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Review

Agroforestry to Achieve Global Climate Adaptation and Mitigation Targets: Are South Asian Countries Sufficiently Prepared?

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Abstract: Traditional agroforestry systems across South Asia have historically supported millions of smallholding farmers. Since, 2007 agroforestry has received attention in global climate discussions for its carbon sink potential. Agroforestry plays a defining role in offsetting greenhouse gases, providing sustainable livelihoods, localizing Sustainable Development Goals and achieving biodiversity targets. The review explores evidence of agroforestry systems for human well-being along with its climate adaptation and mitigation potential for South Asia. In particular, we explore key enabling and constraining conditions for mainstreaming agroforestry systems to use them to fulfill global climate mitigation targets. Nationally determined contributions submitted by South Asian countries to the United Nations Framework Convention on Climate Change acknowledge agroforestry systems. In 2016, South Asian Association for Regional Cooperation's Resolution on Agroforestry brought consensus on developing national agroforestry policies by all regional countries and became a strong enabling condition to ensure effectiveness of using agroforestry for climate targets. Lack of uniform methodologies for creation of databases to monitor tree and soil carbon stocks was found to be a key limitation for the purpose. Water scarcity, lack of interactive governance, rights of farmers and ownership issues along with insufficient financial support to rural farmers for agroforestry were other constraining conditions that should be appropriately addressed by the regional countries to develop their preparedness for achieving national climate ambitions. Our review indicates the need to shift from planning to the implementation phase following strong examples shared from India and Nepal, including carbon neutrality scenarios, incentives and sustainable local livelihood to enhance preparedness.

Keywords: agroforestry; South Asia; climate change; mitigation; adaptation; policy; REDD+; national determined contributions; climate neutrality

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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 [9–11]. 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 [23–26].

Understanding the regional agroforestry status, creating opportunities for further promotion to fulfill climate promises, and ensuring successful acceptance of agroforestry practices are all crucial and pertinent, in light of climate change [27]. For this paper, we performed an initial bibliometric analysis to understand the existing published literature on

regional agroforestry practices and their importance in addressing global climate adaptation and mitigation targets. Based on the limitations of the analysis, we then conducted a detailed review of available literature on Scopus, Web of Science and Google Scholar to obtain a detailed overview of the potential for agroforestry systems (AFS) in supporting country-specific mitigation targets as well as supporting NDCs as proposed by countries in S. Asia. Additionally, this paper discusses the need for integrating AFS into MRV (Monitoring, Reporting and Verification) while providing a critical understanding of key gap areas, existing policies and concerns that need specific attention to be scaled up by adoption and promotion of agroforestry in the region. The review paper critically tries to address the following questions:

1. What is the substantial evidence that AFS and its practices deliver diverse ecosystem services, thereby ensuring human well-being in S. Asia?
2. What are the important climate discussions including agroforestry for climate adaptation and mitigation?
3. What are the key capabilities, and constraints when looking to include agroforestry into climate adaptation and mitigation?

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 [28–30]. 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) [31]. Nair et al. [32] estimated global agroforestry cover to be 1023 million hectares followed by Zomer et al. [33]. Zomer [29] projected global agroforestry cover to be 1020 million hectares [22], thereby agreeing with Nair et al. [32] (Table 1).

Table 1. Overview of global agroforestry cover.

% 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 [34]. 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. [35] provided details on the extensive research on AFS in India from 1970–2018. Nair et al. [36] 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 [37,38]. 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	
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: [39,40].

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 [41]. 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. [42] reported higher tree species richness in agroforests of Nepal compared to natural forests. Chakraborty et al. [43] 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 [44]. 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 [39]. 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 [45]. 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 [22,46].

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 [47]. 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 [34].

2.1. Agroforestry Systems and Human Well-Being

Ecosystem services from natural ecosystems (or semi-natural) largely support and contributes various benefits for human well-being (environmental, material as well as psychological benefits) [48–50]. Agroforests on croplands or pasture lands as an important traditional land management practice and thus provide diverse socio-economic and ecological benefits including NbS for climate change adaptation [35,51]. Agroforestry delivers diverse provisioning, regulating and supporting ecosystem services, and climate adaptation is an important one to address global climate change [5]. Historically, AFS across S. Asian countries have been designed to capitalize and harness diverse benefits for human well-being [52]. The presence of multifunctional landscapes, ensures the conservation of lesser known wild species, encourages traditional agrobiodiversity and also improves pollinator benefits [53]. These well-managed multifunctional sustainable AFS provide considerable livelihood benefits as well as safeguarding diverse ecological functions [42]. It is important to mention here that decisions by farmers for adoption of a land use is not dependent on a benefit cost ratio, but essentially rests on how much net income will be earned. Hence, horticulture-based agroforestry is preferred by farmers in Bangladesh over cropland and homestead agroforestry [54].

AFS have the potential to serve in the restoration and rehabilitation of degraded ecosystems, and could help to reinstate ecosystem services [55]. Food security, land tenure security, enhanced farm-based incomes, management of terrestrial and soil biodiversity, carbon sinks, hydrological functions, wildlife corridors, reduced soil erosion, biodiversity

