Biological Forum – An International Journal **15(7): 370-377(2023)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Agroforestry as a Mechanism for Reforestation: Scenarios within REDD+

Alok Kumar Singh[1], Bipin Kumar Singh[2], Nasam Midhun Kumar[1*], Makhan Singh Karada[3], Dheer Agnihotri[4] and Rupali Singh[5]

[1]Department of Silviculture and Agroforestry,
Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (Himachal Pradesh), India.
[2]Department of Agroforestry,
Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (Uttar Pradesh), India.
[3]Department of Forestry, Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur (Madhya Pradesh), India.
[4]Silviculture, Forest Management and Agroforestry Division,
Tropical Forest Research Institute, Jabalpur (Madhya Pradesh), India.
[5]ICFRE- Eco- Rehabilitation Center, Pryagraj (Uttar Pradesh), India.

(Corresponding author: Nasam Midhun Kumar)*
(Received: 27 April 2023; Revised: 17 May 2023; Accepted: 03 June 2023; Published: 05 July 2023)
(Published by Research Trend)

ABSTRACT: Agroforestry, the deliberate management of trees on farms, is not explicitly included in REDD+ or the current UNFCCC mechanisms. However, many agroforestry systems can be integrated into REDD+ by meeting the UNFCCC forest definition, which sets specific land area, tree crown cover, and tree height criteria. Approximately 46% of global agricultural land already meets at least 10% tree cover, with Southeast Asia and Central America at 50%, and Sub-Saharan Africa at about 15%. These figures indicate that most tree crop production and agroforestry systems qualify as forests under REDD+. Agroforestry contributes to REDD+ in two ways: by meeting specific forest definitions and being part of a broader landscape strategy. It has the potential to reduce degradation by providing sustainable timber and fuelwood, reducing reliance on distant forests. Such study even faces challenges in assessing the socio-economic impacts, monitoring carbon sequestration in agroforestry systems, and implementing policies that incentivize farmers to adopt agroforestry practices for successful reforestation within the framework of REDD+. To effectively contribute to REDD+ and INDCs goals, factors like market infrastructure, tree rights policies, and safeguards must be addressed. Recognizing the benefits of emission reductions, biodiversity preservation, and improved livelihoods, countries should prioritize agroforestry in their REDD+ strategies to enhance its role in achieving the objectives of REDD+ and INDCs. challenges in assessing the socio-economic impacts, monitoring carbon sequestration in agroforestry systems, and implementing policies that incentivize farmers to adopt agroforestry practices for successful reforestation within the framework of REDD+.

Keywords: Agroforestry, CDM, Climate change, GHG emissions, INDCs, REDD+.

INTRODUCTION

REDD+ programs were once seen as a potential revolutionary for tropical forests, but progress has been gradual in implementing the ideas (Minang and Van-noordwijk 2013). REDD+ is designed to reward countries for preserving forests and reducing emissions, but specifics are still being discussed within the United Nations Framework Convention for Climate Change (UNFCCC, 2008). It encompasses various elements like Deforestation decreases emissions, decline in forests, carbon stock conservation, equitable forest management, and carbon stock conservation enhancement. The core concept of REDD+ revolves around forests. Ideally, REDD+ ought to be optional, performance-oriented (measurable and verifiable), and egalitarian, with the goal of generating extra long-term advantages such as safeguarding biodiversity. Other land uses, such as forests (REDD+), agriculture (sectoral methods), and afforestation/reforestation (Clean Development Mechanism) have secured specific places within the UNFCCC, agroforestry remains less prominent, notwithstanding its documented benefits for adaptation and mitigation of climate change in research (Verchot *et al.*, 2007; Albrecht and Kandji 2003; Montagnini and Nair 2004; Thorlakson and Neufeldt 2012).

Agroforestry, a deliberate practice involving the Tree incorporation and administration in farming and landscaping, finds itself in a unique position as a second-tier land usage, straddling both forestry and agriculture. (Kumar *et al.*, 2021; Sharma *et al.*, 2022b). The challenge lies in how it is linked to these domains, with varying perspectives depending on the data gathering and characterization of dominant forests methods employed by FAO. Additionally, the

UNFCCC faces difficulty in accommodating Swidden-fallow systems, which, depending on the perspective, can be seen as either the administration of forests, forest loss, or destruction of forests. The absence of a clear classification for agroforestry within the UNFCCC can be both advantageous and disadvantageous. On one hand, it allows for flexibility, potentially benefiting from multiple mechanisms. On the other hand, this lack of clarity poses the risk of insufficient attention within any of the existing mechanisms. Regrettably, agroforestry has not received the necessary focus within the UNFCCC mechanisms, including REDD+, despite its immense potential (Mertz *et al.,* 2012). As a result, the true value and contributions of agroforestry have yet to be fully recognized and integrated into Mitigating and adapting measures for changing the climate (Sharma *et al.,* 2022a).

A. REDD+ evolution under the UNFCCC

REDD's development occurred through a collection of international discussions, conventions, pacts, and treaties. During the 11th Conference of the Parties (COP11), the Coalition of Rainforest Nations advanced the idea in 2005. The initial document proposed using foreign funding from developed nations to minimize carbon emissions from degradation in tropical areas. In 2007, the Bali Decision on Deforestation recognized the role of deforestation and forest degradation in greenhouse gas emissions and called for urgent action in reducing them. This decision supported various initiatives, including demonstration projects, to combat decline in forests and deforestation while encouraging financial and technical support from convention parties and others.

