Agroforestry and Global Climate Adaptation

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Agroforestry plays a defining role in offsetting greenhouse gases, providing sustainable livelihoods, localizing Sustainable Development Goals and achieving biodiversity targets.

Keywords: agroforestry ; South Asia

1. Introduction

Climate change is a reality and it is well established that the planet is facing climate emergency [1]. Emissions from the agriculture sector alone emits 6 billion metric tons of greenhouse gases (GHG) into the environment per annum [2]. Climate change impacts in certain regions have been more damaging and devastating because of the enhanced exposure to climatic hazards, already prevailing vulnerabilities and lower adaptive capacity [3][4]. Climate change mitigation, food security, conservation of biodiversity, restoration of ecosystems and localizing the sustainable development goals (SDGs) are the fundamental global challenges of present times [5]. With increasing natural disasters and climate variability there is growing urgency for recognizing and supporting efforts for climate adaptation and mitigation [6]. Of these, adaptation efforts to improve land and water management related practices have been identified as central to boosting capacity for overall resilience to climate vulnerability [7].

The South Asia region includes the countries of Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan, and Sri Lanka. S. Asia has huge range of human, cultural, and ecosystem diversity [8]. S. Asia's rapid population growth, widespread poverty, large dependence on natural resources and inadequate adaptive capacity has made the region highly vulnerable to climate change. The region is home to more than one fifth of the world's population, and is one of the most climate disaster-prone areas on earth [9][10][11]. Agriculture and pasture land in the region accounts for one third of the total land cover [2]. Fulfilling the food requirements of a fast-growing population without affecting land use is a primary challenge due to sustenance agriculture, and this has resulted in widespread food shortages [12][13]. Agriculture expansion and intensification are drivers of deforestation and biodiversity loss in the region. Due to low per capita land available for agriculture, production of food with a marginal ecological footprint becomes essential [12]. There are growing expectations on multifunctional land use systems, to fulfill mounting regional land and food demands while addressing emerging climate hazards, as they support sustenance of productive landscapes, habitats, social, economic, and also regulatory aspirations [14].

Adaptation is an urgent requirement under the present climate change scenario, particularly in developing and underdeveloped countries, which are anticipated to be severely impacted by climate extremes [15]. The contribution made by agriculture to achieve the SDGs will require climate adaptation followed by cropland advances that are affordable and profitable to the poor [16]. The Intergovernmental Panel on Climate Change (IPCC) in its first, second, and third assessment reports (1990, 1996 and 2001) have acknowledged the South Asian region for its capacity to incorporate adaptation and mitigation approaches that can also facilitate pro-poor development through carbon-offset arrangements such as farmer managed natural regeneration, agroforestry, and adaptive agriculture practices [17]. While synergies in adaptation and mitigation approaches need to be addressed, they should not be limited to income diversification from tree or forest-based products. Adaptation and mitigation approaches should ideally include approaches for improving soil health and biodiversity, and reducing fire risks, through restoration of natural ecosystems [18]. Intended Nationally Determined Contributions (INDCs) have emerged as the principal tool for benchmarking and reporting under the Paris Agreement. Likewise, removing atmospheric carbon and storing it in terrestrial vegetation is a feasible adaptation and mitigation option that contributes to the NDCs. Researchers have identified agroforestry among critical landscapes as an approach that can fulfill NDC commitments, particularly in developing countries [19][20].

Trees outside forests (TOFs) substantively contribute to livelihood improvement, while also enhancing biomass and carbon stocks. In the last few decades, policy makers have recognized the significance of TOFs, and included them in the national forest inventories [21]. Indigenous and traditional resource management by agroforestry is proven to benefit

livelihood benefits in terms of provisioning, regulating, and supporting ecosystem services [22]. Trees on arable land have the potential to support carbon sinks under Nature-based Solutions (NbS) contributing to climate change adaptation and mitigation through carbon sequestration [23][24][25][26].

2. Traditional Agroforestry Systems in South Asia

Agroforestry systems are dynamic, sustainable food production, and natural resource management systems with high prevalence and acceptance in developing countries in the tropics of South-East Asia, South Asia, and Central, and South America. These systems occupy more than 50% of the land coverage [27][28][29]. Despite global recognition and the presence of AFS, it is still a challenge to find reliable and accurate information on the extent for S. Asia. A list of land areas that are under agroforestry in different countries of the world including S. Asia was prepared by The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) [30]. Nair et al. [31] estimated global agroforestry cover to be 1023 million hectares followed by Zomer et al. [32]. Zomer [28] projected global agroforestry cover to be 1020 million hectares [22], thereby agreeing with Nair et al. [31] (Table 1).

% of Tree Cover Present in the Agricultural Lands	Global Agricultural Land with Trees (in km^2)	% of All Agricultural Land with Trees
>10	10,120,000	46
>20	5,960,000	27
>50	1,670,000	7.5

Source: [29][33].

