Potentials of Agroforestry for Rural Development and Climate Resilient Farming in South Asia

Agroforestry | Climate Resilience
Rural Development | Regional Cooperation

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Foreword

South Asia (SA) is home to nearly 1.9 billion people, accounting for almost one quarter of the world population residing on less than 4.5 percent of the global landmass. Nearly two third of the rural population in the region depends directly on agriculture for their livelihoods and food security. At the same time, SA is bearing the burdern of almost one third of the world's poor. The region also encounter severe climate change impacts such as rising sea level, flood, heat stress and drought, land degradtation and biodiversity losses. Consequent upon these challenges SA emerged as a global hotspot for socioeconomic, demographic, and climate vulnerability.

Agroforestry is an integrated land-use system in which woody perennials are deliberately combined with crops and or livestock in a spatial or temporal arrangement to enhance productivity in a sustainable and resource-efficient manner. As climate-smart agriculture technology, agroforestry significantly contributes to poverty alleviation and climate resilience in SA by diversifying farm-based livelihoods, health and productivity improvement of natural resources, and income generation. Besides year-round food availability, agroforestry also help increase soil fertility, water conservation and ecosystem services. By diversifying production systems, agroforestry helps farming households manage climate and market risks and reduces dependence on single-crop livelihoods.

In these contexts, SAARC Agriculture Centre organised virtually a three-day Regional Expert Consultation Meeting on "Role of Agroforestry in Improvement of Rural Livelihood and Climate Resilient Communities in South Asia" on 23-25 September 2025. The meeting brought together researchers, practitioners, policymakers and entrepreneurs from across the region and abroad and discussed current status, pathways, policy framework for reducing rural poverty and strengthening climate resilience through agroforestry. Sharing of success stories, lessons learnt and future directions for agroforestry development was particularly encouraging.

I am pleased to learn that, based on the papers presented by the country focal points and experts, and the synthesis of the discussions, this document will serve as a valuable reference source for policymakers, researchers and development practitioners and paving the way for regional cooperation policy formulation in agroforestry sector in South Asia.

Dr. Md. Harunur Rashid
Director, SAC

Contents

Acronyms

AAP	Assisi Aid Project
ACIAR	Australian Centre of International Agricultural Research
ADBL	Agricultural Development Bank Limited
ADS	Agriculture Development strategy
AF	Agroforestry
AFS	Agroforestry System
C-AEP	Country Agriculture Extension Profile
AEPSA	Agricultural Extension in South Asia
AFU	Agriculture and Forest University
AHP	Analytic Hierarchy Process
AKC	Agriculture Knowledge Centre
ANSAB	Asia Network for Sustainable Agriculture and Bioresources
ARR	Agroforestry, Reforestation, and Regeneration
CASH	Climate Action for Smallholders
AWABE	Advancing Women in Agroforestry Business Enterprise
BFI	Banking and Financial Institution
BIMSTEC	Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation
LiBIRD	Local Initiatives for Biodiversity, Research, and Development.
BMI	Body Mass Index
BSN	Bajra Samaj Nepal
CARE	Cooperative for Assistance and Relief Everywhere.
CBEs	Community-Based Enterprises
CBTN	Community-Based Tree Nurseries
CCAFS	Climate Change and Food Security
CCDR	Country Climate and Development Report
CFUG	Community Forest User Group
CGIAR	Consultative Group on International Agricultural Research.
CIFOR	Center for International Forestry Research
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (International Maize and Wheat Improvement Center)
CSV	Climate Smart Village
CTCN	Climate Technology Centre and Network

CTEVT	Council for Technical Education and Vocational Training.
DCNepal	Development Connection Nepal
EU	European Union.
FAN	Forest Action Nepal
FAO	Food and Agriculture Organization
FAOUN	Food and Agriculture Organization of the United Nations
FCPF	Forest Carbon Partnership Facility
FECOFUN	Federation of Community Forestry Users Nepal
FFF	Forest and Farm Facility
FFN	Family Forest Nepal
FFPP	Forests for Prosperity Project
FRTC	Forest Research and Training Centre
DoFSC	Department of Forests and Soil Conservation
EnLiFT	Enhancing Livelihood from Improved Forest Management in Nepal
FTA	Forests, Trees and Agroforestry
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Agency for International Cooperation)
GLOF	Galciar Lake Outburst Flood
GMAP	Global Market Access Program
HKH	Hindu Kush–Himalaya
HRT	Horticulture
IAAS	Institute of Agriculture and Animal Science
ICIMOD	International Centre for Integrated Mountain Development
ICMA	International Capital Market Association
ICRAF	International Centre for Research in Agroforestry
ICT	Information and Communication Technology
ID	Identification or Identity
IFAD	International Fund for Agricultural Development
IFC	International Finance Corporation
IIED	International Institute for Environment and Development.
IKI	International Climate Initiative
IMCC	Inter-Ministerial Coordinating Committee

IOF	Institute of Forestry
IRRI	International Rice Research Institute
MoITFE	Ministry of Industry, Tourism, Forests and Environment
IUCN	International Union for Conservation of Nature
IWMI	International Water Management Institute
JICA	Japan International Cooperation Agency
KAFCOL	Kathmandu Forestry College
KC	Khatri Chhetri
KOICA	Korea International Cooperation Agency
KP	Khyber Paktunkhwa
LBU	Lumbini Buddha University
LRP	Local Resource Persons
MAP	Medicinal and Aromatic Plants
MoALD	Ministry of Agriculture and Livestock Development
MoAD	Ministry of Agriculture Development
MoFE	Ministry of Forest and Environment
MScAF	Master of Science in Agroforestry
Mha	Million hactare
mm	millimeter
MRV	Monitoring, Reporting and Verification
MTA	Material Transfer Agreements
MTR	Mid-Term Review
NAF	Nepal Agroforestry Foundation
NAFLQML	National Animal Feed and Livestock Quality Management Laboratory
NAFSCOL	National Agroforestry and Forestry Seed Cooperative Limited
NAP	National Adaptation Plan
NARC	Nepal Agriculture Research Council
NDC	Nationally Determined Contribution
NGO	Non-Governmental Organizations
NIFRA	Nepal Infrastructure
NLSS	Nepal Living Standards Survey
NORAD	Norwegian Agency for Development Cooperation
NPC	National Planning Commission
NPR	Nepalese Rupees
NRB	Nepal Rastra Bank

NSCA	National Sample Census of Agriculture
NSO	National Statistics Office
NTFPs	Non-Timber Forest Products
PES	Payment for Ecosystem Services
PMU	Project Management Unit
PPCA	Public-Private Community Alliance
PPP	Public–private partnerships
RASFN	Regenerative Agroforestry for Sustainable Farming in Nepal
RBGE	Royal Botanic Gardens Edinburgh
RECOFTC	Regional Community Forestry Training Center
REDD	Reducing Emissions from Deforestation and Degradation
REPIC	Renewable Energy & Energy Efficiency Promotion in International Cooperation
RFD	Regional Forest Directorate
SAARC	South Asian Association of Regional Cooperation
SAC	SAARC Agriculture Centre
SARP	South Asia Regional Program
SDF	SAARC Development Fund
SDG	Sustainable Development Goal
SFB	Silviculture and Forest Biology
SFCL	Small Farmer Cooperative Limited
SGP	Small Grants Program
SIDA	Swedish International Development Cooperation Agency
SME	Small and Medium Enterprises
SOP	Standard Operating Procedure
SSP	Shared Socioeconomic Pathway
STRASA	Stress-Tolerant Rice for Africa and South Asia
TNA	Training need Assessment
TU	Tribhuvan University
UK	United Kingdom
UN	United Nation
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
VITA	Village Integrated Transformation of Agriculture

WB	World Bank
WWF	World Wild Fund
WWFNN	Worldwide Fund, Nepal

Chapter 1

Agroforestry in South Asia: A Pathway to Livelihood Upleft and Amelioration of Climate Change

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Background

South Asia (SA) is located between Himalaya mountains to North, Indian ocean, and Bay of Bengal to the South, and comprising eight countries Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. The region is resided by ~1.9 billion people, a quarter of global population on over 4.5% land mass (5.13 million km^2) of the world covering nearly 11.50% of the Asian continent (WB, 2018).

GDP Share of Agriculture	
Afghanistan	34.52%
Pakistan	23.33%
Nepal	21.19%
India	16.0%
Bhutan	14.67%
Bangladesh	11.0%
Sri Lanka	8.28%
Maldives	5.11%

Box 1: Share of Agriculture to GDP

Agriculture is the main land use system as 39% of the total area of South Asia is classified as arable. On country basis share of land use for agriculture activities varies from >70% of total area in Bangladesh to 12.8% in Bhutan. The region accounts for around 4.36% (100.88 trillion) of the world Gross domestic products (GDP), country wise share of GDP of agriculture sector ranges from 34.52% in Afghanistan to 5.11% in Maldives (Box 1; WB and OECD, 2025).

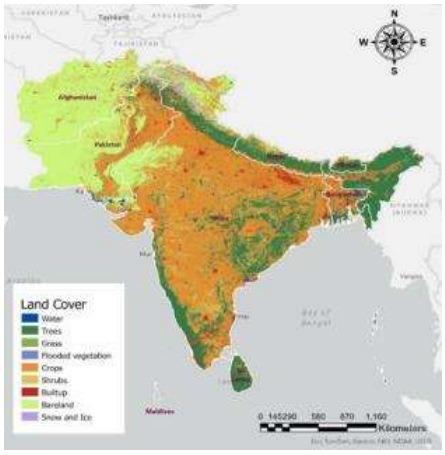

Figure 1. Land cover map of South Asia

Forest and tree cover is an important land use system in South Asia. South Asian region represents diverse forest cover. Land use cover map of SA shows that Afghanistan with land area of 65,223 thousand ha has lowest forest cover of 1.5% mostly spare tree cover. Bhutan in contrast show remarkable forest cover of 72%, followed by Nepal (>40%). Maldives (39%), and Sri Lanka (29.7%), India (24.4%), Bangladesh (15%), and Pakistan (5%) (Figure 1; Brown et al., 2022). In this context forest

occupies a unique and pivotal role from commitment to environmental conservation, supporting biodiversity and livelihood, ecological balance, challenges and prospectives.

South Asia's rural economy is dominated by small, marginal farms with high labor intensity and diversified income portfolios that combine crops, livestock, fisheries, wage labor, and migration remittances. Land fragmentation, limited irrigation security in rainfed belts, and exposure to climate shocks constrain productivity and household resilience. Women and youth are central to on-farm labor and post-harvest value addition, yet often face barriers to asset ownership, extension, and markets.

According to UNDP report (2024), 402 million (35%) of the world poor live in South Asia earning less than 1.9 USD/day. About 70% of the population of South Asia live in rural areas and predominantly depends on agriculture for livelihood. Women folk dominates agriculture workforce in rural areas.

Among South Asian countries India with the largest economy and agriculture sector (agriculture, forestry and fishing) is followed by Pakistan, Bangladesh, Nepal, Sri Lanka, and Bhutan. Agriculture, forestry and fishing constitute more than a 20 percent of GDP in terms of value added as shown in Table 1.

Table 1. Economic significance of the agriculture, Forestry and Fisheries sectors in the six South Asian countries, 2022

Country	GDP (per capita)	Agric. Forestry and Fisheries value addition	Share of GDP	Land under Agri.	Agri. Sector employment (female)
		Million USD	%	(%)	%
Bangladesh	1,785	35,965	11.20	77.35	36.86 (55%)
Bhutan	2,992	343	15.80	13.45	43.96 (54%)
India	2,090	47,0378	16.70	60.05	42.86 (59%)
Nepal	1,083	7,890	21.10	28.75	61.39 (75%)
Pakistan	1,696	84,224	22.40	47.09	36.43 (67%)
Sri Lanka	3,988	6,673	8.80	45.46	26.41 (28%)

Source: Compiled from the World Development Indicators database, World Bank. GDP=gross domestic product. Agriculture value-added data are for 2022 for all countries except Bhutan, for which 2021 data are used

Table 2 shows the direct climate change impacts of the agriculture sector in six countries in terms of Greenhouse Gases (GHG) emissions of methane and nitrous oxide. The water used for irrigatation purpose, created water scarcity in Pakistan, India and Sri Lanka emission was observed in India, followed by Sri Lanka and Bangladesh. Environmental stress has reached critical levels because freshwater withdrawal for agriculture leads to water stress. These levels are acutely high in Pakistan, followed by India and Sri Lanka.

Table 2. Agricultural non-carbon dioxide emissions and Freshwater withdrawals in the Six South Asian countries, 2020

Country	Nitrogen Oxide emission	Methan mission	Annual Fresh water withdraws for Agriculture**	Ground water level***
	MMT CO_2e*		%	
Bangladesh	25.21	60.37	87.82	5.72
Bhutan	0.10	0.39	94.08	1.41
India	230.51	500.26	90.41	66.49
Nepal	1.74	4.39	98.14	8.31
Pakistan	5.88	19.94	93.98	116.31
Sri Lanka	59.79	135.41	87.36	90.79

Source: Compiled from the WB indicators database. Note: GHG = greenhouse gases; MMtCO2e = million metric tons of carbon dioxide equivalent. * Emission data reported are the 3-year average for 2018–2020. ** As percentage share of the country's total freshwater withdrawal. 90.79 *** Also called water withdrawal intensity, this measure is defined as the ratio between total freshwater withdrawn by all major sectors to total renewable freshwater resources, after accounting for environmental water requirements. The main sectors include agriculture; forestry and fishing; manufacturing; the electricity industry; and services

The region has encountered unprecedented crises in recent years. Nearly all countries of South Asia are prone to natural disasters and calamities. Frequently occurring cyclones and floods hit Bangladesh and coastal parts of India. The arid and semi-arid parts of India and Pakistan are proven to recurring.

The Food and Agriculture Organization of the United Nations (FAO, 2023) reported estimated climate induced hidden environmental costs of the agrifood sector due to withdrawal of blue water, land use changes, and nitrogen emissions (FAO, 2023). In addition to environmental repercussions, and social costs due to malnutrition, undernourishment, poverty, and hidden health costs. Climate change impacts induced environmental and social cost are recorded highest in India, followed by Pakistan, Bangladesh, Sri Lanka, and Nepal (Table 3).