In 2008, REDD evolved into REDD+ when the UNFCCC expanded its scope. It now includes the involvement of native people, side advantages including protecting biodiversity, improving forest monitoring, and preserving current forest carbon stores. The Cancun Agreements of 2010 further developed REDD+, addressing deforestation drivers, land tenure, forest governance, gender issues, and relevant stakeholders' participation (Cancun Safeguards). The agreements established a set of activities under REDD+, which include protecting forest carbon reserves, improving forest carbon stocks (Nasam *et al.,* 2022) and encouraging sustainable forest management; lowering emissions from deforestation and forest degradation. In addition to these activities, participating parties were necessary to create national plans for the implementation of REDD+, establish national forest emission reference levels, put in place forest monitoring systems, and address safeguards to ensure the effectiveness and sustainability of REDD+ initiatives. In 2013, the Warsaw Framework for REDD+ was formulated based on earlier COP decisions, serving as the "REDD+ implementation guide". In 2015, A structure for an international carbon trade to provide monetary assistance for REDD+ was added in Article-6 of the Paris Agreement (PA) the same year that REDD+ was introduced to Article-5 of the agreement.

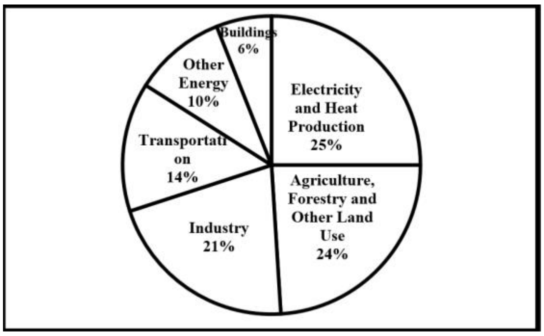

Fig. 1. Global GHG emissions by different economic sector (IPCC, 2014).

B. Deforestation and forest degradation

Deforestation and forest degradation are among the most significant global dangers to forests (Liang and Gamarra 2020). Deforestation involves the conversion of forested areas into non-forest lands for activities such as agriculture and road construction, while forest degradation refers to the loss of vital resources and services that forest ecosystems provide to both humans and the environment (IPBES, 2019). Since the 1960s, The destruction of over half of the the globe's tropical forests, with over one hectare lost or severely degraded every second (Liu *et al.,* 2019). These losses have far-reaching consequences, affecting communities depending on the forest, biodiversity, and the global climate. Stopping the rate of destruction and forest loss, increasing carbon storage in forests, and improving forest management are essential to combating global warming and safeguarding biodiversity. (Seddon *et al.,* 2021; Naz *et al*., 2020). Between 1990 and the present, due to the transfer of forest land to various land uses, almost 420 million hectares of forest have been lost. (Mekuria *et al*., 2021). However, there is some encouraging progress in recent decades. The rate of deforestation has shown improvement, with around 10 million hectares of forest lost annually between 2015 and 2020, compared to 16 million hectares per year in the 1990s (FAO, 2020). Primary forests, which are essential for preserving biodiversity and storing carbon, have also suffered considerable losses. The world has witnessed a decrease of more than 80 million hectares of primary forest since 1990 (FAO, 2020). In addition, more than 100 million hectares of forests are significantly impacted by pests, diseases, invasive species, droughts, and other unfavourable weather conditions, which exacerbates the difficulties encountered by forest ecosystems. (FAO, 2020).

Addressing these threats and implementing effective conservation measures will be crucial in safeguarding the future of our precious forest ecosystems, preserving their biodiversity, and mitigating climate change (IPBES, 2019; Romanak *et al*., 2021). Collaborative efforts from governments, organizations, and individuals worldwide are essential to ensure the sustainable management and protection of forests for generations to come (Santoro *et al.,* 2020; Hansen *et al*., 2013).

C. Drivers of Deforestation and Forest Degradation

Deforestation and forest degradation are the outcomes of diverse factors known as drivers, which can be classified as direct and indirect (Angelsen *et al*., 2014). Direct drivers are human behaviours that directly affect the amount of forest cover, which results in the loss of forest carbon. Indirect drivers, on the other hand, include social, economic, political, cultural, and technical activities that support the occurrence of direct drivers. (Geist & Lambin 2002). These drivers are different among locations and nations and dependent on circumstance, largely arising from the demand for specific commodities. Globally, deforestation and forest degradation are significantly driven by the expansion of agriculture to meet the growing demand for commodities like palm oil, soy, and cattle for beef and leather (FAO, 2020). Additionally, the demand for bioenergy sources such as fuelwood and charcoal also contributes to deforestation (Angelsen *et al*., 2014). Human-induced activities like overgrazing, excessive logging, and fires further exacerbate forest degradation (Geist and Lambin, 2002). Natural causes like insect pests, storm damage, and natural fires also play a role in forest degradation (FAO, 2020).