conservation, microclimate improvement, increased nutrient retention via root capture and cycling, etc. are some of the diverse benefits of AFS reported from the region [20,38,56–58]. Supporting agroforestry interventions to ensure food security in Nepal includes high biomass of fodder, meat, and production by Non Timber Forest Produces (NTFPs) [59]. Areas under agroforestry are reported to result in reduced soil erosion and improved nitrogen fixation in Bhutan [60]. In Bangladesh, there was comparatively less nutrient depletion from soil erosion in AFS than in jhum/slash and burn agriculture [61]. There is considerable evidence that AFS support sustainable production, providing subsidiary household provisions with diversified products, conservation of natural resources, aquifer recharge, etc. [35,62]. According to Muschler [63] agroforests support "sustainable intensification" within a land use archetype that that are based more on ecology than on chemistry and climate science. Article 2 of the Paris Agreement proposed to strengthen global efforts to reduce climate impacts with reference to sustainable development and poverty alleviation. Hence, it is vital to recognize and acknowledge the role of agroforestry and to mainstream it at country level to address global climate targets. Leveraging the mitigation potential of land use sectors is crucial, in meeting emission reduction targets [64]. By endorsing the benefits of diverse AFS practiced across S. Asia, less fertile marginal croplands with low productivity can be included for income diversification. This can be achieved by restoring soil health, improving irrigation efficiency, creating carbon sinks [52,65–67], thereby also strengthening adaptive rainfed dryland agriculture [68].

2.2. Bibliometric Analysis Agroforestry Systems in S. Asia Region

Bibliometric analysis was carried out to take stock of existing information on AFS in S. Asia. A total of 52 published works were retrieved from the Web of Science (WoS) database according to the keywords "Agroforestry" and "South Asia". The retrieved literature spans the period 1991 to 2019, covering 30 journal articles, 7 review papers, 5 proceedings. The metadata of the retrieved literature contains information about the author names, journal, title, abstract, author defined keywords, machine learning generated keywords (known as keyword-plus), local and global citations, referred articles, year of publication, etc. Analysis of the metadata associated with articles provide useful insights about the research structure and themes. In this study we used the *bibliometrix* library of R programming language for the analysis (https://www.bibliometrix.org, accessed on 25 June 2019). The annual scientific production pertaining to the study followed an average growth rate of 6.21%. Most relevant sources (and their h-index) in terms of journals from where maximum papers originated, are Agroforestry Systems (5), New Forests (3), and Society and Natural Resources (2). A word tree-map of keywords is a simple method to visualize the overall spread of the research field. The word tree-map for author keywords is shown in Figure 1, in which the area of the rectangle labelled with the keyword is proportional to the frequency of its occurrence in retrieved literature. Frequency analysis of author keywords indicate that author keywords-conservation, agroforestry, biodiversity, and management have appeared most frequently. Conservation and biodiversity, agricultural management, biomass, carbon sequestration, and climate change topics are also associated with the overall theme of agroforestry in South Asia. Topics related to socio-cultural aspects such as livelihoods of local people and shifting cultivation also appeared in the literature.

The temporal evolution of the research topics can be understood by plotting the most frequent author keywords or keywords-plus with respect to the year of appearance. The trend of author keywords is shown in Figure 2 containing the keywords that have appeared at least twice in any year (considered between 2004–2019). Results indicate that there has been a shift in topics from the physical aspects related to agroforestry such as soil and water conservation, land productivity, and forestry to land use changes, forest disturbances, socio-economic development from 2004–2011. Studies in the last decade were related to shifting cultivation, livelihood of people, rubber plantations, oil palm farming, along with carbon sequestration. The trend in keywords do not reflect aspects related to

climate change adaption and mitigation strategies, and the research momentum has not yet gained traction as expected.