Table 3. Environmental and Social cost indued by Climate Change in South Asia

Country	Environmental cost (Million USD)				Social cost (Million USD	
	Climate change	Agri. Blue water withdraws	Land use change	N emission	Agrifood worker poverty	Burden of disease (undernutrition)
Bangladesh	8,101	316	340	16,293	16,293	1,399
India	77,396	36,322	24,051	144,209	15,7360	15,253
Nepal	2004	243	55	1,474	2,089	148

Pakistan	16,485	5,226	76	7,254	16,216	4,681
Sri Lanka	859	149	36	3,116	341	38

Source: Compiled from estimates reported, FAO

Climate change resulted in rainfall decrease, incidence of drought in central Himalaya, increased trends of flood induced disaster in higher Indus, Ganges, and Brahmaputra couple with higher water stress in Western region vis a vis Eastern part of South Asia and heat stress, drought and flood are bound to jeopardize the food security and sovereignty particularly in India and Pakistan and in the whole region in general.

At this time when South Asia faces insurmountable problems of climate change, fragility of agrifood system, biodiversity loss, degradation of resources, practicing agroforestry by planting in the field and around the farm premises is the most effective use of resources with potential gains. As agroforestry, it can systemically tackle twin menaces of poverty and climate change effectively.

Agroforestry Status in World and South Asia

Agroforestry is defined as land use system that integrated trees with agriculture crops and/or animals, either simultaneously or in sequence, to enhance productivity, economic return, and ecological benefits compared to traditional single-crop farming. Lundgren & Raintree (1983) described agroforestry as the deliberate use of woody perennials, such as trees, shrubs, and bamboo, alongside crop or animals within the same land unit, arranged in spatial or temporal patterns. As interface between agriculture and forestry, agroforestry enhances productivity, biodiversity and sustainability. Agroforestry system (AFS) is 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 covered more than 50% of the land coverage (Zomer et al., 2008, 2014, 2016). Nair et al., (2009) and Zomer et al., (2016) projected global agroforestry over to be 1023 Mha and 1020 Mha respectively.

In South Asia (SA), AFS has a long history of acceptance and adoption of traditional practices across diverse agro-ecological conditions and agroclimatic zones (Dhyani et al., 2021). In comparison to other regions, the percentage of all agriculture areas is covered with trees in SA stands 21% against 82%, 27%, 23% and 46% in South-East Asia, Northern and Central Asia, East Asia, and globally respectively (Zomer et al., 2014; 2016).

CAFRI estimated 13.75 Mha agroforest in India, fulfilling 65% timber and 50% fuelwood need and of the country. In Bangladesh agroforestry support household fuelwood needs reducing household expenses. Fast growing and

high biomass spp. Like popular (*Populus spp*.) and Eucalyptus (*Eucalyptus spp*.) have been recognized as industrial plantation and prefer in SA for industrial agroforestry plantations and shelterbelts due to their economic return and ecological values. Other tree spp. are *populus* spp. *Tectona grandis*, *Casuarina equisetifolia* L. *Moringa oleifera* trees are preferred for medicinal and value-added products in India.

The demographic and land use diversity in SA inculcate different agroforestry systems in the region. Most common and significant AFS in SA are listed below.

Multifunctional Home Gardens: These are traditional, intensive agroforestry systems by integrating trees with a variety of crops, vegetables, and medicinal herbs in and around the house premises. These multi species and multistoried vegetation provide food security, income and nutritional diversity simultaneously (Kumar et al., 2012). Home gardens-based agroforestry systems are practiced in Bangladesh and India and fulfills household needs for fuelwood, vegetables and herbs.

Agri Silviculture System: In this system trees are integrated into agriculture crops**.** Most common examples are poplar-based (*Populus deltoides*), and Eucalyptus (eucalyptus spp.) (Park et al., 2022). Such AFS system is common in northern India and Pakistan.

Plantation Agriculture: Integration of trees with commercial crops like coffee (*Coffea spp*.), tea (*Camellia sinensis*), Cacao (*Theobroma Caocao*), and spices (like black pepper, cardamom) such AFS is common in Sri Lanka.

Silvopastoral System: In this system grazing animal and forestry share same land area. Trees like carob (*Ceratonia siliqua*), and Euphrates poplar (*Populus euphratica*) are commonly used (Nair et al., 2021).

Agrosilvopastoral System: Mahlab (*Cerasus mahaleb*), sumac (*Rhus croiaria*), and laurel (*Laurus nobilis*) are major components (Kumar et al., 2012).

Alley Cropping: In this system trees are planted in wide rows of agriculture crops in the alleys between rows. Besides control of soil erosion, it helps in soil fertility, and providing additional income from trees (Jose, 2009).

Boundary Planting: In this AFS trees are planted around the agriculture fields. This boundary plantation serves as windbreakers, reduces soil erosion, and provides additional income and fruits, timber and fodder without occupying additional cropping areas (Brandle et al.,2004).

Fertilizer trees grow along with tree-grass/crop system: This system involves planting specific trees having potential to improve soil fertility status

in integration with crop or grasses. Such integration helps in resource conservation and enhance agriculture productivity (Park et al.,2022).

Climate and environmental conditions, traditions are major AFS in any country. For example, in Afghanistan trees and crop are integrated into agri-silviculture to enhance soil fertility and crop production at the same time, agrosilvopatroal system integrates crop, trees, and animal help to increase stability of the agriculture system through income return and natural resources conservation. In Bangladesh, homestead agroforesty is the most practiced model where trees, crop with livestock are kept around the home for food, fuel and income all together in rural areas. The agri-silviculture practices in Bhutan involved integration of cropland and forestry to optimize land use and increase land use efficiency and fruits trees are integrated with other crops to ensure economic return and nutritional need simultaneously. Details of major agroforestry systems in SA is given in Table 4.

Table 4. Major Agroforestry Systems in South Asia

Country	Major Agroforestry Systems	References
Afghanistan	Agri silviculture, Agrosilvopastoral systems, Natural regeneration of forests.	Dhyani et al., (2021)
Bangladesh	Homestead agroforestry, ZZCropland agroforestry, Multistory agroforestry	Leuschner et al., (1987), Khan & Alam (2015)
Bhutan	Agri silviculturalsystems, Silvo horticulturalsystems, Agroaquaculture	Tornar & Bhatt (2005); Dhital (2009)
India	Home gardens, Alley cropping, Silvopasture systems, Multistrata agroforestry,	Nair et al., (2009; Dhyani et al., (2021)
Maldives	Coastal agroforestry, Integrated fish and tree farming, Coconut-based agroforestry	Dhyani et al., (2021)
Nepal	Agrosilvicultural system, Agrosilvoanimal system, Silvopasture system, Taungya system, SALT.	Aryal & Pyakurel 2007; Joshi, 2015; Amatya et al., (2018)
Pakistan	Farm forestry, Agri-silviculture, Shrub-based agroforestry	Khan et al., (2017; Hayat et al., (2020)

Country	Major Agroforestry Systems	References
Sri Lanka	Tea agroforestry, Coconut-based agroforestry, multi-tier systems, Taungya	Nelliat et al., (1974; Tejwani (1984)

The land of SA is continuously squeezing due to growing population triggered urbanization. Besides demographic challenges, the region is facing severe climate changes impacts. Climate change induced challenges such as increasing temperature, rising sea level, flood and drought and mass migration enhanced vulnerability of SA. South Asia generated as much as 4.3 Gt CO_2 eq in 2021. IPCC (2014) stated that GHG emissions are responsible for global climate change, and it emphasized the need to explore ways and means to reduce Greenhouse Gases (GHGs) emission (FAO, 2015).

Despite having remarkable development, the South Asian region is still struggle with demographic challenges like poverty, illiteracy, malnutrition and access to clean drinking water. According to UNDP report (2024), about 402 million (35%) of the world poor live in South Asia earning less than 1.9 USD/day.

Subsectors within the agriculture sector such as enteric fermentation (digestible livestock gases), manure management in livestock sector, and crop cultivation particularly rice farming are major contributes to overall GHG emission. There is reportedly higher nitrogen fertilizer use in most countries to level as much as 115.97 kg/ha in some countries possibly contribute to GHG emissions. Current farming practices have not only resulted in yield gaps but also lead to GHGs emission. Low efficiency and imbalance fertilizer application input are further detororiating it. IPCC (2019) and IPBES (2019) assessments have concluded that "many aspects of current food production systems drive 13 degradations of land productivity, water resources and soil health, as well as biodiversity loss at multiple spatial scales, ultimately compromising the sustainability of food production systems".

Role of Agroforestry system and its in Climate Change Mitigation and Adaptation

The term "Climate crisis" refers to global warming, climate change and their impacts. Climate change impact can be seen everywhere affecting human, livestock and environment. The growing climate change trajectory emphasized adoption of mitigation measures to offset the detrimental effect on overall production system. South Asia has witnessed an annual mean increase of about 0.75°C over the past century, may led to loss of glaciers in the Himalayas, rising sea levels and affecting the livelihoods of more than 200 million people in Bangladesh, Bhutan, the Maldives, Nepal, and Sri

Lanka (ADB, 2013; 2014). Climate change impacts have already jeopardized low-income farmers (UNEP, 2009). Under the mean temperature rise of 2°C or less scenario, annual adaptation costs for SA would be on average 0.36% of gross domestic product (GDP), or $31 billion by 2050 and 0.48% of GDP, or $41 billion by 2100 (ADB, 2013). Climate change is overwhelmingly evident with harmful effects on least developed nationals that are vulnerable to declining crop productivity, food and water security, and ecosystem alteration and disruption (Parry et al.,2007; Schroth et al.,2009; Fagre et al.,2009; William and Jackson 2007), Such scenario emphasizes on the urgent need to identify and implement adaptation measures to enhance resilience of livelihoods and ecosystems.

Climate smart agriculture (CSA) practices such as agroforestry is a paradigm shift seeking to solve the interlinked problems of food security and climate change by focusing on sustainable production, adaptation to climate change and mitigation through abating GHGs emission. Agroforestry system potentially contributes to nine out of 17 SDGs including SDG 1 (no poverty); SDG 2 (zero hunger); SDG 3 (good health and well beings); SDG 5 (gender equality); SDG 8 (decent work and economic growth); SDG 10 (reduce inequalities); SDG 15 (life on land); SDG 12 (responsible production and consumption) and SDG 13 (Climate action) (Van Noordwijk et al., 2028; 2020).

IPCC, (2020) Annual assessment report 6 (AAR 6) classified agroforestry as CSA technology with both mitigation and adaptation potentials (Figure 2).

Source: IPCC, 2020; AR6

Figure 2. Mitigation and adaptation potential of Agroforestry

In agroforestry fast growing and nitrogen fixing tree species can improve soil fertility and contribute to crop productivity. Additionally, trees have a crucial role in lowering vulnerability, boosting the resilience of farming systems, and protecting households from threats related to climate (Meragiaw, 2017).

Depending on the crop, agroforestry can increase crop yield by 6-56%, improve soil fertility, and reduce soil erosion by wind and water and Carbon input (Tefera et al., 2019; Murthy et. al., 2013). IPCC, 2019 reported that issues like land degradation, desertification, climate change adaptation, and food security can be addressed by practicing agroforestry. Agroforestry contribute to climate resilience by changing microclimatic conditions such as alley cropping increased crop resilience against extreme climate events (Jacobs et al., 2022), reduced wind erosion and evapotranspiration (Rao et al., 2007; Palsaniya and Ghosh, 2026), enhance carbon capture vis a vis crop or pasturland (Sharrow and Ismail 2004; Tomar et al., 2021, enhance landscape carbon stock to 50-75 Mg C ha^{-1} in comparison to row crop contained <10 Mg C ha^{-1} (Verchot et al., 2007; Montagnini and Nair, 2004), wide range of C stock ranging from 29-228 Mg ha^{-1}, elaborates the significance of agroforestry in climate resilience and based carbon mitigation schemes agroforestry sequester carbon can contribute to mitigation as well as potential

source of income to resources-poor farmers (FAO, 2009) as one of the and it has been reported that on farm timber production generates 450 employment days per hectare per year in India (Singh et al., 2023).

Nexus of Agroforestry and Nationally Determined Contributions

As envisioned in the Paris agreement, countries submitted Intended Nationally Determined Contributions (INDCS) known as Nationally Determined Contributions (NDCs) where countries pledge to reduce GHGs emissions. In Asia 21 % economies have proposed AFS in NDCs, far less than Africa (71%), Americas (34%), but higher than Oceania (7%) (Rosenstock et al., 2019a; 2019b). Status of linkage between Agroforestry and NDCs in the context of South Asia is shown in Table 5.

SAARC developed the SAARC Regional Coordinated Program on Agroforestry (SARCOPA) in 2016 with active facilitation and technical support of the World Agroforestry Center (ICRAF) and SAARC Agriculture Centre (SAC). 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.

Table 5. Agroforestry links with Nationally Determined Contributions

Country	NDC Commitment	Element of Agroforestry in NDC
Bangladesh	• Emission reduction from agriculture and development of forest sector. • Unconditional contribution to reduce GHG emission by 5% by 2030 in power, transport, and industry sectors. • Conditional 15% reduction in GHG emission by 2030 in power, transport, and industry sectors subject to appropriate international support.	○ No mention of agroforestry in NDC Ecosystem based adaptation (Inc. forestry co-management) ○ Community based conservation of wetland and coastal areas ○ Green belt afforestation and reforestation of mangroves.
Bhutan	No NDC available	Potential of Climate smart agriculture, particularly

Country	NDC Commitment	Element of Agroforestry in NDC
		development of agroforesty, agri-silvi-pastroal systems for fodder production, organic and conservation agriculture are included as mitigation measures.
India	Decrease emission by 33-35% from 2005 level by the level 2030 to be achieved through increase in the segment of non-fossile fuel by 40% along with sequestering an additional 2.5-3 billion tonnes oF carbon through tree by 2030.	Not specifically mentioned agroforesty, however it is believed to play a critical role in national carbon mitigation targets under National Action Plan on Climate Change (NAPCC).
Nepal	Decrease dependency on fossil fuel by 2050 and bring at least 40% of land under forest cover.	Agroforestry a mean to achieve the NDC target included.
Pakistan	Mitigation target of 20% of the projected 2030 emission-subject to international financial support.	Agroforestry implementation included in mitigation strategies.
Sri Lanka	Increase forest cover from 29% to 32% by 2030, reduce emission by 20% in energy sector and 10% in forest, transport, and industry etc.	No mention of agroforestry in the NDC.

Source: Cedamon et al., 2019; Dhyani et al., 2021; Tenzin K et al., 2020; Sahoo et al., 2020; Baig et al., 2020; Namirembe et al., 2025

Among SAARC member countries, India and Nepal have National Agroforestry Policy (NAP), showing commitments of these the in promotion of AFS. Bhutan and Bangladesh are moving rapidly to develop NAP. Since developed NAP in 2014, India is considered a pioneer in this regard. Pakistan committed to 100 million trees plants in 5-years under Green Pakistan program or Plantation Tsunami to achieve Bonn Targets (Baig et al., 2020).