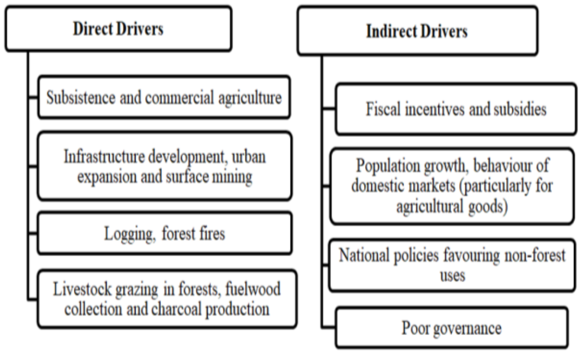

Fig. 2. Drivers of deforestation and forest degradation.

In the tropics, the primary driver of deforestation is the need for land for crop cultivation and livestock rearing (Kissinger *et al*., 2012). Forest loss is also greatly aided by businesses like mining, timber harvesting, and building new infrastructure (Geist and Lambin 2002). Poor forest and land-use governance, coupled with increased food, animal feed, and fuel requirements, make agriculture the predominant driver of deforestation, responsible for up to 80% of global deforestation (Angelsen *et al*., 2014; FAO, 2020). While subsistence farming remains the main cause of deforestation in India, Latin America and Southeast Asia are experiencing a rise in commercial agriculture (Kissinger *et al*., 2012). Global commodities markets will increasingly have an impact on deforestation as middle-income nations continue to rise. (Angelsen *et al*., 2014). Certain commodities such as beef and leather, soy, palm oil, sugar, cacao, timber, pulp, and paper are major contributors to deforestation worldwide (Geist and Lambin 2002). Addressing these diverse drivers will be essential to effectively combat deforestation and forest degradation, ensuring the preservation of valuable forest ecosystems and their vital roles in climate regulation and biodiversity conservation (FAO, 2020; Kissinger *et al*., 2012).

D. Agroforestry: Tool for REDD+

The deliberate management of trees on farms, or agroforestry, is not explicitly mentioned in the current United Nations Framework Convention for Climate Change (UNFCCC) mechanisms, including REDD+. However, many current agroforestry systems globally may be suitable for inclusion into a REDD+ mechanism based on the UNFCCC's forest definition as stated in the Kyoto Protocol. (Van-noordwijk and Minang, 2009; Sharma *et al*., 2021). The UNFCCC's forest definition has three key components, with particular emphasis on the first:

1. Forest is defined by country-specific thresholds for canopy cover (10-30%) and tree height (2-5 meters).
2. These thresholds are determined through "expert judgment" based on the potential to reach such conditions in situ, not necessarily the current vegetation.
3. If a state forest organisation feels that temporarily unstocked lands will, can, or should revert to tree cover conditions, the term "temporarily" remains ambiguous, the areas can still be regarded as forests.

Considering the first rule, a significant number of agroforestry systems fall within the threshold canopy cover of 10-30%, making them automatically eligible for REDD+. Studies conducted by Zomer *et al*. (2009) indicate that approximately 46% of agricultural land globally possesses at least 10% tree cover, with Southeast Asia and Central America having 50% of agricultural land with at least 30% tree cover, and Sub-Saharan Africa with about 15% having similar tree cover. Given that some tree crops, like unpruned coffee, may easily reach a height of five metres, these findings suggest that the majority of tree crop production and agroforestry systems satisfy the minimal forest needs. (Van-noordwijk and Minang, 2009; Sharma *et al*., 2022a).

Table 1: Potential linkage between agroforestry and REDD+ options.

Role of Agroforestry	REDD+ option	Pathway
Agroforestry as part of REDD+	Enhancing carbon stores, conserving agroforest carbon reserves, and sustainable management of agroforests	Agroforest carbon is specifically targeted and compensated for by REDD+.
Using agroforestry to combat the causes of deforestation	lowering deforestation-related emissions	Diversifying and long-term growth
Utilising agroforestry to address the causes of deterioration	lowering emissions caused by deforestation	Growth of fuel wood and timber on-farm

Countries that opt for the lower limit of 10% canopy cover can potentially include more agroforestry systems within the REDD+ mechanism (Verma et al., 2021; 2023c) leading to increased opportunities for sustainable land-use practices to contribute to climate change mitigation (Van-noordwijk and Minang 2009). Table 1 summarizes the potential linkages between agroforestry and REDD+ options.

E. Agroforestry as a strategy to reduce deforestation

According to the land-saving or intensification hypothesis, investments should be made in agriculture to boost production per unit area by using better technology and more inputs. Once these interventions secure sufficient food, fuel, and fiber supply, less forest land would be cleared for agriculture, thus preserving more forests for conservation (Borlaug, 2007). Agroforestry has proven to be a significant sustainable intensification practice in various parts of India, positively impacting soil fertility and productivity by incorporating nitrogen-fixing trees and providing biodiversity benefits (Garima *et al.*, 2021; Verma *et al.*, 2023a, 2023b). Consequently, agroforestry emerges as a promising approach for achieving land sparing. Furthermore, sustainable intensification offers opportunities for profitable labor utilization, diverting labor away from deforestation activities (Sharma *et al*., 2017a, 2017b). Gockowski and Sonwa (2011) the Guinean rainforest of West and Central Africa (Cote D'Ivoire, Ghana, Nigeria, and Cameroon) could have saved 21,000 km^2 of forests and decreased emissions by nearly 1.4 billion tonnes of CO2 if intensifying cacao (*Theobroma cacao* L.) agroforestry systems through seed-fertilizer technologies and integrating timber species had they been implemented in the late 1960s. This is in contrast to the baseline scenario of extensive cacao, cassava, and oil palm expansion into forest areas, accounting for approximately 68,000 km^2 over the same period. Strategies for sustainable intensification and diversification, particularly in areas where large-scale small farm holdings are the main causes of deforestation, can be successful.