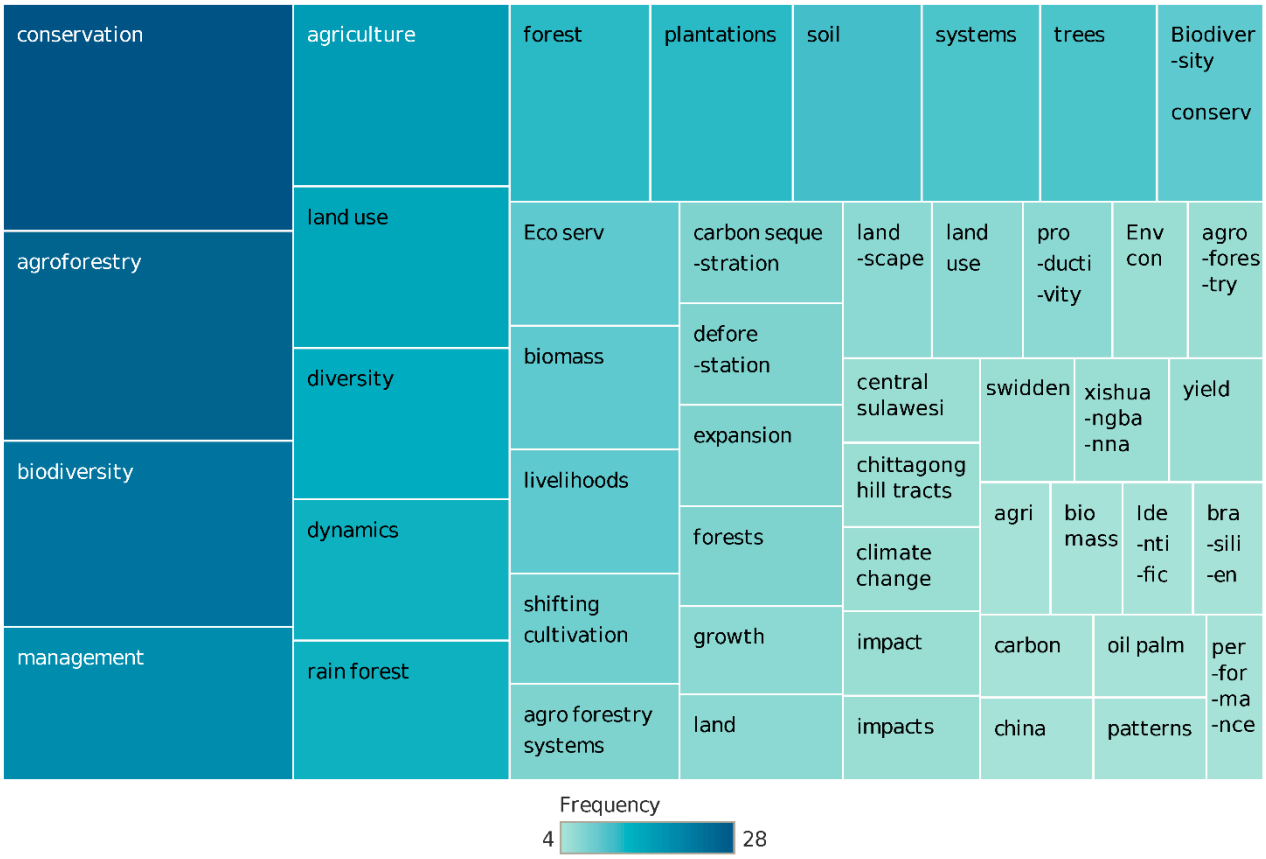

Figure 1. Word tree-map of most frequently used keywords with reference to agroforestry in south Asia.

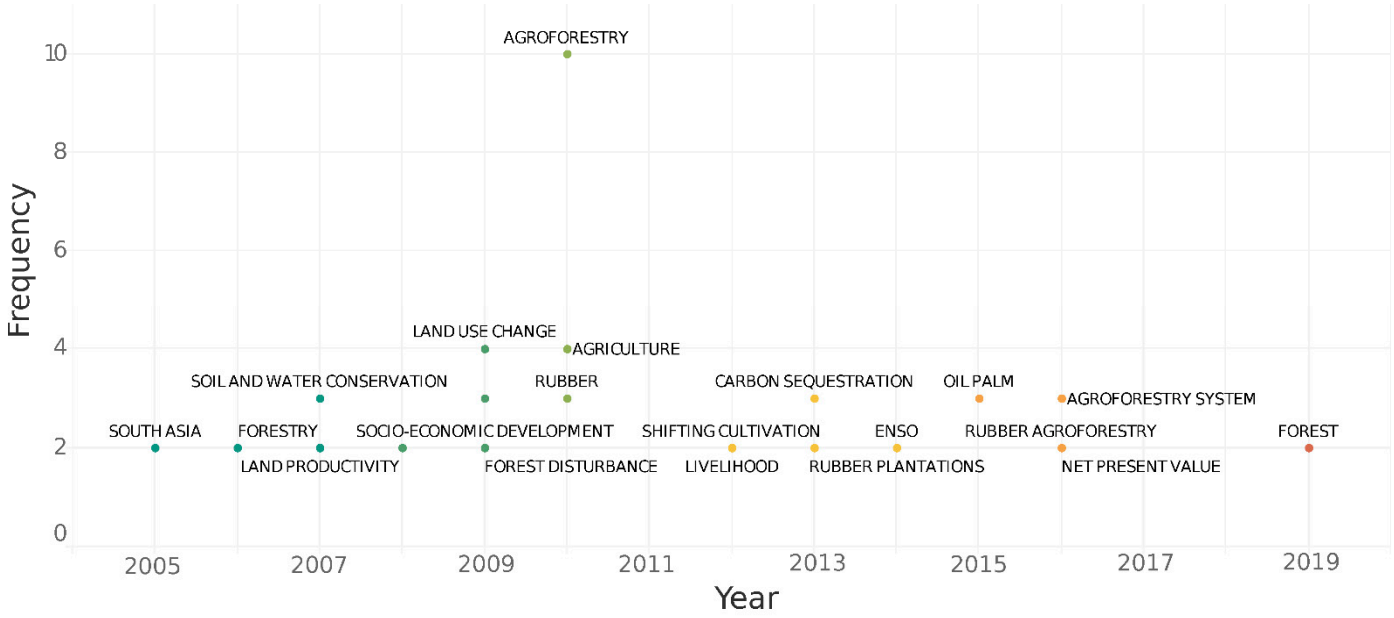

Figure 2. Trends in topics studied from 1991 to 2019 on agroforestry in S. Asia. *Y*-axis represents the frequency of appearance of the author keywords, and *X*-axis represents the year.

Co-word analysis was performed to capture the conceptual structure of research themes by analyzing co-occurrence of author keywords in the bibliometric collection. A bipartite matrix between author keywords and documents has been developed by the *biliometrix* library for analysis. Information on the group of keywords that appear together can be identified and made into clusters based on the k-mean clustering algorithm using R. In order to plot the clusters in a 2D plane, the multiple correspondence analysis dimensionality reduction method was used. The author keywords are grouped into clusters based on proximity in the 2D space, and the keywords that appear in a cluster share same substance of research. The keywords that are placed apart have appeared sparsely together in the collection. Based on our review, the clusters formed according to the analysis is shown in Figure 3. The clusters can be identified as Cluster-1 (land use, forest disturbances, and carbon sequestration), Cluster-2 (AFS), Cluster-3 (land use change, shifting agriculture, rubber plantation, oil palms, livelihood, land use productivity, S. Asia, etc.), and Cluster-4 (bioengineering technology, soil and water conservation, and socio-economic aspects). As the centroid of the Cluster-3 is positioned according to the positive values of *X* and *Y* in the 2D space, these themes are known as motor themes, and are central and highly developed themes in the agroforestry research. Cluster-1 and 2 centroids have negative *X* values and positive *Y* values, and are known as niche themes (or isolated themes) in the research landscape, focusing on land use change and AFS, respectively. Conversely, Cluster-4 indicates the themes that are central to the research area, but are less dense or transversal in nature. Overall Clusters 1 to 3 are close to each other and the themes also agree with literature discussed AFS, carbon sequestration, climate change, land use change, forest disturbance, livelihoods, and biodiversity.