Agroforestry in REDD+ and Nationally Appropriate Mitigation Actions

REDD+ is the key instrument of climate negotiations in United Nations Framwork Conventions on Climate Change (UNFCCC) aims at economic reward to countries for improving forest health by conservation and management that reduce GHG emission. India executed REDD+ with reference to i) COP-16 resolution, ii) Framework of REDD+, iii) Paris agreement and iv) National statutory and policy agenda for conservation of forest, and activities of REDD+ are aligned with National Forest Policy, Nepal prepared the final draft of REDD+ in 2014 align with principles of sustainable development, Pakistan initiated REDD+ in 2010 envisage forest ecosystem as public goods, source of multiple benefits needed for development and climate change mitigation, and supported by National Forest Policy, 2015, climate change Policy, 2012 and Environment Policy, 2005, While Sri Lanka in its 5 years strategy (2018-2022)-National REDD+ Investment Framework and stands at advance stage of REDD+ readiness and includes technical essentials of REDD+ in the light of Warsaw Framework (Dhyani et al., 2021).

Constraints on Mainstream Agroforestry in South Asia for Meeting Climate Change Targets

Despite having widespread environmental and socio-economic benefits, SA is still not able to get the full swing return from AF. In most of the SA countries, institutional constraints such as land right, technical support, high agriculture production per hectare, absence of market, small landholders, insecure land tenure system, lack of right to fell tree for economic benefits are major hurdles to promote AF in the region (Rasul et al., 2006).

In India, Forest Conservation Act, 1988 prohibit farmers from tree harvesting from State Forest (UNEP, 2013). Nepalese farmers are unable to get financial benefits from AFS due to unsupportive regulation in harvesting and marketing of trees (Cedamon et al.,2019). In Pakistan issues such as low training of forest personnel, insufficient understanding of tree species, poor market and wood price are major hurdles (Baig et al., 2020).

Policy Status, Gap Analysis and Recommendations

Enabling policy framework and strategic implementation are prerequisites for the promotion of AFS in South Asia. The drive to achieve NDCs, AFS must be facilitated through conducive policies backing right and ownership to end users and incentivize the sector to develop market-based infrastructure in the region. In this regard the following recommendations are proposed.

i. National and State policies should encourage identification, classification and reporting on AFS, and expand finance flow to AFS by increasing

knowledge and cooperation among stakeholders (Table 5)

ii. National policies are required to take stock of efficient mitigation and adaptation approaches to share pioneering technologies with rest of the world for efficient use of land resources.

iii. Policy framework to address climate risks needs to be comprehensive enough to internalize the negative impacts of climate change, while promoting income from AFS (Feliciano et al., 2018).

Table 6. Overviews of Polices and Programs for Promoting Agroforestry System in SA

Country	Policies/Program	Details
Bhutan	Study of AFS and practice	To contribute to the development of an agroforestry strategy and a national agroforestry program
India	Green India Mission	Mission in national Action Plan on climate change to bring 10 Mha irrigated and 18 Mha rainfed area under AF
	National Agroforestry Policy	Addresses deforestation, and simulation of carbon stocks, biodiversity conservation along with soil and water conservation
	National REDD+ Policy	Achieving financial incentives for local people involved in REDD+
Nepal	National Agroforestry Policy	Drafted Climate Technology Centre, and Network and World Agroforestry Centre
Pakistan	Green Pakistan Program	Tree planting is an effort striving to realize the Bonn Challenges and address global climate concerns.

Source: Inder et al., 2018; Baig et al., 2020

Conclusion and Wayforward

Agroforestry, as strategically integrated with agriculture, offers SA a viable pathway to climate resilience and sustainable rural development. Besides climate resilience, agroforestry can offer as shock observers against climate shocks in SA. Agroforestry can potentially contribute to the alleviation of

poverty by focusing on poor and marginalized population and NDCs to help mitigate climate changes in SA.

As around 21% of agriculture land in SA is under trees, far less than other parts of the world and Asia. For this purpose, bold steps are needed to be taken by countries. Such steps may include creating and facilitating enabling policies and building regional consensus to upscale AFS. Strengthen reginal collaboration and collective efforts to facilitate the development of AF in the region and learn from each other success stories in the context of broader interest of the region.

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Chapter 2

Role of Agroforestry in Improvement of Rural Livelihood and Build Climate Resilient Communities in Bangladesh

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Background

Bangladesh, a low-lying riverine country in South Asia, is globally recognized as the largest delta on the Earth, shaped by the confluence of the Ganges, Brahmaputra, and Meghna rivers. It is a land of striking natural richness and human resilience. With an area of 147,570 km² and nearly 165 million population, Bangladesh stands 8th most populous country in the world (WB, 2023). The annual population growth rate is 1.12%. The net cropped area stands at 9.9 million hectares (mha) with an average cropping intensity of 198% a testimony to the hard work farming communities under the pressures of limited land and growing population (BBS, 2022). The agricultural sector contributes about 11.55% to GDP in FY 2023-24 and employs around 44.42% of total labor force (BBS, 2024).

Climate is tropical monsoon marked by warm temperatures, high humidity, and rich biodiversity, provides a unique ecological foundation for diverse farming systems (FAO, 2018). Despite these rich ecological blessings, Bangladesh is under mounting pressure of forest declining at an annual deforestation rate of 3.3% during 1980-1990 (Annon, 2012). Yet, more recent evidence indicates that forest loss continues, albeit with different dynamics. Between 2002 and 2024, Bangladesh lost about 8.85 thousand hectares of humid primary forest, accounting for approximately 3.4% of its total tree cover (Figure 1; Global Forest Watch, n.d.).

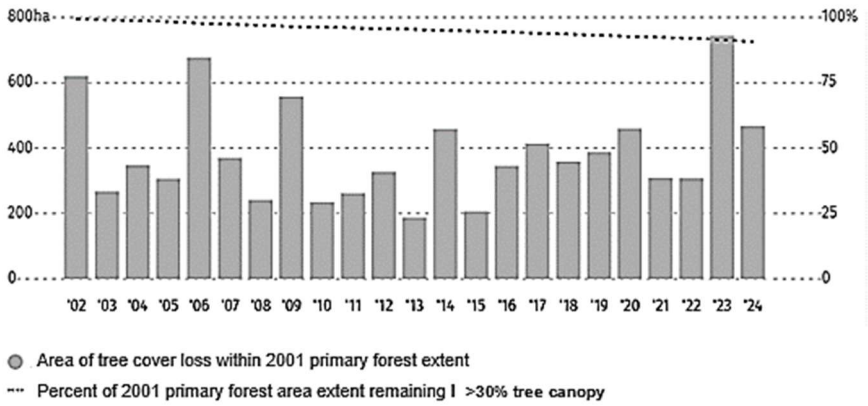

Figure 1. Primary Forest Loss in Bangladesh (Global Forest Watch, n.d.)

Global Forest Watch (n.d.) data show that from 2001 to 2024 the country experienced a net loss of 262 thousand ha of tree cover (a decline of ~13 % relative to its 2000 baseline) (Figure 1). However, BFD 2022 reported that the per-capita forest land availability is only 0.015 ha, far below the global average of 0.60 ha (FAO, 2020b). Forests cover only 17.89% of total land area (Rahman & Alam, 2022) and forest resources contribute modestly to the national economy by contributing 3.11% to national GDP and 1.29% to GNI, while employing around 2% labor force (BBS, 2021). Deforestation, however, remains a serious challenge, occurring at a rate of 3.3% annually (FAO, 2020a), and not only reduces timber and non-timber forest products but also the country's carbon stock, which stands at just 0.42 million tons above ground—of which only 0.14 million tons come from forests (Hassan et al., 2017).

Bangladesh's natural environment offers both remarkable richness and serious challenges. Located in a tropical monsoon zone, the country experiences warm, humid conditions, rich alluvial soils, and high biodiversity that collectively support exceptional agricultural productivity. Globally unique natural features-notably Cox's Bazar, 120 km unbroken sandy sea beach (Miah et al., 2023), and the Sundarbans, the world's largest contiguous mangrove forest shared with India (Iftekhar & Saenger, 2008). These ecosystems sustain fisheries, tourism, and forest-based livelihoods while buffering the coast against cyclones, storm surges, and erosion (Habib, 2024), however, face mounting threats from climate change, sea-level rise, and anthropogenic pressures, including over-exploitation and land conversion. In a national context characterized by high population density, climatic vulnerability and limited arable land, it urgently requires transformative, multifunctional land-use strategies to balance ecological integrity with human needs.

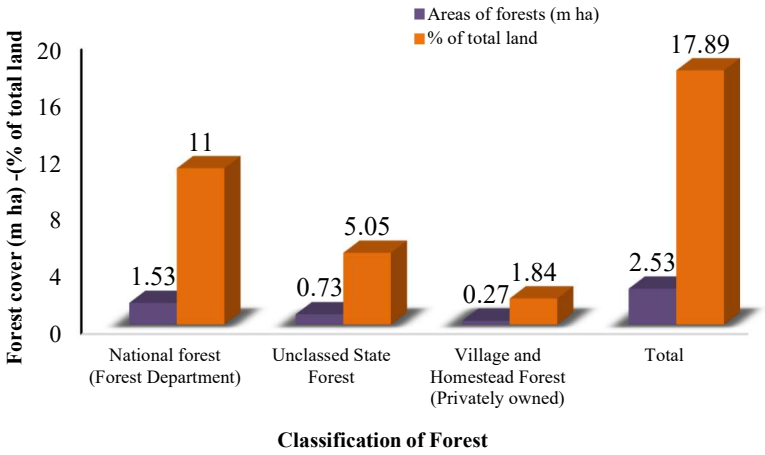

Figure 2. Distribution of forest land in Bangladesh (WB, 2023)

Forest cover accounts for about 17.89% of land area, spread over 2.53 mha, of which the Forest Department manages the largest share (1.53 mha, 11%), followed by the Ministry of Land (0.27 mha, 1.9%) and other agencies (0.73 million ha, 5.05%) (BFD, 2021). The four major forest types are (i) tropical evergreen and semi-evergreen forests (0.67 mha), (ii) mangrove forests such as the Sundarbans (0.73 mha), (iii) moist deciduous Sal forests (0.12 mha), and (iv) village forests—trees planted around homesteads, roadsides, and fallow lands—play a crucial role in meeting local subsistence needs and over 30% cultivated land still has very few trees, highlighting missed opportunities for tree-crop integration (NCS, 2016). Although, remote sensing and GIS studies show that over one billion hectares of farmland have more than 10% tree cover globally, supporting nearly one-third of the 1.8 billion people living on agricultural land (Kumar et al., 2014) affecting daily life, reducing access to fuelwood, timber, fruits, fodder, and clean air for millions of rural households and limiting the country's carbon storage potential to a modest 0.42 million tons (Hassan et al., 2017) (Figure 2).

Long-term land use trends reveal alarming shifts: arable and agricultural land making 70–78% in the 1980s, has now sharply declined to below 25%, while reserved forests have dropped to under 7% (Figure 3). It highlights that Bangladesh is losing agricultural and forest land a serious concern for sustainable land management (WB, 2023) may reduc access to fuelwood, timber, fruits, fodder, and clean air limiting the country's carbon storage potential to a modest 0.42 million tons (Hassan et al., 2017). Such transformations in land cover highlight the urgency of promoting sustainable land-use strategies such as agroforestry, which simultaneously enhance agricultural productivity, conserve ecosystems, and improve rural

livelihoods. These land use trends reveal an unsettling trajectory.

From 1960 to 2022, arable and agricultural land, once covering nearly three-quarters of the country, has fallen to less than one-quarter, while reserved forest areas have dwindled below 7% (Rahman & Alam, 2022).

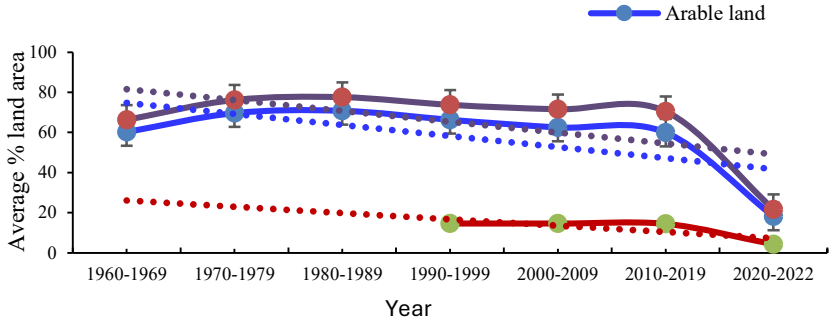

Figure 3: Land Use in Bangladesh (1960–2022)

Against this backdrop, agroforestry - the intentional integration of trees with crops and/or livestock on the same land unit - has a long history in Bangladesh and significant contemporary relevance. Traditional forms of tree–farm integration (e.g. homestead multistoried gardens, roadside trees, boundary plantings, hill-slope tree–crop combinations and tree-based fallows in the Chittagong Hill Tracts) have provided households with fuelwood, timber, fruit, fodder and shade while moderating microclimates and sustaining soil fertility. Hasanuzzaman, (2009) argues that these indigenous and farmer-managed practices represent the "past" of agroforestry in Bangladesh: deeply rooted knowledge systems that have long balanced multiple needs on small, fragmented holdings.

Recent studies highlight scalable systems (e.g., tree–pineapple–spice intercrops in uplands, salt-tolerant mangrove restoration and coastal tree belts) and the contribution of agroforestry to resilience against floods, salinity and drought. At the policy and program level, community forestry, and social-forestry initiatives since the late 1970s have provided institutional pathways for tree planting on marginal and community lands, while more recent climate-adaptation and livelihood programmes increasingly highlight tree–crop integration as a low-regret strategy (World Agroforestry, 2025).

Looking to the future, the transformational potential of agroforestry in Bangladesh is twofold. First, agroforestry can help reconcile the competing demands of food production, timber and fuelwood supply, and ecosystem conservation on extremely limited land area by increasing vertical and temporal productivity (multilayer systems, intensified alley-cropping, and

year-round production). Second, agroforestry offers a practical pathway to deliver multiple ecosystem services essential under projected climate impacts. However, realizing this potential will require addressing institutional, economic, and technical constraints: tenure arrangements and land fragmentation, incentive structures and market access for tree products, availability of improved germplasm and extension services, and integration of agroforestry into national climate and agricultural policies. Recent literature emphasizes the importance of evidence-based policy, market development (including value chains for fruit, timber, and non-timber forest products), and participatory co-design with smallholder farmers to scale agroforestry systems that are both productive and equitable (Ali et al., 2024).