F. Agroforestry as a strategy to reduce degradation

Fuel wood, charcoal, and timber have been identified as primary drivers of forest degradation in numerous countries, and in some cases, they contribute to deforestation, particularly in arid forest regions like Burkina Faso in Africa. Consequently, promoting on-farm timber and fuelwood production holds promise in easing the pressures on forests caused by rising demands for these resources. On-farm timber production is gaining traction as a mainstream source of timber in various tropical countries worldwide (Robiglio *et al*., 2011; Babu *et al*., 2022).

Studies, such as Kimaro *et al*., (2011), showcase the significant role of rotational woodlot systems in reducing forest degradation and offsetting CO2 emissions through on-farm wood supply in semi-arid Morogoro, Eastern Tanzania. After a 5-year cycle, they discovered that the wood output (23 - 51 Mg C ha^{-1}) was adequate to fulfil family fuelwood needs. They also offered proof that the highly productive acacia fallows (*Acacia crassicarpa A. Cunn*. Ex Benth., *Acacia leptocarpa A. Cunn*. Ex Benth., and *Acacia mangium* Wild) needed just 4 to 9 years to replenish the carbon lost by the clearing of Miombo woodland for agricultural development. whereas re-growing Miombo Woodlands necessitated two decades. In Sumatra, Indonesia's Kirinci Seblat National Park, Murniati *et al*., (2001) demonstrated that households with diversified farms (including wetland rice fields and mixed gardens) relied far less on adjacent national park resources compared to households engaged solely in wetland rice farming. Similarly, households with mixed gardens exhibited intermediate dependence on forest resources, particularly in terms of product values. These and other studies underscore the potential of agroforestry diversification in mitigating the mounting pressures on forests (Panwar *et al.*, 2022; Bhardwaj *et al.*, 2023).

G. Afforestation/Reforestation – Clean Development Mechanism

The Clean Development Mechanism (CDM), as defined in Article 12 of the Protocol, enables countries with emission-reduction commitments under the Kyoto Protocol to implement emission-reduction projects in developing nations. These projects can earn certified emission reduction (CER) credits, each equivalent to one tonne of CO2 (Kumar *et al.*, 2023; Iram and Shah 2017) The 1997 Kyoto Protocol established binding targets for greenhouse gas (GHG) emission reductions on Annex I countries (UNFCCC, 2008). To achieve these targets, these countries adopted national measures and three flexible, market-based mechanisms: Emissions Trading, Joint Implementation (JI), and the Clean Development Mechanism (CDM). The CDM has two main goals: promoting sustainable development in host countries and aiding industrialised nations in achieving their emission reduction targets through the purchase or creation of carbon offsets (Sharma *et al.*, 2021).

Essentially, the CDM enables industrialised countries to reach some of their emission reduction goals by acquiring carbon offsets from CDM-registered projects or by initiating/financing such initiatives. Although the CDM recognises a variety of activities that result in carbon offsets, all CDM project activities must be carried out in non-Annex I (host) countries and must advance their sustainable development goals (Figueres, 2006). The geographic limitations on CDM operations and their emphasis on sustainable development set them apart from JI and other carbon-market activities that create or accept various kinds of carbon offsets. Certified Emission Reductions (CERs), which are created via all CDM project operations, are carbon offsets that are equal to one metric tonne of carbon dioxide. Within the CDM, afforestation and reforestation are the sole recognized Land Use, Land-Use Change and Forestry (LULUCF) activities (as designated in Article 3.3 of the Kyoto Protocol) that can create CERs (Schlamadinger *et al*., 2007; Khan and Khan 2020). However, it is anticipated that a post-2012 climate agreement will likely alter the CDM, potentially broadening recognized activities in the LULUCF classification or introducing new classifications such as Agriculture, Forestry, and Other Land Uses (AFOLU) and Reduced Emissions from Deforestation and Forest Degradation (REDD+) (Thomas *et al.*, 2010). There is widespread agreement that CDM A/R (Afforestation/Reforestation) projects have the ability to store carbon and aid in sustainable development. (Jindal *et al*., 2008; Streck and Scholz, 2006; Timilsina *et al*., 2010; Boyd *et al*., 2007). Nevertheless, there are diverging opinions concerning the global implementation of such projects (Unruh, 2008), the definition of "sustainable development" and its implications (Olsen, 2007), the actual contribution of market mechanisms to carbon mitigation, and the equitable distribution of benefits from carbon forestry projects, including CDM A/R projects (Tschakert *et al*., 2007; Gundimeda, 2004; Nelson and De Jong, 2003). In fact, the amount of afforestation and reforestation projects that the CDM has certified has been hampered by challenges with the design, cost effectiveness, and execution of potential A/R projects. In the beginning, there was just one A/R project registered among almost 1,400 CDM projects by early January 2009, and that project was China's Facilitating Reforestation for Guangxi Watershed Management in Pearl River Basin. However, by May 2010, there were 14 registered CDM A/R projects (out of 2,171 total registered CDM projects), and there were another 41 CDM A/R projects that were either being reviewed, being validated, or seeking registration. If all 41 applicants are registered, these 55 A/R projects are projected to produce 15,780 CERs (0.6%) of the 2,854,824 CERs expected to be generated by all CDM projects by 2012 (Fennhan, 2010). Individually, the 14 currently registered CDM A/R projects are expected to capture around 8,084 kg tons of carbon dioxide by 2020 (Fennhan, 2010).