South Asia is recognized for its AFS and its long history of acceptance and adoption of traditional practices across diverse agro-ecological conditions and agro-climatic zones. The diverse AFS in the region showcase the accumulated knowledge related to climate adaptation and mitigation approaches developed by millions of smallholding farmers and marginalized communities over centuries [33]. Approximately 60% of the research on AFS in the Asia-Pacific region has been carried out in India, China, Indonesia, and Australia, with a clear focus on silvi-pastoral systems. Shin et al. [34] provided details on the extensive research on AFS in India from 1970–2018. Nair et al. [35] provided a detailed overview on traditional AFS in S. Asia, along with other regions of the world.

Home gardens are the dominant AFS across S. Asian countries. Traditional AFS in S. Asia are trusted for their diverse benefits from the small land holdings (Table 2). In India, Nepal, Bhutan, Bangladesh, the Maldives and Sri Lanka, growing fuelwood, fodder and fruit trees on cropland bunds by local people is a common practice to fulfill energy and food demands, and are these practices that constitute important livelihood options for the region's rural poor [36][37]. However, in Pakistan, local farmers are hesitant to plant trees on cropland bunds to avoid competition between trees and crops. Hence, their fuelwood and fodder needs are mostly met from natural forests or wasteland vegetation.

Table 2. Traditional agroforestry systems accepted/adopted in South Asia.

Type of AFS	Agro-Ecological Adaptation
Agri-silvicultural systems	
Shifting cultivation, Chena, Taungya, Bewat, dhya, dippa, erka, jhum, kumara, peenda, pothur, podu, rep syrti, zabo	In tropical forest areas in North-East India, Sri Lanka
Plantation-based cropping system	Mainly humid tropical countries (India, Bangladesh, Maldives, Sri Lanka)
Scattered trees on farms, parklands	All regions, especially semiarid, and arid regions
Shelterbelts and windbreaks	In wind-prone areas, especially coastal, arid, and alpine regions of India, Bangladesh, Maldives, Sri Lanka
Boundary Planting and live hedges	In all countries of the region
Woodlots for soil conservation	In hilly areas, along sea coast and ravine lands of the region
Industrial plantations with crops	Intensively cropped area having plantation on bunds
Silvi-pastoral systems	

Type of AFS	Agro-Ecological Adaptation
Silvi-pastures	Sub tropics and tropics with bio-edaphic sub- climaxes
Horti- pastoral	In hilly and non-hilly orchards for soil conservation
Tree on rangelands	In all countries of the region
Plantation crops with pastures	Mostly humid and sub-humid regions with less grazing pressure on plantation lands
Seasonal forestry Grazing	Semi- arid and mountainous ecosystems
Agro-silvi-pastoral systems	
Home gardens	In all countries of the region especially Sri Lanka, India, Maldives, Bangladesh
Others	
Aqua forestry	Low lands
Apiculture with trees	In all countries of the region

Source: [38][39].

The magnitude of agroforestry in the region at present is highly underestimated, because of technical constraints to recognize low-density tree cover common the small landholdings of local farmers [20]. Agroforestry cover reported from different parts of Asia shows that there are fewer areas with trees in S. Asia region, compared to other regions in Asia (Table 3).

Table 3. Extent of agroforestry systems in different parts of Asia.

Regions of the World	Agricultural Area with Trees (in Million km^2)	% Of All Agricultural Area with Trees
South-East Asia	1.34	82
Northern and Central Asia	0.65	27
East Asia	0.41	23
South Asia	0.38	21
Western Asia and North Africa	0.1	9
Total (Global)	10.12	46

Source: [29][33].

The Central Agroforestry Research Institute (CAFRI) based in Jhansi, India estimated agroforests to span 13.75 million hectares in the country [40]. In the biennial State of Forest Report (ISFR) of India for 2019, AFS are located under trees outside forests (TOF) category, spanning an area of 293,840 km^2, or about 8.94% of the geographical area of the country. More than 65% of the country's timber and more than 50% of the fuelwood requirements are supported by AFS. Oli et al. [38] reported higher tree species richness in agroforests of Nepal compared to natural forests. Chakraborty et al. [39] stressed the value of agroforests in Bangladesh. Agroforests in Bangladesh support household fuelwood needs and thus, help in reducing household expenses and dependence on wood from natural forests. The National Research Centre for Agroforestry projected the livelihood potential of 943 million person-days/annum from 25.4 million ha agroforests in India [41]. The Agroforests with species such as teak (*Tectona grandis* L.f.) or Silver Oak (*Grevillea robusta* A. Cunn. ex R.Br.) are an investment option for the region providing significant economic, and ecological returns, for ensuring long and short term diverse ecological and social benefits for local communities [42]. Fast growing high biomass yielding species like Poplar (*Populus* spp.) and Eucalyptus (*Eucalyptus* spp.) have gained larger acceptance and recognition in industrial plantations of Pakistan and India. Fast growing trees (*Eucalyptus* spp., *Populus* spp., *Tectona grandis*, *Casuarina equisetifolia* L. etc) are preferred in industrial agroforestry plantations and shelterbelts because of their economic and ecological values and fast growth rates [43]. Agroforestry trees that have market value are preferred by farmers in the region, as they have less susceptibility to fail as annual crops. *Moringa oleifera* trees are preferred in India because of the medicinal properties and market value of its all plant parts. Similarly, many traditional fodder trees like *Grewia optiva* J. R. Drumm. ex Burret, *Carpinus viminea* Wall. ex Lindl. etc., that can be harvested multiple times a year [22][44].