The general objective of this article is to review the evolution of agroforestry in Bangladesh-exploring its traditional roots, assessing its current contributions to livelihoods, environment, and policy, and identifying future pathways to transform it into a sustainable land-use system that supports both climate resilience and rural development. The ensuing sections (1) review historical trajectories and traditional systems, (2) synthesize contemporary evidence on ecological and livelihood outcomes from agroforestry interventions in Bangladesh, (3) analyses the policy, market and institutional enablers and barriers to scaling, and (4) propose a roadmap for transformative action.

Agroforestry: Conceptual Foundations

Agroforestry (AF) is broadly defined as a land-use system and practice in which woody perennials—trees, shrubs, palms, or bamboos—are deliberately integrated with crops and/or livestock on the same land management unit (Nair, 1993; Leakey, 2017). This integration may occur spatially (simultaneous intercropping, hedgerows, multistoried systems) or temporally (rotations, shifting cultivation), and always involves both ecological and economic interactions between the woody and non-woody components. In simpler terms, agroforestry can be described as:

1. Agriculture with Trees
2. Mimicked Forest
3. Wood Meets Agricultural, and
4. Forest–Farm Fusion

Globally, agroforestry has been recognized as a crucial practice for meeting the Sustainable Development Goals (SDGs), contributing directly to 10 [e.g., SDG: 1 (no poverty), 2 (zero hunger), 3 (good health and wellbeing), 6 (clean water and sanitation), 7 (affordable and clean energy), 8 (decent work and economic growth), 11 (sustainable cities and communities), 12 (responsible

consumption and production), 13 (climate action), and 15 (life on land)] and Indirectly 7 [(e.g., SDG: 4 (quality education), 5 (gender equality), 9 (industry, innovation and infrastructure), 10 (reduced inequalities), 14 (life below water), 16 (peace, justice and strong institutions) and 17 (partnerships for the goals)] (CIFOR-ICRAF, n.d.)., Garrity, 2004; Mbow et al., 2014). Its significance as a science and practice is reflected in its institutional recognition, with agroforestry now regarded as a distinct branch of agricultural sciences (Nair & Garrity, 2012).

By diversifying incomes, food and nutritional security, on-farm ecosystem services (soil conservation, microclimate regulation, and carbon sequestration), and adaptive capacities against floods, salinity and cyclone impacts, agroforestry provides a low-regret pathway to sustainable rural development in a climate-vulnerable country. Empirical studies and program evaluations from Bangladesh document measurable livelihood gains and resilience co-benefits from diverse agroforestry models (ICRAF, 2014; Ali, 2024; Ruba et al., 2023).

Agroforestry in Bangladesh: From Tradition to Transformation

Bangladesh has a long tradition of tree-based farming practices rooted in homestead agroforestry, shifting cultivation (*jhum*), *betel leaf* cultivation under tree shade, and *sal* coppice-based systems (Chowdhury & Mahat, 1993; Rahman et al., 2015). Village forests and homestead gardens are particularly vital, supplying more than 80% of the country's fuelwood, 90% of bamboo, and significant shares of fruit and timber (Kabir & Webb, 2009). In recent decades, research organizations such as BFRI, BARC, and universities have worked to formalize and expand agroforestry practices, shifting them from indigenous knowledge-based systems to scientific and policy-supported strategies.

Looking ahead, agroforestry is increasingly positioned as a transformative solution for sustainable land use in Bangladesh. It offers a pathway to simultaneously address food security, rural poverty, biodiversity loss, deforestation, and climate change mitigation. By blending traditional practices with modern innovations, agroforestry has the potential to move Bangladesh's land-use system from fragmented resource exploitation to integrated sustainability.

History of Agroforestry in Bangladesh

Agroforestry in Bangladesh has a long and evolving history significantly since its inception in 1871, moving from transforming from traditional practices to modern, early plantation-based systems to participatory,

livelihood-based programs and modern climate-smart interventions, integrated systems that enhance environmental sustainability and rural livelihoods.

Early Development: The Taungya System (1871)

The introduction of the Taungya system in 1871 marked the beginning of agroforestry in Bangladesh. The Taungya system-a form of plantation establishment that integrates temporary food cropping with tree planting — was introduced in the late nineteenth century and is widely recognized as the starting point of organized agroforestry/taungya practices in the region (Menzies, 1988; JICA, 2011). This system, originating from Myanmar, involved cultivating crops like rice and vegetables between young teak plantations. Taungya established the paradigm of combining short-term agricultural benefits with longer-term timber and forest regeneration objectives, particularly in upland and plantation settings. It aimed to generate income for farmers while promoting forest regeneration. The Forest Department implemented this system in the Chittagong Hill Tracts, integrating agriculture with forestry to meet the dual objectives of food production and forest conservation (Jashimuddin & Inoue, 2012).

Community Forestry Initiatives (1970s–1980s)

In the late 1970s and early 1980s, Bangladesh initiated community forestry projects, notably in Rangunia and Pomora sub-districts of Chittagong. These projects aimed to empower local communities by involving them in forest management and decision-making processes. The Betagi–Pomra community forestry initiatives (started 1979–1980) are widely cited as the country's first formal experiments in community forestry, demonstrating participatory planting on degraded hills and a community benefit-sharing approach (Poush/IGES, 2000). Parallel programmes such as the Asian Development Bank-supported Community Forestry Project and the Thana Afforestation and Nursery Development Project (TANDP) strengthened extension capacity, nursery production, and smallholder tree planting across districts (FAO, n.d.; FAO, 2004). These initiatives focused on participatory approaches to resource generation and management, emphasizing benefit-sharing mechanisms between the government and local communities.

Expansion and Integration (1990–2024)

Between 1990 and 2024, Bangladesh implemented a series of donor-supported agroforestry initiatives promoting sustainable land use, environmental restoration, and rural livelihoods. Early programs included homestead and rubber-based agroforestry under the Upland Settlement Project in the Chittagong Hill Tracts (1993–2000), the Coastal Greenbelt Project (mid-1990s) to protect coastal zones, and the Village and Farm Forestry Project (VFFP), which pioneered village-level tree enterprises and extension models. Later, livelihood-oriented projects such as SHABGE (1999–2004) emphasized the role of *bari* (homestead gardens) in nutrition and income generation.

From the mid-2000s, Swiss Development Cooperation (SDC) programs, eg., Livelihoods, Empowerment and Agroforestry (LEAF), Agroforestry Improvement Partnership (AFIP), and SAMRIDDHI—expanded commercial nursery systems, planting material supply chains, and private-sector linkages to scale up agroforestry nationwide (Rana, 2021). Subsequent initiatives like SAAKTI and NATP agroforestry sub-projects further integrated tree-based systems into agricultural extension and value-chain development.

In the 2010s–2020s, approaches evolved toward climate-smart and farmer-centred models. Projects under NATP-1 (2011–2014), NATP-2 (2017–2021), and the ongoing PARTNER Agroforestry Project (2023–2028) promote participatory co-design, commercialization of fruit, timber, and non-timber tree crops, and resilience in flood- and cyclone-prone landscapes (Rana, 2021; Ahammad et al., 2023).

Overall, Bangladesh's agroforestry history reflects three phases—state-led plantations, community forestry, and market-driven scaling—blending traditional knowledge with modern silviculture to establish agroforestry as a national development priority (FAO, n.d.; Rana, 2021).

The Timeline (selected milestones; dates approximate) include

- 1871 — Taungya / teak plantation practices established in upland plantation areas (early documented taungya introductions). (Menzies, 1988; JICA, 2011).
- 1967 — Forestry Extension Service Phase I (early formal extension structures). (Forestry records).
- 1979–80 — Betagi & Pomra community forestry pilots launched. (Poush/IGES, 2000).
- 1980–85 — Forestry Extension Service Phase II; ADB-supported community forestry scaling. (FAO, n.d.).

- 1982–87 — Community Forestry Project (ADB/FD pilots). (FAO, n.d.).
- 1979–89 & 1990–95 — Jhumia (Jhum) rehabilitation and rubber plantation programmes in CHT with mixed social outcomes. (IWGIA; case studies).
- 1987 — Village and Farm Forestry Project (VFFP) and Thana Afforestation & Nursery Development Project (TANDP) begin or scale. (VFFP records; FAO).
- 1993–2000 — Upland Settlement Project (USP) and rubber/homestead agroforestry in Khagrachari and Bandarban. (Project reports).
- 1995–2000 — Coastal Greenbelt Project (coastal protection). (Forestry Master Plan/FAO).
- 1997–2004 — Forestry Sector Project (sector modernization). (Project documents).
- 1999–2004 — SHABGE (Strengthening Household Access to Bari Garden Extension). (FAO/CARE review).
- 2002–2005 — Small Farmers' Agroforestry Development Project (SFADP). (Project briefs).
- 2004 onward — LEAF, AFIP and other SDC-supported agroforestry projects scale nursery systems, planting material supply and farmer commercialization (Rana, 2021).
- 2005–2010 — SAAKTI (Sustainable Access to Agroforestry Knowledge, Technology and Information). (Samriddhi/SDC).
- 2011–2014 — Agroforestry Practices for Better Livelihood and Environment. (NATP-1 reports).
- 2017–2021 — Upliftment of Farmers Livelihood and Enrichment of Environment through Improved Agroforestry Practices in Char Land Ecosystem of Bangladesh (NATP-2 reports).
- 2023–2028 — PARTNER Agroforestry Project (national scaling effort). (Project brief).

These projects collectively contributed to the evolution of agroforestry as a national development priority in Bangladesh, integrating environmental conservation with socio-economic development.

Private Sector's Initiatives

In recent years, initiatives like the Varaha project, in collaboration with the Syngenta Foundation for Sustainable Agriculture (n.d.), have focused on efficient mango cultivation through modern drip irrigation techniques. Operating in 22 districts, this project has empowered 30,000 farmers, promoted commercialization and intercropping, and saved up to 70% of water consumption. (klimate.co[1])

The integration of agroforestry with climate-smart practices, such as floating farms in flood-prone areas, demonstrates the adaptability of agroforestry systems in Bangladesh. These systems not only enhance food security but also contribute to climate change mitigation and adaptation strategies.

The history of agroforestry in Bangladesh reflects a dynamic interplay between traditional knowledge and modern scientific approaches, aiming to achieve sustainable land use and improved livelihoods for rural communities.

Agroforestry Systems in Bangladesh

Based on scientific literature, government reports, and FAO/ICRAF classifications, Bangladesh has around 10–12 major types of agroforestry systems**,** which can be grouped into three main categories**:** (1) land-use based**,** (2) functional/ecological based**,** and (3) socio-economic based**.** Here's a synthesized overview:

Major Agroforestry Systems in Bangladesh

1. Land-use Based Classification

According to *Bangladesh Forest Department (BFD, 2022), ICRAF (2025), and Jashimuddin & Inoue (2012)*:

i. **Homestead Agroforestry**
- Most widespread (~85% of rural households).
- Combines fruit, timber, vegetables, spices, and livestock.
- Key species: Mango (*Mangifera indica*), Jackfruit (*Artocarpus heterophyllus*), Coconut, Banana, and vegetables.

ii. **Cropland Agroforestry**
- Integrate trees with field crops (rice, jute, pulses, and vegetables).
- Common models: Mango–Vegetable, Eucalyptus–Rice, Akashmoni Turmeric, and Jujube–Vegetable systems.

iii. **Forest Land Agroforestry (Taungya System)**
- Originated in 1871 in Kaptai Hills for teak (*Tectona grandis*) plantations.
- Combines forest trees with short-term crops.

iv. **Shifting Cultivation (Jhum) Agroforestry**
- Practiced in Chittagong Hill Tracts by indigenous communities.
- Mix of upland rice, vegetables, and tree species.

v. **Coastal/Greenbelt Agroforestry**
- Combine salt-tolerant trees (e.g., *Sonneratia*, *Casuarina*, *Tamarix*) with crops and livestock.
- Aims at erosion control and storm protection.

vi. **Rubber-based Agroforestry**
- Found in Bandarban, Khagrachari, and Sylhet.

- Rubber (*Hevea brasiliensis*) combined with pineapple, ginger, turmeric, banana, or medicinal plants.

vii. **Roadside, Railway & Embankment Agroforestry**

- Linear plantations with fruit/timber trees.
- Social forestry projects introduced income-sharing models (BFD, 2022).

viii. **Char Land (Riverine Sandbar) Agroforestry**

- Integrate trees (Acacia, Babla, and Neem) with seasonal crops like maize, vegetables, and pulses.

ix. **Institutional & School Agroforestry**

- Community-level plantations for shade, fruit, and educational demonstration.

x. **Aquaforestry / Pond-dike Agroforestry**

- Combines aquaculture with tree crops on pond embankments (banana, papaya, bamboo).

2. Functional / Ecological Classification

i. **Silvoarable systems** – trees + crops
ii. **Silvopastoral systems** – trees + livestock
iii. **Agrosilvopastoral systems** – trees + crops + livestock
iv. **Aqua-silvicultural systems** – trees + aquaculture

3. Socio-economic based Agroforestry Classification

Socio-economic-based agroforestry classification focuses on how agroforestry systems are designed and managed based on their social and economic roles rather than purely ecological or technical characteristics. It essentially links land-use practices with livelihood, income, and social needs of communities.

1. Home garden Agroforestry: A small-scale, multi-layered system of trees, shrubs, and crops integrated around homesteads is called home garden Agroforestry**.** For example, homestead gardens with mango, jackfruit, banana, papaya, vegetables, and poultry integration. Smallholder farmers and rural families are main users of this system.

Socio-economic Role:

- Provides food, fruits, fuelwood, and fodder for household consumption.
- Generates supplementary income through sale of fruits, vegetables, and timber.
- Promotes household nutrition and food security.

2. Boundary/Linear Agroforestry: Planting trees, *ie*., Eucalyptus, Acacia, Casuarina, bamboo, along field boundaries, roadsides, canals, or fences.

Farmers with small to medium plots who need multipurpose trees along boundaries are the typical users of this system.

Socio-economic Role:

- Produces timber, fuelwood, or fodder.
- Serves as a source of extra income from selling tree products.
- Provides protection from wind and soil erosion, indirectly supporting crop yields.

3. **Agrisilvicultural Systems:** this system **i**ntegrated annual crops with woody perennials on the same land unit. Rice or vegetables grown under timber trees like teak or mahogany is available in Bangladesh.