H. Lands suitable for CDM-AR

Globally, it has been found that over 760 million hectares (Mha) of land meet the minimal eligibility criteria for Clean Development Mechanism - Afforestation and Reforestation (CDM-AR) activities, both statutory and biophysical (Fig. 2). Just over 9% of all Non-Annex I nations' land surface area is represented by this region. With the exception of a few nations in Europe and Central Asia, which combined make up a small fraction of appropriate land, the global totals provided in this research include six areas that span the majority of the countries with considerable CDM-AR potential. Initially, 749 Mha of land were determined to be biophysically appropriate among these six zones.

According to Sathaye and Ravindranath (1998), in 10 tropical and temperate Asian nations, an estimated 300 Mha of land may be accessible for mitigation, comprising 181 Mha of degraded land suitable for plantation forestry and 79 Mha of degraded forestland suitable for regeneration. Another study by Zomer *et al.* (2008) Large tracts of appropriate land were found in Sub-Saharan Africa (27%) and South America (46% of all eligible areas globally), which may be ascribed to these regions' bigger landmasses and, to some degree, lower population concentrations. In comparison, South America and Africa constitute about 330 Mha and over 200 Mha, respectively, whereas the three Asian areas together only make up around 200 Mha, with Southeast Asia making only 8% of the world's land surface. It is significant to highlight that these estimations may overstate the real accessible areas because they are primarily based on biophysical parameters and UNFCCC regulations.

In actuality, a more intricate collection of factors, including national, local, and site-specific socio-economic and ecological settings, determines the locations that may be suitable for CDM-AR initiatives. These variables include elements like land opportunity costs, market access, land and tree tenure, national level infrastructure, and assistance, in addition to CDM-AR regulations and tree growth characteristics. As a result, only a much smaller fraction of the appropriate area identified will satisfy the more stringent requirements needed for CDM-AR to be a practical alternative for landowners, land managers, communities, and/or national planners (Sharma *et al.*, 2021).

I. The challenges for agroforestry in REDD+

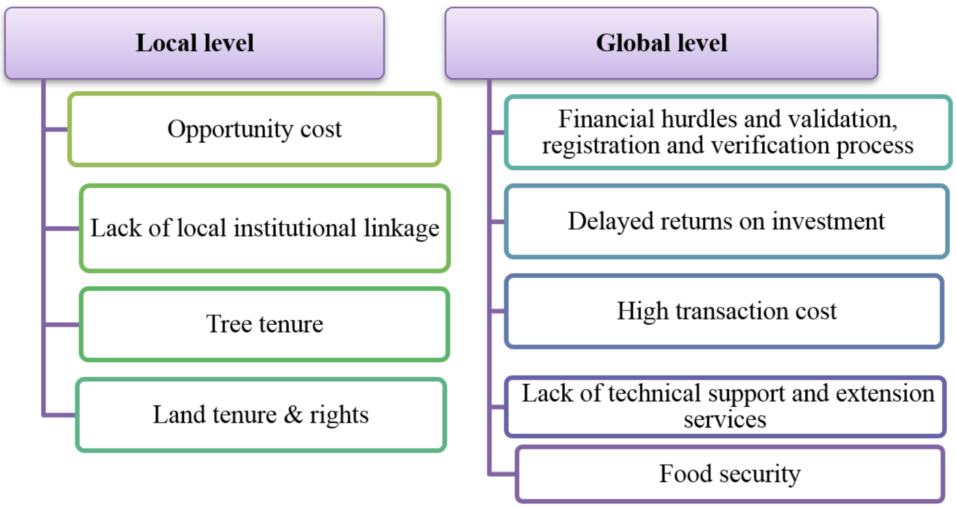

Fig. 3. Challenges for agroforestry in REDD+.

CONCLUSION

Agroforestry has the potential to play a significant role in REDD+ programs, contingent on how each country defines its forests. By incorporating agroforestry into REDD+, it can serve as a viable and sustainable pathway for intensification and diversification, effectively curbing deforestation. Notably, the demand for fuel wood, charcoal, and timber acts as primary drivers of forest degradation. However, agroforestry can address this issue by increasing on-farm timber and fuel wood production, thereby reducing the pressures on natural forests.

Agroforestry also helps REDD+ projects that focus on improving and preserving carbon stocks. Through the intentional integration of trees on farms, agroforestry can mitigate emissions from forest degradation while fostering sustainable land use practices. Moreover, agroforestry provides an increasing agricultural yield is a chance for farmers to boost their revenue, making it a key driver in climate change mitigation efforts. By embracing agroforestry as part of their REDD+ strategies, countries can harness its multiple benefits to foster sustainable development and combat climate change.