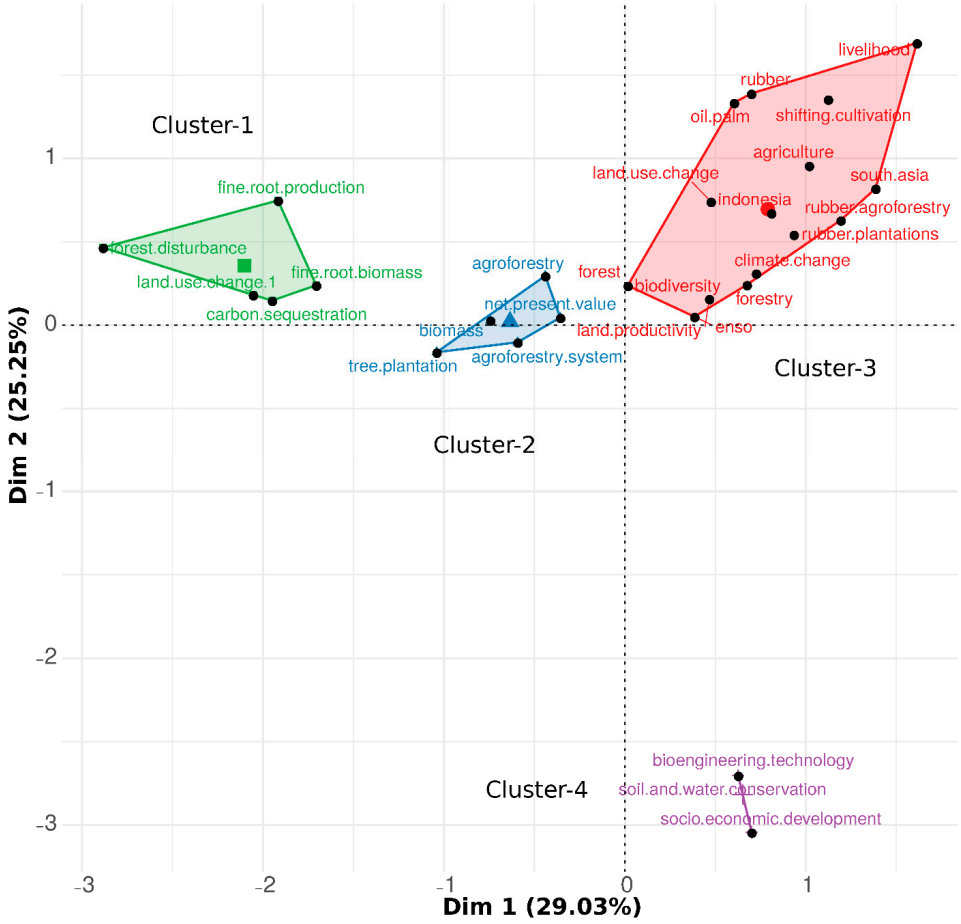

Figure 3. Conceptual structure map of research topics related to agroforestry in S. Asia, prepared using Multiple Correspondence Analysis of author keywords. (Dimension 1 and 2 on *X* and *Y* axes, respectively).

The bibliometric analysis was not able to capture the increasing concerns and interest of AFS in the climate dialogue. In general, most of the available information was very fragmentary and isolated in a few case studies. There is a need to further explore the literature to capture and synthesize the available information. Effort to consolidate the information and present it in this paper will be of significant interest to academicians, policymakers, and researchers working on AFS and for mainstreaming AFS in climate dialogues.

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 [69–71]. 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 [72] (https://agroforestrynetwork.org/, accessed on 25 June 2019). Figure 4 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 [30,70]. 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 [73]. 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 [74]. 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) [75–77]. AFS are an important climate mitigation tool, and can help both developing and underdeveloped to achieve policy synergy amongst technologies, landscapes, rights and markets [78] while also improving localization of SDGs (especially 2.4; 13.2 and 15.3), restoration of multifunctional 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 [79–81].

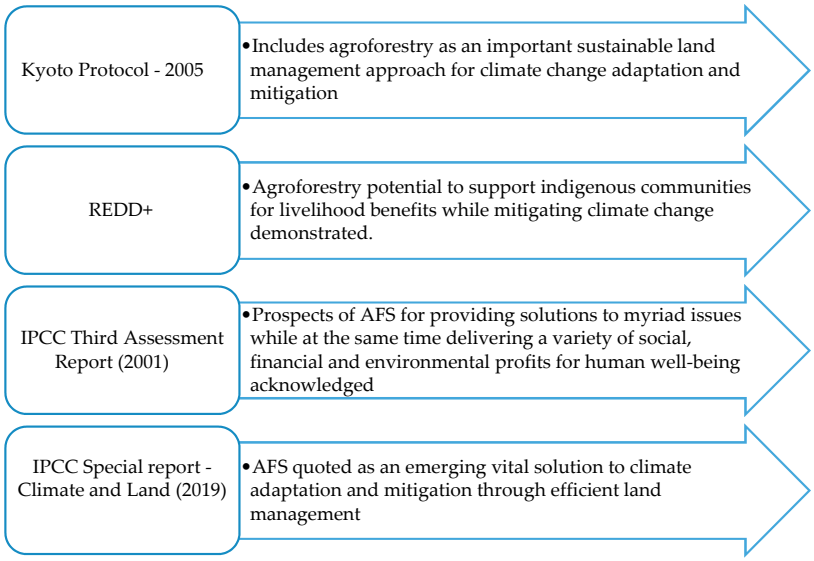

Figure 4. Agroforestry System in key agreements and reports (Source: [82–84]).