   Socio-economic Role:

   - Optimizes land productivity and income by timber or fruit with food crops.
   - Provides early returns from crops while waiting for long-term tree harvest.
   - Reduces financial risk by diversifying products.

4. **Silvopastoral Systems:** In this system, livestock-dependent rural households integrate trees and shrubs with livestock, eg**.,** *Leucaena* spp. with cattle grazing, fodder trees along grazing land**.**

   Socio-economic Role:

   - Provides fodder, shelter, and medicinal plants for livestock.
   - Enhances livestock productivity and farmers' income.
   - Generates additional revenue from timber or non-timber products.

5. **Agrosilvopastoral System:** This System is a combination of crops, trees, and livestock in one system. Mixed farming households with access to moderate land is suitable for this system. It consists, crops under timber trees, with goats or cows grazing on the undergrowth.
   Socio-economic Role:

   - Maximizes land use efficiency and income streams.
   - Supports food security through crops, fodder, and livestock products.
   - Reduces economic risk by diversifying production.

6. **Special-Purpose Agroforestry:** This system is designed for specific socio-economic goals**,** such as soil conservation, fuelwood production, or commercial timber production. It includes, Bamboo plantations for commercial sale, vetiver grass strips for erosion control, etc.
   Socio-economic Role:

   - Provides targeted income or ecosystem services.
   - Can be community-managed (e.g., village fuelwood plantations) or household-managed (e.g., high-value fruit trees).

Key Principles of Socio-Economic Agroforestry Classification

i. **Primary purpose:** Systems are classified based on their main benefit to people — food, income, fodder, fuel, or combined benefits.
ii. **Landholder type:** Smallholder vs. medium/large-scale farmers, and resource-dependent communities.
iii. **Livelihood contribution:** Systems are evaluated for their ability to reduce poverty, generate cash income, and enhance food security.
iv. **Integration level:** Ranges from simple (homegarden) to complex (agrosilvopastoral).

Socio-economic agroforestry classification emphasizes how agroforestry supports human livelihoods, rather than just the ecological or technical arrangement of crops and trees. It helps policymakers and planners tailor interventions based on community needs, land availability, and income goals.

Agroforestry Models in Bangladesh

Bangladesh exhibits a rich types of agroforestry models (Figure 4-8), many of which combine fruit, timber, vegetables, medicinal plants, and sometimes livestock or apiary components to maximise land use and livelihood benefits.

In homestead systems, combinations such as Mango-Banana-Sweet Gourd-Cauliflower, Banana-Eucalyptus-Papaya-Chili, and Jackfruit-Betel Nut-Mango are commonly observed. These systems often have multiple vertical layers — fruit and timber trees in the upper story; shrubs, vegetables, and herbs in the middle and lower stories. For example, a study in Kamalganj Upazila reported 29 homestead agroforestry combinations involving timber, fruit, vegetable, and medicinal plants, with six vertical layers (Singha et al.2018).

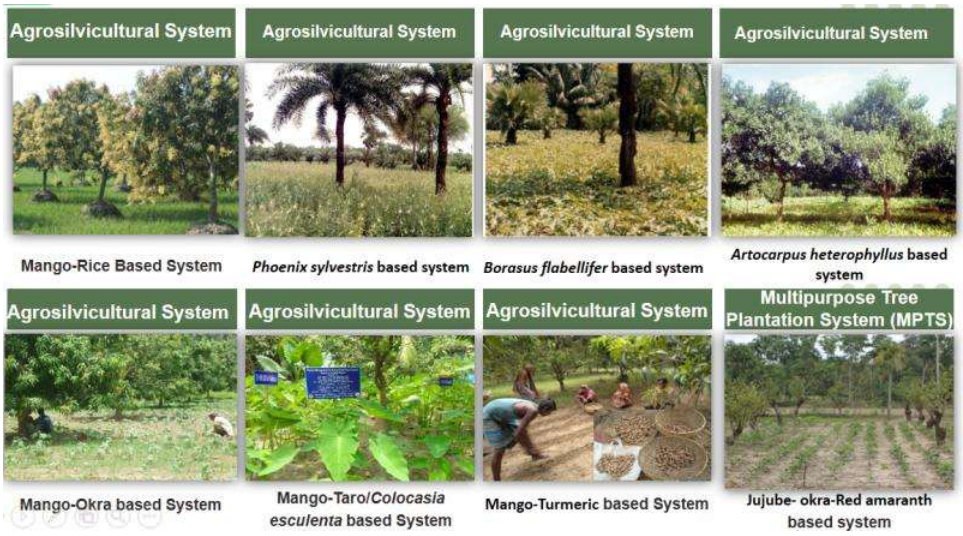

Figure 4. Agroforestry Models in Bangladesh

On cropland, researchers have documented systems such as jackfruit-based multistory agroforestry in the terrace ecosystem: upper storey with jackfruit; midstorey with papaya, citrus (lemon, mandarin, sweet orange); and lower storey with seasonal vegetables like bottle gourd, ash gourd, brinjal, etc. These multistoried systems improve topsoil fertility and produce multiple types of yields from one field.

Figure 5. Agroforestry Models in Bangladesh

Similarly, under jackfruit orchards, understory crops like aroids (e.g. *Colocasia esculenta*) have been tested; though yield of the understory is often reduced compared with open field, total productivity, and Benefit:Cost of the agroforestry system is markedly greater than for sole crop systems (Riyadh et al.,2019).

Fruit-tree/timber-tree combinations with vegetables and spice or herb crops also feature prominently. A study in Madhupur Sal forest assessed agroforestry models such as Litchi-Pineapple-Ginger-Papaya-Banana, Akashmoni (*Acacia* spp.)-Ginger-Banana, Jackfruit-Akashmoni-Turmeric-Aroid, etc., and found that such systems were more profitable than non-agroforestry alternatives, had greater land equivalent ratios (LER), and added soil fertility benefits (Akter et al., 2020).

Tree-crop boundary or intercropping models also exist. In char and hill districts (Mymensingh, Sherpur, Jamalpur, Rangamati, Bandarban), models include earleaf acacia or eucalyptus planted on crop field boundaries; mahogany with turmeric, ginger and mango in homesteads; sponge gourd, brinjal, betel nut, etc., used in mixed crop-tree arrangements (Jewel, et al., 2019).

Agroforestry systems are not only about production: many models integrate medicinal species, herbs, and cash crops. For example, homestead systems often include medicinal plants alongside fruit trees and timber species. In Golapganj Upazila of Sylhet, combinations like Guava-Papaya-Tomato-Indian Lilac and Jackfruit-Litchi-Burmese Grape-Wild Orange have been recorded (Datta et al., 2023).

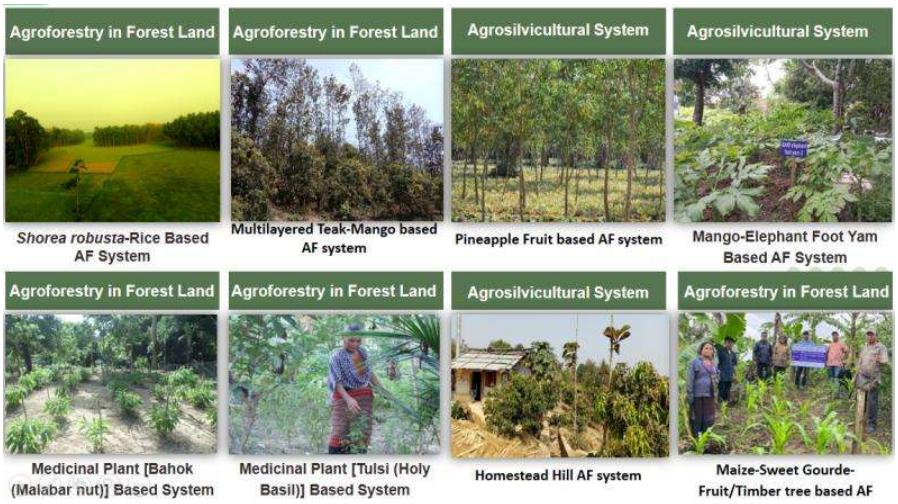

Figure 6. Agroforestry Models in Bangladesh

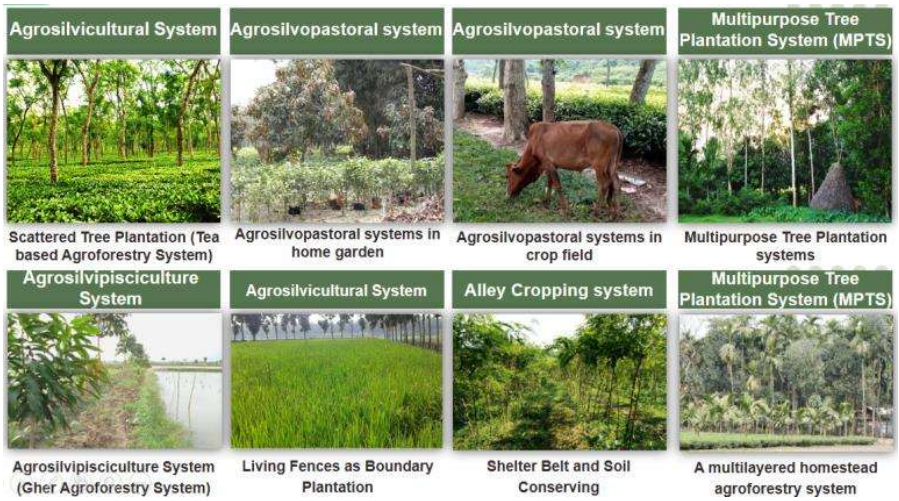

Figure 7: Agroforestry Models in Bangladesh

Finally, innovative practical examples have emerged. The multistory agroforestry systems with jackfruit in terraces, intercropping in orchards (e.g. mango/orange orchards with bottle gourd, country bean, cauliflower), and mixture of fruit/timber trees with seasonal vegetables illustrate how

smallholder farmers are adapting agroforestry models to local ecological and economic contexts.

Figure 8. Agroforestry Models in Bangladesh

Table 1 show summarizing several agroforestry models in Bangladesh with their species components, ecological benefits, and economic role—based on current field studies. This can serve as a visual aid in your report.

Table 1: Comparison of Agroforestry Systems in Bangladesh

Agroforestry System / Model	Key Components (Trees + Crops / Livestock / Functions)	Ecological Benefits	Economic & Livelihood Role
Homestead Agroforestry in Kamalganj (Sylhet / Moulvibazar)	*29 different combinations; e.g.* Areca nut–Mango–Banana–French bean, Coconut – Betel nut – French bean – Cabbage, Banana-Eucalyptus, Jackfruit-Betel nut, Turmeric-Eucalyptus, Mango-Banana-Sweet Gourd-Cauliflower, *etc. (Singha et al., 2018)*	High plant species diversity (timber, fruits, medicinal, vegetables), multi-layer vertical structure; improved microclimate, shade; enhanced biodiversity. (Singha et al., 2018)	Greater food diversity and year-round food supply; income from sale of fruits, vegetables, medicinal plants; more stable livelihoods; better resilience to shocks. (Singha et al., 2018)
Cropland Agroforestry across Forest, Plain & Char Lands	Woody perennial species (e.g. *Acacia auriculiformis*, *Gmelina arborea*, *Tectona grandis* etc.) integrated into croplands in different ecosystems. (Hasan et al., 2025)	Carbon stocks vary by ecosystem; forest & plain lands show significantly higher carbon storage; greater woody species diversity; better structural metrics. (Hasan et al., 2025)	Potential for carbon sequestration income; timber/wood supply; enrichment of farmland; diversifies farmer incomes; contributes to climate-mitigation goals. (Hasan et al., 2025)
Charland Boundary /	Boundary tree plantations (e.g.	Green belts reduce soil	Improved access to fuelwood,

Agroforestry System / Model	Key Components (Trees + Crops / Livestock / Functions)	Ecological Benefits	Economic & Livelihood Role
Homestead with Trees + Crops (Teesta/Jamuna Basins)	*Eucalyptus*, *Acacia auriculiformis*), scattered trees in croplands; homestead fruit trees (*Mango*) etc. (Sultana and Bari, 2021)	erosion, buffer flood impacts; trees provide shade; improve species diversity in otherwise unstable or flood-prone land. (Sultana and Bari, 2021)	fodder, fruit; diversification of livelihood; income generation from trees; risk reduction for annual crop failure. (Sultana and Bari, 2021)
Char and Hill Ecosystems: Charland vs Hill Agroforestry Practices	In charlands: homestead trees + cropland margin trees; in hills: turmeric-ginger-mango combinations, etc. Species include *Mahogany, Mango, Betelnut, Earleaf Acacia, Eucalyptus* etc. (Jewel et al., 2019).	Tree diversity supports soil stability, microclimate, erosion control; hills benefit from understory cropping; chars from shade & wind-breaks. (Jewel et al., 2019).	Provides alternate income sources and non-timber forest products; food access; helps in marginal land utilisation; improves livelihood among poorer & remote households. (Jewel et al., 2019).
Comparative Financial Models: Homestead, Cropland, Orchard (Dinajpur)	Three types: Homestead agroforestry, Cropland agroforestry, Orchard agroforestry. Practice includes fruit/trees with annual crops; orchards more monocultural tree focus (Rahman et al., 2020).	Orchards have higher long-term returns per ha; homestead and cropland systems have lower initial cost and faster returns; diversity reduces risk (Rahman et al., 2020).	Homestead and cropland systems have higher Benefit-Cost Ratios earlier; orchard agroforestry yields larger absolute incomes in later years; mixed systems provide year-round livelihood security (Rahman et al., 2020).

Livelihood Improvement through Agroforestry

Empirical evidence from multiple studies reveals that smallholders adopting

homestead and farm-based agroforestry systems enjoy higher and more stable incomes than those dependent solely on annual crops.

- **Diversified income streams:** Agroforestry combines short-term returns from vegetables, medium-term fruit harvests, and long-term timber or fuelwood benefits, thereby reducing income volatility and enhancing resilience to crop failure (CIFOR-ICRAF, (n.d.); Akter et al., 2022).
- **Economic advantages:** Farm-level analyses from northern and hill districts report favourable benefit–cost ratios and land equivalent ratios (LER > 1) for multistorey agroforestry compared with monocropping (ICRAF/CIFOR, (n.d.); Ruba et al., 2023).
- **Food and nutrition security:** Homegarden and bari systems contribute to household food availability**,** dietary diversity**,** and nutrition improvement**,** particularly for women and children.

Thus, agroforestry serves as a foundation for rural livelihood diversification, linking ecological restoration with economic empowerment.