FUTURE SCOPE

Countries should prioritize agroforestry by giving it a special place in their strategies for Reducing Emissions from Deforestation and Forest Degradation (REDD+) and Nationally Appropriate Mitigation Actions (NAMAs). Agroforestry offers significant benefits in terms of emission reductions, biodiversity conservation, and improved livelihoods. Therefore, it is essential to assess whether the current forest definition under REDD+ adequately includes agroforestry and other tree-based systems and their associated benefits. Policymakers must also consider directing REDD+ funds towards intensification pathways, including agroforestry, as these pathways can substantially contribute to achieving REDD+ goals. However, there has been limited exploration of such approaches and the development of a comprehensive policy framework for managing agriculture as a driver of deforestation within the REDD+ context. Thus, more research is needed at both scientific and policy levels to effectively integrate agroforestry into REDD+ strategies.

Agroforestry and other tree-based systems can play a crucial role in enhancing synergies between climate change mitigation and adaptation. One way to promote these systems is by utilizing adaptation funding to support agroforestry and tree-based farming practices. Although these systems have the potential to contribute to emission reduction, they may face challenges in terms of initial investments, especially during the initial two years when no immediate revenues are expected. Integrating adaptation funding into these projects can optimize both mitigation and adaptation efforts, which are currently facing shortages of funding. Policy reforms for REDD+ should encompass legal, incentive, and market frameworks that facilitate tree-based enterprises and their role in emission reduction beyond traditional "forests." Evidence from Asia, Africa, and Latin America indicates that the success of agroforestry and tree-based systems depends on robust market infrastructure, value addition to tree products and services, and comprehensive extension services. For instance, experiences from Niger's tree rights reforms and the subsequent transformation it fostered, as well as market-oriented policy reforms in Vietnam's coffee sector, offer valuable lessons for shaping the necessary approach (Minang *et al*., 2011).

Conflict of interest: None

REFERENCES

Albrecht, A. and Kandji, S. T. (2003). Carbon sequestration in tropical agroforestry systems. *Agriculture Ecosystem and Environment, 99*, 15-27.

Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N. J., Bauch, S. and Wunder, S. (2014). Environmental income and rural livelihoods: a global-comparative analysis. *World development, 64*, S12-S28.

Babu1, B. H., Kumar, M. K. E., Arya, S. Kumari, B. and Nanda, K. (2022). Mapping and change detection analysis of agroforestry area in Ambala District of Haryana State, India using geospatial techniques. *Biological Forum – An International Journal, 14*(2), 450-456.

Bhardwaj, D. R., Salve, A., Kumar, J., Kumar, A., Sharma, P., and Kumar, D. (2023). Biomass production and carbon storage potential of agroforestry land use systems in high hills of north-western Himalaya: an approach towards natural based climatic solution. *Biomass Conversion and Biorefinery*, 1-14.

Borlaug, N. (2007). Sixty-two years of fighting hunger: personal recollections. *Euphytica, 157*, 287-297.

Boyd, E., Gutierrez, M. and Chang, M. Y. (2007). Small-scale forest carbon projects: Adapting CDM to low-income communities. *Global Environmental Change-Human and Policy Dimensions, 17*(2), 250-259.

FAO, (2020). Food and Agriculture Organization of the United Nations, World Food and Agriculture. Statistical Yearbook, Rome.

Fennhan, J. (2010). UNEP Risoe CDM/JI pipeline analysis and database. Retrieved from.

Figueres, C. (2006). Policies and programs under the CDM, Sectoral CDM: Opening the CDM to the yet unrealized goal of sustainable development. *McGill International Journal of Sustainable Development Law and Policy, 2*(5), 5–26.

Garima, Bhardwaj, D. R., Thakur, C. L., Kaushal, R., Sharma, P., Kumar, D. and Kumari, Y. (2021). Bamboo- based agroforestry system effects on soil fertility: Ginger performance in the bamboo subcanopy in the Himalayas (India). *Agronomy Journal*, *113*(3), 2832-2845

Geist, H. J. and Lambin, E. F. (2002). Proximate causes and underlying driving forces of tropical deforestation: Tropical forests are disappearing as the result of many pressures, both local and regional, acting in various combinations in different geographical locations. *BioScience*, *52*(2), 143-150.

Gockowski, J. and Sonwa, D. (2011). Cocoa intensification scenarios and their predicted impacts on CO2 emissions, biodiversity conservation and rural livelihoods in the Guinea rainforest of West Africa. *Environmental Management, 48*, 307-321.

Gundimeda, H. (2004). How 'sustainable' is the 'sustainable development objective' of CDM in developing