3.1. Agroforestry: Role in Climate Change Mitigation and Adaptation

Despite agroforestry being acknowledged for its carbon sequestration potential among all land uses considered in the IPCC (2000), the understanding of carbon sink in different AFS in the region is still very elementary because of insufficient authentic data on carbon stocks of AF interventions, in comparison to agriculture and forestry [85]. While agriculture along with forestry results in large amounts of emissions and also accounts for nearly 21% of the total emissions [86], AFS have significant mitigation potential that has not been scientifically evaluated in global carbon financial plans or national carbon accounts [30]. Limited studies at the global, national and zonal scale have reported carbon stocks in AFS (Table 4). However, for S. Asia, these studies and reports are mostly at the local level. In most of the studies, there is a lack of comprehensive information on both tree and Soil organic carbon (SOC) trends in carbon stocks [82,87,88]. It has been very challenging to gain an understanding of how diverse agroforestry practices can become potential carbon sinks [14,85,89,90].

In farmland biodiversity, the scattered trees in agroforests are the 'keystone species' that expedite and support the movement of wildlife through the landscape [91]. This role of AFS as wildlife corridors is significant under projected climate change as it allows species to adapt in response to unstable climatic conditions by providing the necessary migration paths [90]. In order to optimize the use of AFS in climate adaptation and mitigation, strategic integrated efforts to enhance benefits and reduce negative impacts on climate are needed. Mbow et al. [90] provided an overview of both positive and negative impacts of AFS on the adaptation and mitigation potential. Since most countries in the region are predominantly agrarian, S. Asia region has tremendous potential to promote agroforestry as a tool for climate adaptation and mitigation. A recent study claimed that 69% of the total geographical area of S. Asia retains 55% or even higher suitability for agroforestry [92].

Table 4. Reported carbon stocks in agroforestry systems. Source: [93–97].

Location	Carbon Stock (Mg C ha^{-1})
Global	Biomass—0.29–15.21 Soil—30–300
Global	0.7–1.6
Global	6.3
Pakistan	29.7
India	25.4
Semi-arid	9
Sub-humid	21
Humid	50
Temperate	63

3.2. Nationally Determined Contributions and Agroforestry

Under the Paris Agreement, countries submitted their Intended Nationally Determined Contributions (INDCs) under the Paris Agreement. INDCs, once submitted to UNFCCC, are known as Nationally Determined Contributions (NDCs) and they are the key mechanism towards reducing emissions as per national urgencies, competencies and accountabilities. According to Duguma et al. [98], within the purview of NDCs, agroforestry can provide multi-dimensional benefits by supporting climate adaptation and mitigation actions [98,99]. Nearly 40% of the Non-Annex I countries (developing countries recognized by the UNFCCC as vulnerable to the adverse climate impacts, including areas threatened from sea level rise, desertification and drought) have explicitly proposed agroforestry in their NDCs. A total of 21% of Asian countries have proposed AFS in their NDCs, a ratio that is less than Africa (71%) and the Americas (34%) but higher than Oceania (7%) [20,58].

The S. Asian countries list adaptation actions both at the farm and landscape level. Bangladesh, Nepal, Sri Lanka and Bhutan have proposed "ecosystem-based adaptation" [100], which includes landscape-level actions, spanning management of water resources, crop management by crop rotation, agroforestry and management of natural vegetation. As the sum of carbon flux fundamentally depends on the composition of trees, there needs to be more understanding on it during the implementation phase [101–103].

It is evident from Table 5 that, although countries have not explicitly included agroforestry in their NDCs (Bhutan and Nepal), the existing traditional systems and supporting policies in these countries indicate potential inclusion of AFS as part of a larger mitigation strategy. For example, in Bangladesh, the need to reduce emission from agriculture and further development of the forestry sector is indicated. In line with this, [20] the TOF (croplands, homestead and horticulture based agroforestry) provides significant opportunities in Bangladesh, as it already spreads over 4.1 million hectares or 27.7% of the total land area [20].

Table 5. Nationally determined contributions committed by S. Asian countries and role of agroforestry.

Country	NDC Commitment	Elements of Agroforestry in NDC
Bangladesh *	Emissions reduction from agriculture and development of forest sector. Unconditional contribution to reduce GHG emissions by 5% by 2030 in the power, transport and industry sectors, based on existing resources. Conditional 15% reduction in GHG emissions by 2030 in the power, transport, and industry sectors, subject to appropriate international support	- No mention of agroforestry in the NDC Ecosystem based adaptation (incl. forestry co-management) - Community based conservation of wetlands and coastal areas - Green belt Afforestation and reforestation of mangroves
Bhutan	"No NDC Available"	- Potential of climate-smart agriculture, particularly the development of agro-forestry, agri-silvi-pastoral systems for fodder production, organic agriculture and conservation agriculture are included as mitigation measures [104]
India	- Decrease emissions by 33–35% from the 2005 levels by the year 2030—to be achieved through increase in the segment of non-fossil fuel by 40%, along with sequestering an additional 2.5–3 billion tonnes of carbon through added tree cover by 2030 [105,106]	- Despite India's INDC not mentioning agroforestry specifically, it is believed to play a critical, if not pivotal role in national carbon mitigation targets, given agroforestry is of the sub-missions of the Green India Mission—one of the eight missions under the National Action Plan on Climate Change (NAPCC) [107].
Nepal	- Decrease the dependency on fossil fuels by 2050 and further aim to bring at least 40% of the area of the country under forest cover.	- Ameliorative forest practices including agroforestry as a means to achieve the NDC targets included [107]
Pakistan *	- Mitigation target of 20% of the projected 2030 emissions-subject to international financial support	- Agroforestry implementation included among mitigation strategies.
Sri Lanka *	- Increase forest cover from 29% to 32% by 2030, reduce emissions by 20% in the energy sector and by 10% in other sectors including forest, transport, industry, etc.	- No mention of agroforestry in the NDC.