Evidence for Climate Resilience and Ecosystem Services

Agroforestry enhances both adaptation and mitigation capacities in farming systems:

- **Microclimate regulation:** Trees create favourable shade and windbreaks, reducing crop stress from heat and drought.
- **Soil and water improvement:** Root networks and organic litter improve soil structure, nutrient cycling, and moisture retention.
- **Erosion and salinity control:** Tree-based buffers stabilize riverbanks and coastal soils, reducing erosion and saltwater intrusion in coastal and char areas.
- **Carbon sequestration:** Perennial biomass increases on-farm carbon stocks, directly supporting climate mitigation objectives**.**

Case studies from charlands, coastal belts, and hill tracts confirm that agroforestry systems reduce crop losses during extreme events and provide post-disaster income from fruit or timber sales, aiding faster household recovery (Ali, 2024; Akter et al.,2022; CIFOR-ICRAF, n.d.).

Programmatic Evidence and Scaling Pathways

- AFIP expanded agroforestry nationwide, improving seedlings and markets.
- SHABGE, LEAF, SAAKTI integrated agroforestry in extension systems.
- Research stresses quality materials, markets, tenure, gender inclusion.
- Collaboration drives agroforestry mainstreaming in rural development.

Quantitative Outcomes Reported

- Income: Higher household earnings across regions.
- Nutrition: Better diets and food security.
- Resources: More fuelwood, fodder, and timber access.
- Environment: Greater tree cover and carbon storage.

Barriers and Challenges

Despite well-documented benefits, adoption remains constrained by multiple factors:

i. **Insecure tenure:** Unclear land and tree ownership, particularly in char and hill regions, discourage investment in trees.
ii. **Market limitations:** Weak value chains for timber and NTFPs, with inadequate processing and aggregation systems.
iii. **Seedling quality:** Poor germplasm and low-quality nursery services undermine productivity.
iv. **Gender inequities:** Women face limited access to land, capital, and training opportunities (Jahan, 2022).
v. **Financial constraints:** Long gestation periods and upfront costs deter resource-poor farmers.
vi. **Institutional gaps:** Agroforestry remains underrepresented in mainstream extension and research agendas**.**

These constraints underscore the need for comprehensive policy reform, capacity building, and institutional coordination**.**

Policy Context and Institutional Framework

National Policy Support

Bangladesh's major policy instruments provide a supportive, though fragmented, framework for agroforestry:

- National Agriculture Policy (NAP) 1999 & 2018: Encourages agroforestry, intercropping, women's participation, and climate resilience.
- National Forest Policy (2016): Promotes private plantation, technical support, and a national target of 20% tree cover by 2035**.**
- Forest Investment Plan (2017): Prioritizes sustainable management, homestead tree planting, and climate adaptation.
- MoEFCC Action Plan & 7th FYP: Recognizes agroforestry's role in char land development and SDG alignment. Additional supporting frameworks include the National Land Use Policy (2011)**,** National

Organic Agriculture Policy (2017), Bangladesh Delta Plan 2100, and the SDG 2030 Agenda.

Agroforestry in NDCs

Under Bangladesh's updated Nationally Determined Contributions (NDCs):

- Unconditional target: 6.73% GHG reduction (≈27.56 Mt CO_2e) by 2030.
- Conditional target: 15.12% reduction (≈61.9 Mt CO_2e) with international support.
- AFOLU sector contribution: Agroforestry and forestry projected to reduce approximately 0.64 Mt CO_2e (unconditional) and 0.4 Mt CO_2e (conditional).

Although small in relative scale, the AFOLU contribution represents an important carbon mitigation opportunity if agroforestry is systematically scaled.

Policy Implications and Recommendations

To maximize agroforestry's livelihood and resilience benefits, the following priorities are essential:

1. Secure tenure and benefit-sharing: Clarify ownership and benefit rights for trees on private and community lands (Rana, 2021; FAO).
2. Seedling systems and quality nurseries: Establish accredited nurseries and improved germplasm systems to ensure planting material quality.
3. Market and value-chain development: Build aggregation, processing, and market information systems to convert tree products into reliable income streams.
4. Gender-responsive extension: Design training, credit, and input services that address women's specific needs (Ruba et al., 2023).
5. Integration with climate policy: Link agroforestry to NDCs, adaptation plans, and national agricultural programs to leverage climate finance (FAO; GEF).

Constraints and Opportunities

Constraints

- Weak institutional coordination and governance gaps.
- Limited R&D funding and technical expertise.
- Competition between trees and crops for resources.
- Insufficient environmental valuation and land availability.
- Limited extension services and market access.

Opportunities

- Regional leadership: Establish Bangladesh as a South Asian hub for adaptive agroforestry.
- Global collaboration: Strengthen ties with CIFOR–ICRAF and global research networks.
- Institutional reform: Create a dedicated Agroforestry Division within NARS.
- Capacity development: Implement training, fellowships, and field demonstrations.
- Technology integration: Apply remote sensing and AI for monitoring tree cover and ecosystem health.
- Policy alignment: Embed agroforestry into future Five-Year Plans (9th–12th).

Way Forward

1. Formulate a National Agroforestry Policy to guide planning and implementation.
2. Establish a National Agroforestry Working Group for research coordination.
3. Promote co-managed agroforestry in forest peripheries for sustainable resource use.
4. Enhance extension services and farmer training for skill development.
5. Encourage community participation in conservation and biodiversity protection.
6. Foster public–private partnerships for nursery development and marketing.

Recommendations for Policy Action

Priority Area	Recommendation	Rationale / Expected Impact
Tenure & Incentives	Clarify and secure tree land tenure; implement benefit-sharing mechanisms.	Ensures long-term incentives for farmers to plant and maintain trees (Rana, 2021).
Planting Material Systems	Support accredited nurseries, improved germplasm, and seedling certification.	Higher survival, productivity, and farmer trust in yield returns (CIFOR-ICRAF, n.d.).

Market & Value Chain Development	Facilitate aggregation, processing, market linkages, and price information.	Converts tree products into reliable income sources and reduces post-harvest loss.
Extension & Capacity Building	Integrate agroforestry into mainstream agricultural extension; ensure gender-responsive training and access.	Expands reach and uptake, addresses equity gaps (Ruba et al., 2023).
Climate Finance & Policy Integration	Link agroforestry targets to NDCs, coastal/forest adaptation programs, and funding instruments.	Unlocks climate funding and institutional alignment (FAO / GEF briefs).
Monitoring, Research & Evidence	Invest in longitudinal trials, farmer participatory research, and impact tracking.	Strengthens the evidence base, supports adaptive scaling and course correction.

Conclusion

Agroforestry in Bangladesh has evolved from traditional, household-level practices to more formalized, climate-smart systems capable of generating multiple benefits: food security, biodiversity enhancement, carbon sequestration, and resilience to environmental shocks. Yet the full potential remains under-realized. If policy, institutional, market, and social barriers can be addressed, agroforestry could play a central role in Bangladesh's sustainable land use trajectory, helping reconcile competing land demands, strengthening rural livelihoods, and contributing to national and international climate and development goals.

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Chapter 3

Role of Agroforestry in Improvement of Rural Livelihood and Build Climate Resilient Communities in Bhutan

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Background

Bhutan is a small, landlocked, and mountainous country situated in the Eastern Himalayas, encompassing an area of 38,394 km². It lies between India and China, extending from 88°E to 93°E longitude and 26°N to 29°N latitude, with a maximum East–West length of approximately 325 km and a north–south width of 170 km. Despite its limited size, the country exhibits pronounced altitudinal variation ranging from 97 m in the southern foothills to 7,570 m in the northern high mountains. (Figure 1)

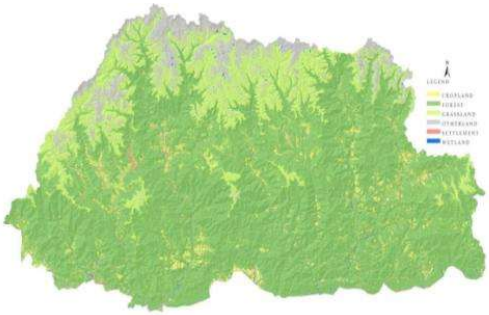

Figure 1. Bhutan Land types

These elevation gradients, coupled with steep slopes and deeply incised valleys, create distinct agroecological zones strongly influence the country's climate, biodiversity and hydrological systems. Bhutan's rugged terrain supports exceptional range of ecosystems, from subtropical lowlands to alpine meadows, contributing to its extensive forest cover and rich biological diversity. As approximately 7.6% of Eastern Himalaya region (Chettri, et al, 2010), Bhutan forms part of the Himalayan biodiversity hotspot adjoining the Indo-Burma and Mountains of Southwest China. Its diverse freshwater ecosystems harbor numerous aquatic species, mostly are endemic to the region (Thoni et al., 2016; Thoni & Gurung, 2018).

Administratively, Bhutan is divided into 20 districts (dzongkhags). The total population stands at 784,043 (IALC, 2025), with about 44% residing in rural areas and primarily dependent on agriculture and livestock-based livelihoods (BTR1, 2024). Mostly land area is under forest cover, justified the ecological

foundation of Bhutan's environment and natural resource base (Table 1).

Bhutan's forest cover stands as 69.71% of the total land area (FMID, 2023), while arable land constitutes about 7%, and registered agricultural land accounts for 4.41% (NLCS, 2023), grasslands occupy approximately 2.69% (Table 1), 26,275.50 acres that have been developed as improved pasture to support livestock feeding systems (APR 2024). Of the total 2.75% agricultural land, around 0.1% is under orchard plantation plantations and orchards, in addition to crop and vegetable cultivation (Figure 1).

Table 1. Bhutan total land types and their share

Land type	Coverage (%)
Forests	70.67
Shrub land	13.03
Grassland	2.69
Agriculture	2.75
Bare area	2.51
Settlement	0.21
Snow and glaciers	7.52
Water bodies	0.62
Total	100

Source: Wangda P, 2017

Notably, the Million Fruit Tree Plantation Project has established approximately 4,384,012 fruit trees across 38,000 acres nationwide (DoA, 2025), contributing significantly to household nutrition, income diversification, and ecosystem services.

Bhutan has six major agroecological zones, each characterized by distinct climatic and altitudinal conditions and experiencing four distinct seasons of spring, summer, autumn, and winter. Broadly, these zones can be classified into three major climatic regions: Southern foothills, Central inner Himalaysa and Northren Himalaysa (Table 2).

Bhutan's development philosophy is guided by the principle of Gross National Happiness (GNH), which seeks to balance economic progress with human well-being and environmental sustainability, places the individual at the center of development, promoting a holistic and multidimensional approach to achieving and sustaining happiness. It emphasizes that equitable socio-economic development can be realized through the conservation of the environment, preservation and promotion of culture, and enhancement of good governance (Bhutan, 2020).

Table 2. Distinct Agroecological zones and the climate

Agroecological Zone	**Altitude range** (masl)	**Climate**	**Temperature**	**Rainfall** (Avg. Annual, mm)
Southern foothills	97 - 2000	Hot & humid	15 – 30° C	2500 - 5000
Central inner Himalayas	2000 - 4000	Cool temperate	12 – 15° C	1000
Northern greater Himalayas	4000	Severe alpine	-5 – 7° C	4000

Source: Khanal, 2020

This overarching philosophy underscores Bhutan's integrated approach to development and provides a strong policy foundation for sustainable land-use practices, including agroforestry, that contribute simultaneously to livelihoods and ecological resilience. With approximately 98% of its land area classified as mountainous, maintaining natural vegetation cover in Bhutan is not only an ecological imperative but also a geographical necessity. This has fostered a strong national ethos of forest protection and environmental conservation. Over the past several decades, Bhutan has introduced progressive forest conservation measures, including the nationalization and strict regulation of the forestry sector, the gradual phasing out of shifting cultivation, and the establishment of an extensive protected area network (Bruggeman et al., 2016). The country's commitment to scientific forest management predates its planned development era demonstrated by the creation of the Forest Service Division in 1952 (Buffum, 2012), well before the launch of the First Five-Year Plan in 1965. These measures culminated in a constitutional mandate requiring that a minimum of 60% of Bhutan's total land area remain under forest cover in perpetuity (RGoB, 2008). This policy commitment has enabled the country to preserve vast stretches of natural landscapes, ensuring the continuity of ecosystem services and biodiversity. Among the world's 34 recognized biodiversity hotspots, the Eastern Himalayas represent one of the largest. Bhutan forms part of 23 Important Bird Areas, encompassing 5,114 faunal species, and 8 ecoregions, as well as designated Important Plant Areas that harbor 5,369 plant species, including 55 cultivated agricultural plant species, and 8 recognized livestock species (BSB, 2017). The country in between with significant wetland ecosystems, including two Ramsar-designated sites as Tashiyangtse and Wangdue.

Bhutan's commitment to conservation has led to one of the highest forest coverages in the world, estimated at 73% (26,826 km²) of its total land area (Rahut et al., 2015), and more recently at 70.46% (Banerjee & Bandopadhyay, 2016) and 69.71% in 2023 (NFI, 2023). These efforts have earned Bhutan global recognition for environmental stewardship, including the 31st Blue

Planet Prize in 2022 (Asahi Glass Foundation, 2022) and the J. Paul Getty Conservation Leadership Award in 2006. Bhutan is celebrated as the world's first carbon-negative nation, having pledged to remain carbon neutral in perpetuity. The total emissions stood at 1752.5 Gg CO_2e against total sequestration potential was -11356.30 Gg CO_2e in 2022. The country offsets its limited greenhouse gas emissions primarily through its vast forest carbon sinks and relies on hydropower as a renewable and low-emission energy source. Likewise, Total Carbon Stock was 609.1 million tons, with contribution from forest biomass at 341.54 million tons and Soil Carbon Stocks (SOC) at 182.33 million tons (BTR1, 2024). Based on its diverse biophysical conditions, Bhutan's forest systems can be broadly classified into eleven forest types which may be relevant to agroforestry practices (Table 3).

Table 3. **Forest types in Bhutan at different elevations**

Forest Type	Altitude (m)
Subtropical Forest	200-1000 (-1200)
Warm Broad-leaved Forest	1000-2000 (-2300)
Chir Pine Forest	900-1800 (2000)
Cool Broad-leaved Forest	2000-2900
Evergreen Oak Forest	1800-2000 (-2600)
Blue Pine Forest	2100 – 3000 (-3100)
Spruce Forest	2700 – 3100 (-3200)
Hemlock Forest	2800 – 3100 (-3300)
Fir Forest	3100 – 3300 (-3800)
Juniper/Rhododendron scrub	(3700-4200)
Dry alpine scrub	(4000-4600)

Source: DoFPS, 2022

Given the country's exceptionally high forest cover, forests remain deeply interwoven with the livelihoods and cultural values of Bhutanese communities. It provides fuelwood, fodder, timber, and non-wood forest products (NWFPs) to 44% of the population. The close interdependence between forests and farming systems underscores the potential and practicality of agroforestry as a sustainable land-use approach that aligns with Bhutan's socio-ecological context.