Noticeable examples of AFS include multifunctional landscapes such as home gardens that secure food and support conservation of lesser known underutilized biodiversity in Sri Lanka, Maldives, Bangladesh and India [45]. These tree-based land management practices (spice gardens in Kerala, India, and in Sri Lanka) have proven their potential in providing livelihood opportunities for rural industrialization. Integrated agri-silvi-horti production systems that favor resource conservation and support conservation of traditional agro-biodiversity also ensures climate adaptation and mitigation in the region [33].

3. Global Climate Dialogue around Agroforestry Systems

The United Nations Framework Convention on Climate Change (UNFCCC) along with other prominent international environmental and scientific organizations have stressed the growing need for mainstreaming and implementation of sustainable land management approaches that specifically includes AFS [46][47][48]. AFS have received substantial recognition from international organizations like the UNFCCC, the Food and Agriculture Organization (FAO), the Convention on Biological Diversity (CBD), and the World Bank [49] (https://agroforestrynetwork.org/, accessed on 25 June 2019). Figure 1 presents an overview of major Conventions and reports that have brought AFS into global focus. The Kyoto Protocol was the first international arrangement to acknowledge the importance of AFS in climate mitigation. Since, then global attention for enhancing carbon sequestration using AFS has increased [29][47]. Although, the Kyoto Protocol was rooted in the Clean Development Mechanism (CDM), the addition of AFS into CDM was hindered due to a lack of uniform protocols to estimate carbon sinks, and associated land right concerns [50]. However, REDD+ (Reduced Emissions from Deforestations and Forest Degradation) brought AFS back into focus in 2007, and several countries have made considerable progress to improve their national planning by understanding the importance of agriculture, forestry, and other land-use (AFOLU) sectors in climate change adaptation and mitigation [51]. AFS are known for their potential to contribute to nine out of the 17 SDGs including SDG 15 (life on land), 13 (climate action), 12 (responsible production and consumption), 2 (zero hunger), 1 (no poverty), 3 (good health and well-being), 8 (decent work and economic growth), 5 (gender equality) and 10 (reduce inequalities) [52][53][54]. AFS are an important climate mitigation tool, and can help both developing and underdeveloped to achieve policy synergy amongst technologies, landscapes, rights and markets [55] while also improving localization of SDGs (especially 2.4; 13.2 and 15.3), restoration of multi-functional landscapes, climate adaptation and mitigation; reforestation targets in line with the Bonn challenge, UN decade on restoration (2021–2030); and improving food and water security [56][57][58].

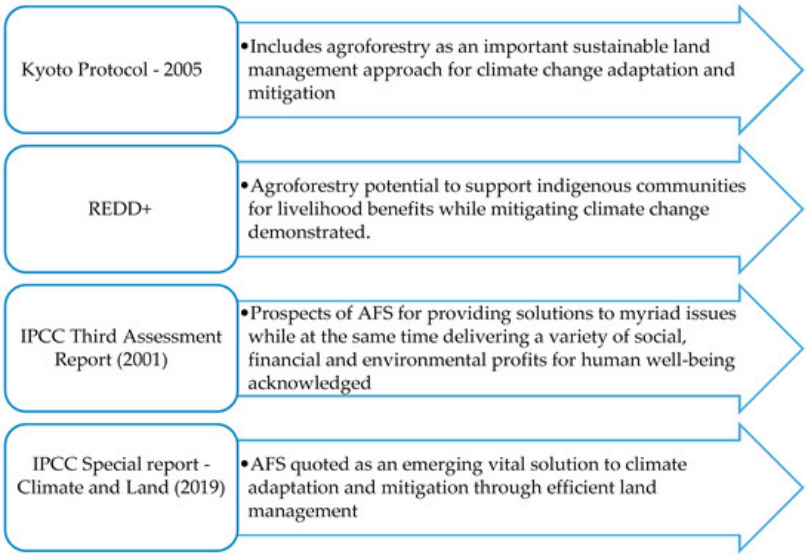

Figure 1. Agroforestry System in key agreements and reports (Source: [59][60][61]).

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