countries like India. *Forest Policy and Economics, 6*(3–4), 329–343.
Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A. and Townshend, J. (2013). High-resolution global maps of 21st-century forest cover change. Forest Science, *342*(6160), 850-853.
IPCC. (2014). Climate change 2014 synthesis report. IPCC: Geneva, Szwitzerland, 1059-1072.
IPBES. (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science- Policy Platform on Biodiversity and Ecosystem Services.
Iram, Ar. and Shah D. (2017). Urbanization and environment in a sustainability framework –A study of Dehradun. *International Journal on Emerging Technologies, 8*(2), 19-23.
Jindal, R., Swallow, B. and Kerr, J. (2008). Forestry-based carbon sequestration projects in Africa: potential benefits and challenges. *Natural Resources Forum, 32*(2): 116–130.
Khan, A. S. and Khan, A. B. (2020). Assessment of land use and land cover dynamics in shingla river basin using multi temporal satellite imageries. *International Journal on Emerging Technologies*, *11*(1), 263-269.
Kimaro, A. A., Isaac, M. E. and Chamshama, S. A. O. (2011). Carbon pools in tree biomass and soils under rotational woodlot systems in Eastern Tanzania. Carbon Sequestration Potential of Agroforestry Systems: Opportunities and Challenges, 129-143.
Kissinger, G. M., Herold, M. and De-Sy, V. (2012). Drivers of deforestation and forest degradation: a synthesis report for REDD+ policymakers. Lexeme Consulting.
Kumar, R., Kumar, R., Karmakar, S., Kumar, A., Singh, A. K., Kumar, A., and Singh, J. (2023). Impact of Amide Fertilizer on Carbon Sequestration under the Agroforestry System in the Eastern Plateau Region of India. *Sustainability*, *15*(12), 9775.
Kumar, R., Singh, J. K., Singh, A. K., Minz, S. D., and Kumar, N. M. (2021). Boron management in green gram (Vigna radiata L. Wilczek) under Custard Apple (Annona squamosa L.) based agri-horti system in semiarid region. *Annals of Arid Zone*, *60*(3-4), 01-05.
Liang, J. and Gamarra, J. G. (2020). The importance of sharing global forest data in a world of crises. Scientific Data, *7*(1), 424.
Liu, J., Coomes, D. A., Gibson, L., Hu, G., Liu, J., Luo, Y. and Yu, M. (2019). Forest fragmentation in China and its effect on biodiversity. Biological Reviews, *94*(5), 1636-1657.
Mekuria, W., Diyasa, M., Tengberg, A. and Haileslassie, A. (2021). Effects of long-term land use and land cover changes on ecosystem service values: An example from the central rift valley, Ethiopia. *Land*, *10*(12), 1373.
Mertz, O., Muller, D., Sikor, T., Hett, C., Heinimann, A., Castella, J., Lestrelin, G., Ryan, C. M., Reay, D. S. and Schmidt-Vogt, D. (2012). The forgotten D: challenges of addressing forest degradation in complex mosaic landscapes under REDD+. *Danish Journal of Geography*, *1*, 63-76.
Minang, P. A. and Van-noordwijk, M. (2013). Design challenges for reduced emissions from deforestation and forest degradation through conservation: leveraging multiple paradigms at the tropical forest margins. *Land Use Policy, 31*, 61-70.
Minang, P. A., Bernard, F., Noordwijk, M. and Kahurani, E. (2011). Agroforestry in REDD+: Opportunities and Challenges. ASB Policy Brief No. 26, ASB Partnership for the Tropical Forest Margins, Nairobi, Kenya.
Montagnini, F. and Nair, P. K. R. (2004). Carbon sequestration: an underexploited environmental benefit of agroforestry systems. *Agroforestry Systems, 61*, 281-295.
Murniati, G. D. P. and Gintings, A. N. (2001). The contribution of agroforestry systems to reducing farmers dependence on resources of adjacent national parks: a case study from Sumatra, Indonesia. *Agroforestry Systems, 52*, 171-184.
Nasam, M. K., Bheemareeddyvalla, V. R., Vainala, V., Bathula, J. and Bodiga, S. (2022). Influence of Assisted Natural Regeneration in Increasing Carbon Stocks of Tropical Deciduous Forests. *Environment and Ecology*, *40*(1), 82-92.
Naz, S., Mallah, G. A., Solangi, M. A., Chandio, J. A. and Soomro, M. B. (2020). Intelligent system for classification of residential areas in forest. *International Journal on Emerging Technologies*, *11*(5), 531-535.
Nelson, K. C. and de-Jong, B. H. J. (2003). Making global initiatives local realities: carbon mitigation projects in Chiapas, Mexico. *Global Environmental Change: Human and Policy Dimensions, 13*(1), 19–30.
Olsen, K. (2007). The clean development mechanism's contribution to sustainable development: a review of the literature. *Climatic Change*, *84*(1), 59–73.
Panwar, P., Mahalingappa, D. G., Kaushal, R., Bhardwaj, D. R., Chakravarty, S., Shukla, G., ... and Gurung, T. (2022). Biomass production and carbon sequestration potential of different agroforestry systems in India: A critical review. *Forests*, *13*(8), 1274.
Robiglio, V., Minang, P. A. and Asare, R. (2011). On-farm timber production for emission reduction with sustainable benefits at the tropical forest margins. ASB Policy Brief No. 23. ASB Partnership for the Tropical Forest Margins, Nairobi, Kenya.
Romanak, K., Fridahl, M. and Dixon, T. (2021). Attitudes on Carbon Capture and Storage (CCS) as a Mitigation Technology within the UNFCCC. *Energies*, *14*(3), 629.
Santoro, A., Venturi, M., Bertani, R., and Agnoletti, M. (2020). A review of the role of forests and agroforestry systems in the FAO Globally Important Agricultural Heritage Systems (GIAHS) programme. Forests, *11*(8), 860.
Sathaye, J. and Ravindranath, N. H. (1998). Climate change mitigation in the energy and forestry sectors of developing countries. *Annual review of energy and the environment, 23*, 387-437.
Schlamadinger, B., Bird, N., Johns, T., Brown, S., Canadell, J. and Ciccarese, L. (2007). A synopsis of land use, land-use change and forestry (LULUCF) under the Kyoto Protocol and Marrakech Accords. *Environmental Science and Policy, 10*(4), 271–282.
Seddon, N., Smith, A., Smith, P., Key, I., Chausson, A., Girardin, C. and Turner, B. (2021). Getting the message right on nature- based solutions to climate change. Global change biology, *27*(8), 1518-1546.
Sharma, P., Bhardwaj, D. R., Singh, M. K., Nigam, R., Pala, N. A., Kumar, A and Thakur, P. (2022a). Geospatial technology in agroforestry: Status, prospects, and constraints. *Environmental Science and Pollution Research*, 1-29.
Sharma, P., Bhardwaj, D.R., Singh, M.K., Verma, K., Vishwakarma, S.P. and Kumar, D., (2021). Carbon trading in agroforestry: potential prospects and constraints. In Climate change: Adaptation, loss and