Rural and Socio-Economic Profile of the Country

Bhutan's economy is predominantly dependent on agriculture and hydropower, sectors that are central to national development and highly vulnerable to the impacts of climate change. While hydropower generation serves as the cornerstone of national revenue and the primary source of

domestic energy, the agriculture sector remains the mainstay of livelihoods, engaging over 44% of the total population and ensuring national food security. In 2024, Bhutan's Gross Domestic Product (GDP) stood at Nu. 273 billion (NAS, 2025), with an economic growth rate between 6.06% and 7.50%. The key contributors to GDP include services and tourism sectors, with hotels and restaurants subsector showing a significant growth rate of 32.9%. Additionally, the public administration and electricity generation and supply sectors contributed positively to overall economic performance.

The primary sector, comprising agriculture, livestock, and forestry, contributed 14.96% to the national GDP in 2024 (NAS, 2025). The sector is vital to Bhutan's agri-food system, which underpins food security and the broader well-being of rural communities (BASS, 2024). Subsector contribution stands 6.57% by agriculture, 5.91% by livestock and 2.48% by forestry sector.

Agriculture in Bhutan remains largely rain-fed, with productivity strongly influenced by seasonal precipitation patterns (Thinley et al.2023). The government provides targeted subsidies and policy support to promote sustainable agriculture and enhance national food security. Looking ahead, the Bhutan AgriFood Sector Strategy 2034 (BASS,2034), Ministry of Agriculture and Livestock (MoAL) emphasizes on refocusing interventions toward export promotion, market diversification, and private-sector participation. The strategy seeks to accelerate commercialization, empower farmers, and strengthen institutional foundations to build a high-performing, climate-resilient sector capable of generating employment, achieving the Sustainable Development Goals (SDGs), and reinforcing the principles of GNH.

Climate Change Challenges

The agriculture industry in Bhutan struggles with issues like conflicts between humans and wildlife, more unused land, and an aging group of farmers., labour shortage, subsistence-level farming, and low adoption of modern agricultural technologies. However, the most urgent challenges arise from climate change, which manifests as increased floods, landslides, loss of agricultural land, damage to civil infrastructure and farms, untimely snowfall, erratic weather patterns, dry spells, pest and disease outbreaks, and heat stress (EU-TACS, 2022) which cannot be prevented from occurring.

Bhutan is ranked the 32nd most vulnerable country according to the Global Climate Change Adaptation Index (Yoezer et al., 2022). The agrifood sector is highly susceptible to climate variability and other natural hazards, including the emergence and spread of pests and diseases. For example, incessant

rainfall from 16–21 October 2021 affected over 2,500 acres of farmland, causing an estimated crop loss of 2,400 metric tons across 17 dzongkhags (WB, 2023). Climate change-induced pests, such as the Fall Armyworm, were first reported in 2019 and are now prevalent in most maize-growing dzongkhags.

Bhutan experienced multiple outbreaks of notifiable animal diseases across the country. In recent years, these outbreaks have become more frequent and impactful, affecting livestock, farmers, and government resources. For instance, 153 outbreaks of Lumpy Skin Disease (LSD) resulted in the death of 4,110 cattle, including yaks, and caused substantial economic losses due to reduced livestock productivity. In August 2023 alone, the MoAL spent Nu. 20.83 million on LSD vaccination, excluding additional costs incurred for mass vaccination campaigns (ADH, 2024).

Emerging transboundary animal diseases such as African Swine Fever (ASF) and Highly Pathogenic Avian Influenza (HPAI H5N1), which are aggravated by climate change, have also repeatedly affected Bhutan. Multiple ASF outbreaks since May 2021 impacted 132 farmers, resulted in 343 pig mortalities, and necessitated the culling of 2,467 pigs to contain the disease. Containment measures for ASF have cost the Ministry approximately Nu. 34.58 million since 2021. Similarly, HPAI (H5N1) outbreaks since 2010 have incurred government expenditures of Nu. 29.53 million (AHD, 2024).

Land degradation and encroachment of rangelands by unpalatable plant species further threaten farmers and highland herders (ICIMOD, 2024). Untimely extreme weather events, such as the heavy snowfall in 2022, resulted in the death of 594 yaks across five highland dzongkhags, causing an estimated economic loss of Nu. 9.90 million to herders and stakeholders involved in emergency response (BBS, 2022).

The frequency and severity of floods and thunderstorms leading to agricultural land and livestock losses are increasing annually. However, the lack of reliable climate services and information systems, including comprehensive data on damages and losses, continues to constrain evidence-based planning and climate adaptation efforts (Thapa R, 2024). While Bhutan benefits from a supportive government and remains a carbon-negative country, it remains highly vulnerable to the adverse impacts of climate change, with significant opportunity costs for its small and developing economy.

Agroforestry Sector in Bhutan

Agroforestry (AF) is a collective term for land-use systems in which woody perennials, such as trees, shrubs, and bamboo, are integrated with herbaceous plants (crops or forage/pasture species) and/or livestock, either in spatial

arrangements, rotations, or both. These systems create ecological and economic interactions between the tree and non-tree components. In Bhutan, three major AF systems practiced include:

Agri-silvicultural systems, where trees are incorporated within agricultural land to support crop production; Silvi-pastoral systems, where woody perennials are intentionally integrated with pasture and livestock; and Agri-silvi-pastoral systems, where trees are combined with crops, pasture/forage species, and livestock.

The key components of Bhutanese AF include: (i) trees and shrubs, (ii) agricultural crops, (iii) pasture and forage species, and (iv) livestock, including cattle, sheep, goats, yaks, native pigs, poultry, bees, and fish. These components are adapted to diverse climates, soils, and landforms, and their relative balance depends on the needs of farmers and herders within individual farming systems or community forestry programs.

Figure 2. Paddy in Chuzhing

Figure 3. Maize in warm temperate Kamzhing

Estimated approximate of 70,278 rural households in Bhutan (IALC, 2025) directly benefit from AF practices as these households engage in both agriculture and livestock rearing, integrated with forestry components. Tshering et al., 2023 stated that data from 2021 indicated 108,879.49 ha of forest area, representing about 4% of the total Government Reserve Forest (GRF), under 839 Community Forest (CF) groups which was handed over to 34,169 rural households. These CFs provide essential livelihood support and reinforce AF practices nationwide.

A study conducted in 2021 (EU-TACS, 2021) to stock take the AF systems and practices in Bhutan, the development of the Agroforestry Strategy and a National Agroforestry Program, highlighted the evolving socio- economic context of Bhutanese agriculture. Since the early 2000s, the rural population has been transitioning from subsistence farming toward semi-subsistence, semi-entrepreneurial, and fully entrepreneurial livelihoods. The study also noted that the next generation is likely to be largely town-based, maintaining claims on parental land. Approximately 26% of the country's agricultural land

was found to be underutilized or lying fallow. However, such fallow, or absentee-owned land could, over time, be converted into private tree-based systems, creating a growing asset base that delivers both social and environmental services.

Despite its widespread adoption, Bhutan currently lacks a dedicated policy or legal framework to systematically guide AF development. However, several sectoral policies, Acts, and guidelines (Table 4) provide indirect support for promoting AF as a sustainable land-use approach. The Department of Agriculture (DoA), Department of Livestock (DoL) under MoAL, and Department of Forests and Park Services (DoFPS) each integrate AF elements into their respective programs. While the absence of a designated lead agency has historically limited coordination and implementation of a unified national program, the DoFPS has recently assumed a leadership role in developing the National Agroforestry Strategy for Bhutan.

Table 4. Policy farmwork to support Agroforestry

Agency	Policy and governance document	Remarks
MoAL	Vision (MoAL website)	Strongly supports AF
	Forest and Nature Conservation Rules & Regulations of Bhutan 2006	The Rules 2006 considers AF
DoFPS	National Strategy for Community Forestry 2010	Community Forestry vision fully supports AF
	National Forest Policy of Bhutan 2011	Encourages AF in private forest only
	Forest & Nature Conservation Rules & Regulations of Bhutan 2017	Defines AF
	Forest Management Code of Bhutan 2020	FMCB 2020 is yet to be approved
	Community Forestry Field Manual for Bhutan 2018	Chapter V of the Manual supports AF
	National Action Program to Combat Land Degradation 2009	Proposes tree plantation in the degraded land
DoA	Agriculture Land Development Guidelines 2017	Promotes AF
	FNS Policy of the Kingdom of	Objectives promote AF

Agency	Policy and governance document	Remarks
	Bhutan 2014, 2023	
DoL	13 Five Year Plan (under dairy component)	Proposes Silvo-pasture

Source: Adapted from draft National Agroforestry Strategy, 2025

Practices typology of agroforestry in Bhutan

The landscapes are steep slopes with varied climate zones, and strong cultural traditions that have shaped land use over centuries. Agroforestry (AF) is vital in sustaining livelihoods, conserving soils, regulating microclimates, and delivering ecosystem services. Yet, systematic documentation remains limited, highlighting the need for a structured typology to characterize practices, evaluate performance, and guide interventions. As shown in Table 5 and Table 7, AF systems can be classified into following types

System Classification

- **Agrosilvicultural systems:** Integration of tree species with crops, which is practiced in *Chuzhing* (Figure 2) (wet land like paddy fields) or *Kamzhing* (dryland) (Figure 3). For instance, understory cultivation of cardamom, citrus orchards interspersed with crop species. Long rotation fallows are practiced in *Tseri* (shifting cultivation) as well as *Pangzhing* (fallow lands).
- **Silvopastoral systems:** Trees integrated with livestock (Fig. 4) and traditional fodder tree plantations, used as live fences are elements of this system. This is practiced mainly in *Kamzhing* and *Khemsa* (homesteads, kitchen-gardens) (Figure 5 and 6).
- **Agrosilvopastoral systems:** Mix of crops, trees, and livestock on the same farm parcel. Home gardens often embody this, combining fruit, vegetables, livestock and multipurpose trees.

Structural Components

- **Tree species and density:** Multipurpose species including fodder species like *Salix babylonica* (willow), *Quercus semecarpifolia, Ficus auriculata*, etc., in spatial configuration varying from scattered trees to woodlots (Roder et al., 2003).
- **Crop component*:*** Staple crops include maize, paddy, millet, barley; horticultural crops like citrus and vegetables in lower zones; and high-altitude crops such as buckwheat. Maize intercropped with legumes to improve productivity (Thinley et al., 2023).

- **Livestock component*:*** Cattle (local & exotic breeds), yaks, goats, native pigs & poultry and beekeeping is integrated to support household food and nutrition while also adding livelihood income. Such integration is through grazing and fodder tree leaves (Tshering and Thinley, 2017) and sourcing domestic feeding resources for native poultry, piggery, fishery and bees.
- **Spatial arrangement / Vertical structure:** Multi-layered system with trees boundaries on terrace risers for scattered shade, and vertical layers in home gardens (Chetri et al., 2018).

Functional Components

- **Productive:** Food (cereals, legumes, oilseeds, mushrooms, species, vegetables, fruits), fodder (tree leaves, plantations, pastures), fuelwood, timber, non-timber forest products and herbs. Fodders tree contribute about 20 % of livestock fodder needs in temperate zones (Roder, 1992).
- **Protective*:*** Soil erosion control, slope stabilization, water conservation, microclimate moderation, preventing land degradation.
- **Ecological:** Biodiversity maintenance, carbon sequestration, conserving native and landrace genetic diversity. The NBC reports that many landraces adapted to high elevation zones (NBC, 2021).
- **Socioeconomic:** Income diversification, food security, risk reduction (e.g. in case of crop failure), cultural and traditional values.

Management Practices

Native and multipurpose tree (fodder, fruits and shade); pruning and lopping of trees for fruits and fodder. Intercropping and strip planting (e.g. maize-legume intercropping) to increase land equivalent ratio and economic return. Reliance on organic fertilization, minimal use of chemical inputs in most smallholder farms to optimize the use of local resources in the circular economy. Grazing by livestock in forest-pasture mosaics; rotational grazing in some areas.

The agroecological zone (AEZ) based AF is presented in Table 5. Bhutan can be divided into zones based on altitude, rainfall, and climate that influence AF types.

Table 5. Agroforestry typology in Bhutan

Type	Traditional land use typology	Agroecological zone	Tree spatial arrangement	Main tree species	Main intercrop
Agri-silviculture systems					
Scattered trees in wetland fields	*Chuzhing* or *Kamzhing*	Sub-tropical to temperate	Scattered along bunds, field boundaries	Many	Rice (wetland), food crops (dryland) and fodder trees
Hedgerows and boundary trees	*Chuzhing* and *Kamzhing*	Sub-tropical to temperate	Planted in intervals, may be with electric fencing.	Many, Salix sp. in temperate zone	All food crops, Beekeeping, fodder
Contour hedgerows	*Kamzhing*	Sub-tropical to warm temperate	Along the contour	Many depending on regions	Fodder as grass, shrubs and perennials
Long-rotation fallows	*Tseri; Pangzhing*	Sub-tropical (Tseri); temperate fallow	Mostly thicket, often abandoned and full of trees	Many depending on region	Interval: altitude dependent food crops
Horti-silviculture systems					
Orchards or plantations	*Kamzhing*	Sub-tropical / cold temperate	Spaced at specific interval	Orange, apple, pear, peach, hazelnut, mango, areca nut, grape, kiwi, coffee, agarwood, tea, jackfruit, lime, lemon, avocado,	Fodder (grasses and legumes), Beekeeping

				etc.	
Cardamom plantations	*Kamzhing*	Sub-tropical / warm temperate	Closed canopy	Many: Alnus, etc.	Cardamom as intercrop
Homestead	*Khemsa*	Sub-tropical to warm temperate	Scattered	Many	Vegetables, bean, flowers for aesthetics and religious purpose, mushrooms, herbs, fodder grasses, Beekeeping, etc.
Timber plantation	*Kamzhing* and Pvt. Forest	Sub-tropical	Closed canopy	Timber: Teak, Acacia	Fodder grasses and legumes
Bamboo plantation	Pvt. dryland + State	Sub-tropical	Closed canopy	Bamboo	None
Silvi-pastoral systems					
Fodder trees	*Kamzhing*	Sub-tropical to temperate	Scattered around the fields	Ficus	Fodder grasses
Trees in pasture	*Tsamdro* (pasture)	Sub-tropical to temperate	Scattered, sometimes in clustered	Many, region based	Fodder grasses
Non-wood forest product production	Community forestry	Sub-tropical to temperate	Closed canopy or clustered	Many	NWFPs
Woodlot	*Sokshing* (woodlot)	Sub-tropical to temperate	Clustered	Mostly oak, pine, Catanopsis	Fodder grasses

Source: Adapted from EU-TACS report, 2021

Figure 4. Fish pond integrated in orchard

Figure 5. Private nursery and forest in Khemsa

Figure 6. Pasture, cash crop and multipurpose trees in *Kamzhing*

Socioeconomic Context

Most AF in Bhutan is practiced by smallholder farmers with fragmented landholdings. The sector experiences acute labor shortages, particularly for managing integrated treecrop–livestock systems. Domestic and institutional demands from Gyalsung Academies, schools and hospitals are the main markets. Generally, market access remains uneven, with remote areas experiencing limited opportunities to sell tree-based products. Consequently, the extraction of NWFPs has shown a declining trend over the past five years (SYB, 2025), derived after removing the inanimate components (sand, riverbed materials, boulders, etc.) of the NWFPs (Figure 7).