* Details taken from https://www4.unfccc.int/ (accessed on 25 June 2019), [59,104,106,108,109].

South Asian Association for Regional Cooperation (SAARC) Member States (Afghanistan, Bangladesh, Bhutan, India, the Maldives, Nepal, Pakistan and Sri Lanka) developed the SAARC Regional Coordinated Programme on Agroforestry (SARCOPA) in 2016 that has received active facilitation and technical support from the World Agroforestry Center

(ICRAF) and SAARC Agriculture Centre (SAC). The programme has been divided into two-phases, the first 6-year phase focused on establishing the mechanism and delivery systems and the second 6-year phase focused on upscaling and out scaling the AFS benefits to larger beneficiaries. SARCOPA's first phase is focusing on generating awareness and developing guidelines, policy, and databases of existing information on AFS. India and Nepal already have National Agroforestry Policy in place clearly showing their intent to promote AFS while, Bhutan and Bangladesh are working to develop a National Policy to endorse and recognize the benefits of AFS. In fact, a mere 30% increase in area under AFS is projected to significantly reduce India's total emissions by 2050 [110]. Under SARCOPA there has been support provided for institutional and individual level capacity building and identifying and re-designing specific AFS, and sharing information on successful AFS. The Government of Nepal is implementing a Local Adaptation Plan of Actions through 90 Village Development Committees and seven municipalities. Additionally, about 375 local adaptation plans and approximately 2200 Community Adaptation Plans of Action for community forests have been enacted that will also include the benefits of natural forests, community conservation efforts and traditional AFS [97]. Agroforestry policy put in place by India in 2014 was the first in the region and was seen as a low hanging fruit to not only ensure the benefits from a successful land-use system, but also to harness its economic potential for locals as well for the country [111].

Sri Lanka also committed to supporting climate resilient human settlements, minimizing climate change impacts by ensuring food security, improving climate resilience for key economic support and protection of natural resources and biodiversity. Here again, although agroforestry is not explicitly mentioned, the country has a significant area of land under home gardens (13% of its current land area) that has historically helped in addressing drought and storms disasters, by supporting climate adaptation and so this, by default, will be part of the programme. The Government of Pakistan has initiated a 5-year plantation programme of 100 million trees under the Green Pakistan Programme or Plantation Tsunami to achieve Bonn Targets [108]. Here again, AFS is not explicitly a part of the NDC, but could be included.

The review and synthesis of existing information makes it clear that in S. Asia, there is already a process and approach in place to harness the benefits of AFS in all countries in the region and they are collaborating to share experience and technical support to make implementation a reality across the region.

3.3. Agroforestry in REDD+ and Nationally Appropriate Mitigation Actions (NAMAs)

Trading carbon sinks could be a potential livelihood opportunity for marginalized communities of underdeveloped and developing countries who practice agroforestry [86]. In S. Asian countries, the demand for firewood and timber results in rapid loss of forests and fragmentation, and AFS can help conserve natural forests. REDD+ has been a key feature of climate negotiations in the UNFCCC since 2007. Through REDD+, countries have made considerable progress in national planning to include AFOLU sectors for mitigating extreme climate impacts [74]. The REDD+ policies propose to economically reward countries for improving forest health by conservation and management that reduces GHG emissions [73]. The REDD+ initiative has supported eco-agricultural practices, that help produce surplus food while safeguarding native biodiversity and includes AFS [109]. Co-benefits from AFS are significant to the Koronivia Joint Work on Agriculture (KJWA) of the UNFCCC that addresses resilience building, enhancing soil carbon stocks, soil health, biodiversity and fertility, by supporting sustainable livestock management as well as providing varied nutritional benefits and livelihood diversification [20,58]. However, AFS are not explicitly mentioned in the KJWA. There are also encouraging and substantial evidence to showcase the successful support of AFS by indigenous and local communities [110]. Under the premise of REDD+, activities that lead to improving the capacity of forests to sequester carbon, reduce pressure on forests, and advance diversified livelihood approaches are

included. A review of REDD+ strategies in S. Asia show that REDD+ strategies in S. Asian countries are at different stages of development (Table 6).

Table 6. Reduced Emissions from Deforestation and Degradation+ policies and strategies in S. Asian countries.

Country	Status	Scope of REDD+
India	Execution of REDD+ with reference to significant resolutions of COP-16, Warsaw Framework for REDD+, Paris Agreement, and national statutory and policy agenda for conservation and enhancement of forests	Covers forests and TOFs, which potentially includes AFS. The activities of REDD+ contribute to the objective of improving forest and tree cover, thereby ensuring alignment with the National Forest Policy.
Nepal	First draft of REDD+ strategy prepared in 2014, facilitating further consultations and drafting of Version 2 of REDD+ strategy.	- The REDD+ strategy statement established in line with the principles of sustainable development objectives that includes national forestry sector vision of forests for people's prosperity. Scope of the policy is limited to various forest classes including forests under Protected Areas as per Forest Act (1993), the National Parks and Wildlife Conservation Act (1973), and Forest Policy (2015). - Likelihood of inclusion of leasehold forests, sacred forests, forests on public lands and private forests at an advanced stage, to broaden the scope of REDD+ defined.
Pakistan	REDD+ initiated in 2010, envisages forest ecosystems as public goods, a source of multiple benefits required for development and with potential to mitigate climate change, while, building community and ecosystem resilience.	Has key policies that support conservation of forests and ecosystems, viz. National Forest Policy 2015, Climate Change Policy 2012 and Environment Policy 2005-foundation of REDD+ strategy.
Sri Lanka	- 5-year strategy (2018–2022)—National REDD+ Investment Framework and Action Plan prepared with support from UN-REDD Programme. - Is at an advanced stage of REDD+ readiness and includes technical essentials of REDD+ as per the Warsaw Framework (i.e., UNFCCC Decisions 9-15/CP.19).	- 13 policies to address the identified drivers of forest cover change identified. - Policy measure, that cover other forested lands supports agroforestry models for addressing forest degradation, with an objective "to create enabling conditions for making existing agroforestry arrangements financially viable for adoption and implementation".

