1 Impact and Responsible Investors:

Impact investors play a unique role in advancing sustainable agriculture through climate mitigation finance, complementing the efforts of institutional and private investors (Mattoon, 1938; Gibson et al., 2019). In the area of livestock, impact investors can prioritize investments that not only support sustainable livestock practices but also prioritize animal welfare and promote regenerative grazing systems through investing in financial instruments like Green *Schuldschein* (Scoones, 2022). They can focus on financing projects that integrate holistic management approaches such as solar dryers to enhance the life of crop, solar panels as energy alternative, and promoting sustainable land use practices like agroforestry. In soil over tilling, impact investors can emphasize investments in regenerative agriculture, which promotes soil health through practices like no-till farming, cover cropping, and rotational grazing (Ogieriakhi & Woodward, 2022; World Business Counsel for Sustainable Development, 2018). By supporting regenerative practices, impact investors contribute to carbon sequestration, improved water retention, and enhanced soil fertility (World Business Counsel for Sustainable Development, 2018). In ground water management, impact investors can fund projects that promote water-efficient irrigation systems, precision agriculture technologies, and sustainable water conservation practices (Levidow et al., 2014; Carroll, 2020). Impact investors can prioritize investments in projects that promote responsible crop residue management, such as investing in technologies for residue utilization and developing markets for biomass products (Downing et al., 2022; Ravindra, Singh, & Mor, 2021). In renewable energy, impact investors can focus on financing community-based renewable energy projects, decentralized energy systems, and off-grid solutions for rural farming communities, enabling them to transition to clean energy sources (European Union European Regional Development Fund, 2020). Lastly, impact investors can promote sustainable agriculture practices by investing in projects that encourage diversification, agroforestry, and the restoration of biodiversity in monoculture-dominated regions (Walter Schindler, 2022). By considering both financial returns and positive environmental and social impacts, impact investors have the potential to drive transformative change in sustainable agriculture and contribute to a more resilient and sustainable food system.

7.2 Government, International Institutions, and Philanthropic Organisations

Philanthropic organizations and government and other international organizations play distinct roles in promoting sustainable agriculture through climate mitigation finance, complementing the efforts of institutional investors, private investors, and impact investors. Philanthropic organizations can provide grants and funding to support research, development, and implementation of innovative solutions in livestock, soil over tilling, ground water management, crop residue, renewable energy, and monoculture farming. They can support capacity-building programs, knowledge sharing initiatives, and awareness campaigns to drive adoption of sustainable practices among farmers. Government and international organizations, on the other hand, have the ability to enact policies, regulations, and incentives that promote sustainable agriculture. They can allocate funds for research and development, provide financial assistance to farmers for adopting climate-smart practices, and establish programs that incentivize sustainable farming techniques. Additionally, government and international organizations can facilitate collaboration among stakeholders, promote sustainable land use planning, and support the implementation of large-scale renewable energy projects in agriculture. By leveraging their resources and influence, philanthropic organizations and government and international organizations play vital roles in mobilizing climate mitigation finance and driving the transition to sustainable agriculture at a broader scale

8. Outcome and Conclusion

The discussion surrounding the utilization of climate finance for promoting sustainable agriculture practices in various domains, including livestock management, soil conservation, groundwater control, crop residue management, renewable energy adoption, and the mitigation of monoculture farming, has garnered significant attention (McKinsey Sustainability, 2021; Davis, 2023). However, despite the allocation of climate finance funds to India, it is evident that these resources have not been fully harnessed through the appropriate channels (Muralidharan et al., 2021). The insufficient utilization of climate finance can be attributed to a multitude of factors, including a lack of awareness, complex application procedures, and inadequate institutional support (IFAD, 2020). The agriculture sector in India is expansive, encompassing both rural and urban regions, underscoring the importance of effectively leveraging climate finance to foster sustainable agricultural practices. To maximize the impact of climate finance, it is imperative to ensure the effective allocation of available funds, avoiding overlapping investments in similar agricultural practices (World Bank Group, 2016).

Climate finance, characterized by its focused approach on climate change mitigation and adaptation, tailored funding mechanisms, and incentives for sustainable farming techniques, emerges as a valuable instrument in addressing the challenges posed by climate change in agriculture. Nevertheless, several challenges hinder the optimal utilization of climate finance within the agriculture sector. These hurdles, which include low awareness, complex application procedures, and a lack of institutional support, can be surmounted through coordination and collaboration among a spectrum of stakeholders, including private investors, institutional investors, impact investors, government agencies, and international organizations (Negra et al., 2020).

The collaborative efforts of private investors, institutional investors, impact investors, philanthropic organizations, governments, and international institutions are instrumental in harnessing climate finance for the betterment of sustainable agriculture. By strategically aligning their initiatives, orchestrating capacity-building programs, and raising awareness among stakeholders, the full potential of climate finance can be realized, catalyzing the transition towards sustainable agriculture. Through the judicious utilization and strategic deployment of climate

finance instruments, coupled with concerted efforts from all stakeholders, we can pave the way for a resilient, climate-smart, and sustainable agricultural sector that ensures food security, bolsters resilience, and curtails greenhouse gas emissions in the face of a changing climate.

The significance of this study transcends agriculture, encompassing the finance and engineering industries. In agriculture, the research provides critical insights into the effective use of climate finance, addressing the pressing issues of food security, environmental sustainability, and climate resilience. In the finance sector, it underscores the importance of innovative financial models and collaborative approaches, facilitating access to and efficient utilization of climate finance. The engineering industry, too, stands to gain from the technological aspects of this research, emphasizing the integration of technology and capacity building in the implementation of sustainable agricultural practices. Engineers, in particular, can play a pivotal role in developing and deploying advanced technologies that support sustainable farming, ultimately contributing to environmental conservation and food production. In essence, this research article acts as a bridge between these industries, offering a comprehensive strategy to address global challenges and pave the way for a more sustainable and resilient future.

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