damage, Yadav, L., Yadav, S.K. (eds.), Neel Kamal Prakashan, Delhi. pp. 185-197.

Sharma, P., Singh, M. K., and Tiwari, P. (2017b). Agroforestry: a land degradation control and mitigation approach. *Bulletin of Environment, Pharmacology and Life Sciences*, *6*(5), 312-317.

Sharma, P., Singh, M. K., Tiwari, P. and Verma, K. (2017a). Agroforestry systems: Opportunities and challenges in India. *Journal of Pharmacognosy and Phytochemistry*, *6*(6S), 953-957.

Sharma, P., Singh, M., Verma, K., and Prasad, S. K. (2022b). Soil weed seedbank under different cropping systems of middle Indo-Gangetic Plains. *Plant, Soil and Environment*, *68*(11), 542-551.

Streck, C. and Scholz, S. M. (2006). The role of forests in global climate change: whence we come and where we go. *International Affairs, 82*(5), 861–789.

Thomas, S., Dargusch, P., Harrison, S. and Herbohn, J. (2010). Why are there so few afforestation and reforestation clean development mechanism projects. *Land Use Policy, 27*(3), 880-887.

Thorlakson, T. and Neufeldt, H. (2012). Reducing subsistence farmers' vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya. *Agriculture and Food Security, 1*, 15.

Timilsina, G. R., Degouvello, C., Thioye, M. and Dayo, F. B. (2010). Clean development mechanism potential and challenges in sub-Saharan Africa. *Mitigation and Adaptation Strategies for Global Change, 15*(1), 93–111.

Tschakert, P., Coomes, O. T. and Potvin, C. (2007). Indigenous livelihoods, slash-and-burn agriculture, and carbon stocks in Eastern Panama. *Ecological Economics*, *60*(4), 807–820.

UNFCCC. (2008). Clean Development Mechanism, In Brief. Bonn, Germany.

Unruh, J. D. (2008). Carbon sequestration in Africa: the land tenure problem. Global Environmental Change. *Human and Policy Dimensions, 18*(4), 700–707.

Van-noordwijk, M. and Minang, P. A. (2009). Forests and Climate Change: Adaptation and Mitigation. Tropenbos International, Wageningen, 5-10.

Verchot, L. V., Van-noordwijalbrek, M., Kandji, S., Tomich, T., Ong, C. and Albrecht, A. (2007). Climate change: linking adaptation and mitigation through agroforestry. *Mitigation Adaptation Strategies for Global Change, 12*, 901–918.

Verma, K., Prasad, S. K., Singh, M. K., and Sharma, P. (2023a). Assessment of Agronomic Zinc Biofortification of Alley Cropped Pearl Millet. *Bangladesh Journal of Botany*, *52*(1), 203-209.

Verma, K., Prasad, S. K., Singh, M. K., and Sharma, P. (2023b). Response of alley-cropped pearl millet (Pennisetum glaucum) to nitrogen and zinc schedules under semi-arid regions. *Indian Journal of Agronomy*, *68*(1), 105-109.

Verma, K., Sharma, P., Bhardwaj, D. R., Kumar, R., Kumar, N. M. and Singh, A. K. (2023c). Land and Environmental Management through Agriculture, Forestry and Other Land Use (AFOLU) System. Land and Environmental Management through Forestry, 247-271.

Verma, K., Sharma, P., Kumar, D., Vishwakarma, S. P., and Meena, N. K. (2021). Strategies sustainable management of agroforestry in climate change mitigation and adaptation. *International Journal of Current Microbiology and Applied Sciences*, *10*(01), 2439-2449.

Zomer, R. J., Trabucco, A., Bossio, D. A. and Verchot, L. V. (2008). Climate change mitigation: A spatial analysis of global land suitability for clean development mechanism afforestation and reforestation. *Agriculture Ecosystem and Environment*, *126*(1-2), 67-80.

Zomer, R. J., Trabucco, A., Coe, R. and Place, F. (2009). Trees on farm: analysis of global extent and geographical patterns of agroforestry. ICRAF Working Paper No. 89. World Agroforestry Centre, Nairobi, Kenya. P. 156.

How to cite this article: Singh A.K., Singh B.K., Kumar N.M. Agnihotri D., Karada M.K. and R. Singh (2023). Agroforestry as a Mechanism for Reforestation: Scenarios within REDD+. *Biological Forum – An International Journal, 15*(7): 370-377.