4. Constraints in Using Agroforestry for Meeting Global Climate Targets

There is a noteworthy gap in country-specific targets and their technical capabilities to measure agroforestry carbon stocks and report to the UNFCCC. SARCOPA will be a great support to bridge this gap in the coming years, but it will take time to develop capacities with reference to carbon stocks stores in AFS. Insufficient data on carbon stocks before land use change along with non-existent reporting on soil carbon stocks is one of the crucial limitations of the AFS database existing in the region [5]. Monitoring, Reporting and Verification (MRV) is a prerequisite for achieving climate adaptation and economic growth aims of countries [112]. Developing robust MRV for AFS in S. Asia is a crucial first stage to facilitate access to national and international funding sources and further backing. Despite the, mounting importance of AFS and TOF in global climate change dialogues, it has been difficult to integrate agroforestry in MRV systems, as proposed by the UNFCCC. MRV protocols developed by one country may not always work for another country. For example, Nepal has comparatively low forest threshold (0.5 ha, 10% tree cover) that supports the addition of AFS in MRV; whereas, in Bangladesh, TOF (also AFS) are omitted from the forest definition in the policies [20]. Local carbon stock change factors are mainly used, which is a limitation. Lack of continued financial support, deviations in government directives, along with the concerns and capacity for data gathering and analysis are projected as other potential constraints in realizing the benefits of AFS in the

region. Limited investment in agroforestry sector compared to intensive agriculture adds a key structural restriction for adoption of AFS [18,90].

Institutional constraints have been the most common limiting factor in the majority of countries in S. Asia. Expectations of high agricultural production per hectare followed by non-existent markets, land rights, and technical support are other challenges that impede realization of benefits of AFS in climate policies and implementation. Small landholdings are key limitation for AFS adoption in the region. Livestock size, distance of forest from villages, and a lack of awareness among farmers meanwhile, are other local reasons that limit adoption of AFS. However, poor and marginalized famers show interest in adopting AFS [25]. Shortage of water is another major constraint for promotion and adoption of AFS [108]. In India, the Forest Conservation Amendment Act of 1988 banned wood felling from state forests, amplifying wood prices and providing financial motivation to adopt AFS [113].

Despite widespread environmental and economic benefits, there is still low adoption of AF is largely because of legal and policy constraints including insecure land tenure, complex transit rules, taxes on agriculture based commodities, and socio-economic marginalization of local farmers [61]. Certainly, some key requirements for adoption include a growing need in the regional countries to fulfill market requirements, and formulation of policies that provide clear information on land and tree rights and ownership to enable REDD+ and NAMA contributions. However, farmers in the region are hesitant to plant trees because they do not have the rights to fell the tree for economic benefits. Further, harvesting and transporting of the tree wood from cropland to market is not permissible without prior approval from the forest department, which again deters adoption and promotion of AFS [108]. Farmers in Nepal stress their inability to get financial benefits from AFS because of unsupportive regulations surrounding harvesting and marketing of trees [59]. Farmers and experts in Bangladesh support the need for regulations and guideless for effective implementation of AFS to harness its ecological, economic and climate benefits. In Pakistan, too few trained forest personnel, lack of technical support to farmers, insufficient understanding of tree species, and poor market access along with wood price emerged as major limiting factors [108]. The failure of agroforestry related extension services across S. Asian countries has severely limited the opportunity for AFS to improve land use systems and promote its adoption to address global climate dialogues.

Policy Concerns

The advantage of promoting AFS is the familiarity of small and medium holder farmers, thereby making it a potential low hanging fruit for achieving the NDCs, and contributing to climate mitigation and adaptation. Hence, promotion of AFS alone will not be enough to address the larger concern of using the practice to provide a solution to global climate change. Promotion of AFS in region needs to be backed with an enabling and effective legal policy environment and strategic implementation to achieve the NDCs. Such policy backing would guarantee rights and ownership to communities, and bring incentives and investments, thereby creating a market-based infrastructure. Given the multiple benefits of AFS, countries should consider giving AFS a special place in REDD+ and NAMAs. However, the multiple challenges stressed in the previous sections should be appropriately discussed and addressed for agroforestry to reach its full potential. The following approaches are recommended:

- National and state policies should encourage ways to identify, classify and report on AFS, and expand the finance flow to AFS by increasing knowledge and cooperation among key stakeholders (Table 7).
- National policies addressing agriculture, forest conservation and management practices are required to take stock of both efficient mitigation and adaptation approaches to position agriculture and forestry practices for worldwide sharing of pioneering technologies and improve efficient use of land resources (Table 7).

- Financial incentives and regulatory approaches, are presently being used; however, effective enactment requires recognition of how land-use choices and emerging social-political and economic powers have the capacity to guide this practice in future [89].
- Policy framework to address climate risks need to be comprehensive enough to internalize the negative impacts of climate change, while promoting income from AFS [5].

Table 7. Overview of policies and programmes for promoting Agroforestry system in South Asia

Country	Policies/Programmes	Details
Bhutan	Study of AFS and practices in Bhutan	To contribute to the development of an agroforestry strategy and a national agroforestry programme.
India	Green India Mission	One of the eight missions under the National Action Plan on Climate Change with a target of AFS on 10 Mha of irrigated land, and 18 Mha of rainfed land.
	National Agroforestry Policy	Highlights the environmental implications of AFS including averting deforestation, and stimulating carbon stocks, biodiversity conservation, along with soil and water conservation.
	National REDD+ Policy	Includes broad values for evolving and realizing REDD+ programmes to receive benefits of the international REDD+ mechanism and produce financial enticements for local people who are involved in conservation of forest ecosystems
Nepal	National Agroforestry Policy	Drafted by Climate Technology Centre and Network and World Agroforestry Centre
Pakistan	Green Pakistan Programme	Tree planting efforts striving to realize the Bonn Challenge and address global climate concerns

Source: [44,108].

While AFS in India, through the Agroforestry Policy, aims to contribute to the goal of enhancing forest cover from the existing 23% of geographical area to 33%, the REDD+ strategy aims to slow down forest degradation and halt deforestation. Another programme that is working in this direction, the Green India Mission is another programme that supports AFS in rural parts of the country [45]. The National Agroforestry Policy of Nepal follows up its Nationally Determined Contributions (2016) and the Climate Change Policy (2011) that recognizes forests and trees including AFS to promote climate adaptation and mitigation. A study in Bhutan initiated in June 2020 is facilitated by an EU funded project on Technical Assistance for Renewable Natural Resources and Climate Change Response and Local Governments and Decentralization-Bhutan (EU-TACS). Such agroforestry relevant policies are already being drafted and developed in other smaller countries like Bangladesh and Bhutan, and more efforts will be required under the larger umbrella of SARCOPA for Pakistan, Sri Lanka and the Maldives to draft agroforestry policies relevant for these countries and agro-climatic zones.

5. Recommendations to Improve Mainstreaming of AFS in Climate Change Dialogues

SARCOPA, with support from the World Agroforestry Center (ICRAF), SAARC Agriculture Centre (SAC) and all national governments is a landmark effort in the region to acknowledge and mainstream the benefits of AFS with a special focus on country specific climate action. The UNFCCC encourages countries to produce data from field-based local investigations and carry out reporting under MRV to help create country-specific factors for robust assessment of biomass and SOC stocks [114,115]. Two-phase sampling approaches using laser scanning followed by field-based surveys is an effective method for assessing TOF resources. The region requires more country-specific research on improving TOF models for biomass calculation, that are amended to AFS tree resources [21]. As a first

step, it is important to standardize protocols for carbon stock estimation following national REDD+ strategy. India is one of the few countries in the region to pioneer regular basis satellite-based surveys involving RS-GIS tools and has been doing this since the 1980s to assess forest cover changes. India's NDC target could be met by TOF, so its National Agroforestry Policy formulated in 2014 and its National REDD+ strategy, 2018, will benefit the entire process. Incentives for AFS across the region will need more external financial support to strengthen the existing systems. Developing agroforestry pilots for REDD+ can be the next step to building capacity of foresters and local communities, and to generate awareness on mainstreaming AFS for increased benefits. Conflicts with reference to AFS could be avoided by adopting a cautious, site-specific, and participatory approach to project development [18,116]. Skill development and capacity building as per the first phase plan of action SARCOPA by creating model agroforestry farms are already underway across the SAARC region. Discussions on similar issues are becoming common at national and sub-national levels especially in India, Nepal, Bhutan and Bangladesh. Forthcoming research in the region on AFS will requires more mechanistic and process-based surveys followed by models linking AFS and crop development with soil water, carbon and biogeochemical cycles [117].

6. Conclusions

The synthesis presented in this paper clearly supports the importance and potential of AFS in securing human well-being for marginalized and impoverished people that can also help the countries in S. Asia to meet their NDCs and contribute to mitigation of climate change. Although, there are already benefits from AFS that are considerable but they have not been sufficiently harnessed at the local or national level. One key enabling condition for mainstreaming AFS is a regional consensus at the country level and this has already begun as countries work on facilitating and extending support to each other under the larger umbrella of SARCOPA. It is important to mention here that national commitments to acknowledge benefits from AFS and recognize them under national agroforestry policies is the next important step. The phase-wise implementation as per SAARC Resolution on Agroforestry has been initiated and will continue for the next 12 years. These are promising commitments by regional countries and their governments. Countries like India and Nepal have proactively developed agroforestry policies considering AFS is a low hanging fruit that should be appropriately used. Recently, Bhutan, Bangladesh and the Maldives have also initiated their efforts in developing national agroforestry policies. It is certainly relevant for the mountain country of Bhutan, the coastal nation Bangladesh and island countries of Sri Lanka and the Maldives to proactively work in this direction to promote synergy for climate change mitigation and adaptation in the region. Around 21% of the agriculture land area in S. Asia is under trees which is less than other parts of Asia, except for Central Asia (Table 3). Countries across the region need to take steps to set an achievable target to restore degraded AFS and improve the systems by at least 50% in the coming five years as a first step. With years of experience and a traditional knowledge base of AFS across the region, this knowledge could be used to improve the conditions and address the NDCs. Moving beyond awareness and technical cooperation to realize the benefits, fulfilling local livelihood demands and creating more opportunities, is urgently needed to strengthen the ongoing momentum on AFS in the region. Important mechanisms to enhance agricultural productivity of forest dependent marginalized communities and farmers by using enhanced inputs, innovative technologies, and incentives to improve agricultural intensification, and livelihood diversification can help in achieving NDC targets and make headway on several SDGs.

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