Table 6. Agroecological based agroforestry in Bhutan

AEZ	**Elevation**(masl)	**AF components**	**AEZ features**
Sub-tropical zone	up to ~1200 m	Citrus, cardamom, areca nut, legumes, high diversity homesteads and Beekeeping	Warm climate, higher biodiversity
Temperate zone	(~1200-3500 m	Tree species such as willow and improved pasture is important; winter fodder shortages drive use of tree leaf fodder, apiculture	Cold winters; comparatively shorter growing period
Alpine zone	above ~3500 m	pasture-dominated; yak grazing; limited woody species; seasonal transhumance	Very cold; Very short growing period; livelihood depends on livestock herding and NWFP collection

Agroforestry practices linked to dominant land use categories

Bhutan most of land is covered in forests and hence the dominant AF practice is linked to three main typologies (Table 7). Peri-urban AF is practiced in major town areas in the form of Green-zones, Parks, aesthetic tree plantations, hedges and flowers, fodder trees, fruit trees and home gardens which provide aesthetic value and easy access to daily resources for both humans and animals.

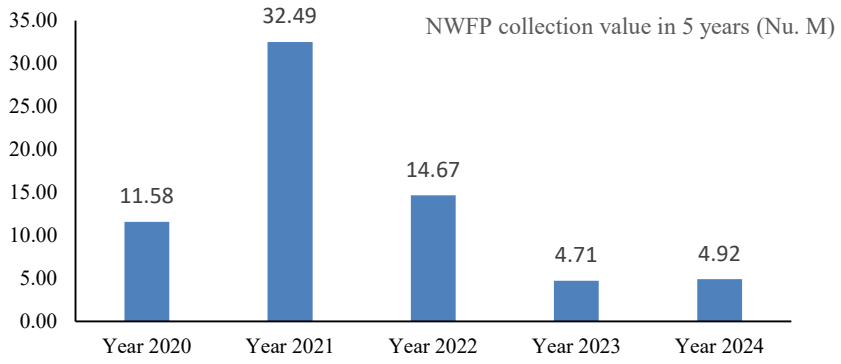

Figure 7. Value of collection

Table 7. Tenure and agroforestry systems in Bhutan

Typologies	Dominant tenure	Primary purpose	Production, functions or uses
Agri-silviculture Systems			
Scattered trees in wetland fields	Private	Subsistence	Edible oil, fodder, fruits and nuts, spiritual
Hedgerows and boundary trees	Private	Subsistence	Protection; Fodder; Fruits; Fuel
Contour hedgerows	Private	Subsistence / environmental	Soil conservation; multipurpose; and for sale
Long-rotation fallows	Community / Private	Subsistence	In some part farmers still practice this system

Typologies	Dominant tenure	Primary purpose	Production, functions or uses
Horti-silviculture Systems			
Orchards or plantations	Private	Subsistence / commercial	Fruits and nuts
Cardamom plantations	Private	Commercial	Shade trees
Homestead	Private	Subsistence	Mostly fruits, nuts, spiritual
Timber plantation	Private	Commercial	Construction, furniture, etc.
Bamboo plantation	Private	Commercial	Handicrafts, construction
Silvi-Pastoral Systems			
Fodder trees	Private	Subsistence / commercial	With improved cattle breeds, high quality fodder trees become important.
Trees in pasture	Common	Subsistence	Fodder, timber, fuelwood, spiritual. Seasonal migration of cattle.
NWFP	Community	Subsistence / commercial	Tree management; non-timber forest product
Woodlot	Private	Subsistence	Compost, manure

Ecosystem services deliverables

Ecosystem service deliverables refer to the actual, measurable benefits or outputs that result from the functioning of ecosystem services. With vast forest cover and unaccounted resources (WWF, 2017), the flow of fresh water, clean air and wildlife is part and parcel of the ecosystem services provided to Bhutan as well as the world in the form of Carbon sink and biodiversity hotspot. They bridge the gap between ecosystem functions and socioeconomic benefits to the Bhutanese population. These deliverables can be quantified and monitored through national frameworks like the Bhutan

National Adaptation Plan, National Forest Inventory, and the Carbon Neutral Bhutan Strategy. Major categories of ecosystem service deliverables in Bhutan are presented in Table 8.

Table 8. Ecosystem Service Deliverables derived by Bhutan

Major categories	Examples of Ecosystem Service Deliverables
Provisioning Deliverables (Direct products or outputs from ecosystems) (Dhital DB, 1997)	Large number of community forest user groups engaged in AF for timber, fuelwood, fruits, fodder, fiber, honey, medicinal plants; Water for irrigation and drinking; Livestock forage and biomass yield
Regulating Deliverables (Quantifiable benefits from ecosystem regulation functions) (BTR1, 2024)	Carbon sequestration (t CO_2/ha/year); Reduced soil erosion (tons soil saved/ha/year); Improved water infiltration and microclimate regulation
Supporting Deliverables (Outputs that maintain ecosystem health and productivity) (NBC, 2021)	Increased soil organic matter (%); Improved biodiversity indicators (species richness, Shannon index); Pollinator abundance and habitat restoration
Cultural Deliverables (Social and intangible outcomes)	Visitors or community participation in eco-tourism sites; Strengthened cultural landscapes and local stewardship

Recently, some Dzongkhags like Tsirang (DFO, 2020) and Mongar (Norten U, 2021) and a few other Dzongkhags have initiated payment for ecological services (PES) as compensation for maintaining a buffer zone of the main water source. Similarly, compensation to communities in the Phobjikha valley, is provided for reducing the negative impact on Wetland ecology and its quality as habitat for the black-necked cranes visiting the area every winter.

Role of Agroforestry in Economic Return and Social uplift

It is difficult to account for the exactly monetary value derived from AF to the rural population in Bhutan. However, the Forest Plantation Impact Assessment Report (DoFPS, 2022) shows that the investment value on 57,034.46 acres for forest plantation far exceed Nu. 496.20 million. Further, the EU-TACS (2021) study reported 87% of respondents stating economic production and soil conservation services as primary reasons that drive

motivation for on-farm AF. It helped produce diverse crops for household consumption and cash income in addition to fodder, wood product availability, soil conservation and windbreaks.

The economic value would be far higher if the total ecosystem services of forest plantation is considered. For instance, WWF-Bhutan (2017) reported a USD 15.5 billion worth of PES from a pilot study in Chamkharchu sub-basin. Similarly, the restoration of vegetation through AF greatly contributes to reviving ecological processes, energy flow, nutrient recycling, water cycling and hydrological regulation, air and water purification and sustaining their production and protective functions. Likewise, the traditional rural livelihoods depend on non-timber edibles for food security, herbs for home remedies, non-timber plants for cash income, etc. On the cultural front, the indigenous medicine, traditional arts and crafts, home remedies, wild edibles, fodder culture, etc. are also partly derived from the AF systems.

Agroforestry in National Education Curricula

Integrating AF into Bhutan's national education curricula presents a strategic opportunity to cultivate environmental stewardship, food security, and climate resilience among youth. Evidence from a cluster-randomized trial in 18 Bhutanese schools (n = 468) show that school-based agricultural learning can drive behavioral and nutritional change (Schreinemachers et al., 2017). Such results highlight the potential of experiential AF education, linking classroom learning with practical tree–crop–livestock systems, to foster ecological awareness and sustainable lifestyles.

The School Agriculture Program (SAP), jointly initiated by MoAL and Ministry of Education in 2000, currently operates in about 190 of the country's 551 schools, involving students in crop cultivation, livestock care, and composting activities (MoE & MoAF, 2020; EMRO, 2016). Embedding AF modules into this platform, covering fodder tree management, soil conservation, and carbon sequestration, could diversity capacity of early learners in sustainable land management.

Cultural and institutional foundations further support this integration. Bhutan's Social Forestry Day (2 June), observed since 1985 mobilizes school and community participation in nationwide tree planting (Dhital, 1997; DoFPS, 2019) for celebrating the Coronation of His Majesty the 4th King of Bhutan. Establishing a complementary National Agroforestry Day could reinforce agroforestry awareness, linking education with Bhutan's carbon-neutral and biodiversity goals (Nair et al., 2010; FAO, 2021).

Business Models in Agroforestry

Bhutan's agrifood system is undergoing a gradual transformation from

traditional subsistence farming to semi-commercial and commercial enterprises (EU-TACS, 2021). Traditionally, most rural households were smallholders managing less than five acres, maintaining kitchen gardens, a few fruit trees, and one or two livestock for household needs. Emerging livelihood groups now include semi-subsistence and semi-commercial farmers cultivating 5–10 acres and marketing surplus produce, though labor shortages and limited technical capacity often constrain full land utilization.

A distinct and declining group comprises pastoral and nomadic yak herders in alpine areas and cattle herders in temperate zones, who migrate for pasture and water (Gyeltshen et al., 2020). Meanwhile, a new class of absentee landowners has emerged, urban-based inheritors or salaried professionals who retain rural properties, often renting them out, leaving them fallow, or investing post-retirement in commercial ventures such as orchards or high-value crop farms. This trend is especially visible in peri-urban regions where better market access and export linkages exist (EU-TACS, 2021).

Agroforestry-based entrepreneurship is gradually developing within this landscape. Some rural entrepreneurs operate small nurseries supplying saplings for fruit trees, bamboos, or other cash crops, supported by Regional Agriculture Research and Development Centres (RDCs). The Department of Agriculture's horticulture program, comprising fruits and nuts, vegetables, medicinal and aromatic plants, and mushrooms, plays a pivotal role in research, germplasm multiplication, and dissemination to farmers across agroecological zones (DoA, 2025).

Likewise, DoL facilitates enterprise models in beekeeping, and integrated livestock–tree systems/ Silvo-pastoral system. For instance, in 2024, more than 7,500 households engaged in apiculture produced approximately 42 metric tons of honey, generating Nu. 36 million in revenue (MoAL, 2023). Similarly, the cattle farms under DoL and NBC planted 5000 fodder tree saplings to supplement nutritious roughage for cattle. Despite these initiatives, private-sector participation in input supply and value-chain development for AF-related products remains limited due to small domestic markets and logistical constraints (EU-TACS, 2021; Wangchuk et al.,2023).

Barrier and Strategic Pathways to Agroforestry

Agroforestry in Bhutan faces multiple challenges that constrain its contribution to rural livelihoods and ecological resilience. These challenges span over socio-economic, technical, market, and environmental domains. Rural–urban migration, absentee households, fallow lands, labour shortages, and wildlife conflicts further exacerbate adoption constraints. Farmers require inputs, markets, and financial literacy to realize entrepreneurial AF, while successful systems demand effective technical services, integrated research, and climate-resilient practices. In Bhutan, private land dominates AF tenure,

followed by community and common lands, providing a favorable context for expansion.

Constraints and opportunities

- Policy and Institutional Gaps: Bhutan lacks a dedicated AF policy, limiting coordinated development, despite supportive sectoral policies in forestry and agriculture (Wangmo, 2025).
- Technical Knowledge Deficiencies: Farmers often lack expertise in species selection, spacing, pruning, and integrated management, limiting system productivity.
- Market and Value Chain Limitations: Poor infrastructure and weak value chains constrain commercialization of tree products, non-timber forest products, and fodder (DAMC, 2025).
- Environmental Challenges: Soil erosion, wildlife damage, and climatic variability threaten agroforestry sustainability (AFoCO, 2020).
- Policy and Institutional Support: Bhutan's commitment to environmental protection, climate change mitigation, and GNH provides a strong enabling context (NEPA, 2007).
- Traditional Knowledge and Local Species: Existing practices and well-adapted species can be leveraged for resilient AF systems.
- Growing Demand for Sustainable Products: Increasing interest in sustainable agriculture, timber, fodder, fuelwood, and ecosystem services supports AF adoption.
- Evidence of Improved Land Productivity: Studies confirm AF systems enhance land productivity and rural livelihoods (Wangmo, 2025).

Regional Integration as a Strategic Pathway

Agroforestry promotion in Bhutan can benefit from enhanced regional collaboration under frameworks such as SAARC and the ASEAN–SAARC forestry dialogues. Cross-border knowledge exchange, joint research, and coordinated training programs can improve technical capacity, market linkages, and climate-resilient practices. Regional integration also facilitates shared strategies for value chain development, certification of sustainable products, and wildlife management, enhancing both economic and ecological outcomes.

Strategic Pathways: in the context of Bhutan, following may be some of the strategic pathways to support and implement AF:

- National Agroforestry Policy: Establish a dedicated framework for coordinated planning and support.
- Capacity Building and Extension Services: Strengthen farmer knowledge

through training and demonstration plots.

- Market Development: Develop value chains and infrastructure to commercialize AF products.
- Research and Development: Promote climate-resilient AF systems through applied research.
- Community Participation: Engage local communities to implement culturally appropriate and widely adopted AF practices.
- Regional Cooperation: Leverage SAARC and neighboring country networks for technical exchange, market development, and collaborative AF initiatives.

Enabling Frameworks and Initiatives

Bhutan has a enabling policy; however, this is limited to lack of a framework strategy and action plan to guide the implementation of AF at farmers' field. Table 4 presents the Act, plans, policies and guidelines that are available within the strategic partners of the AF. The development of the National Agroforestry Strategy by DoFPS puts Bhutan on track in helping the rural communities.

Support Services to community

Following support services may be useful to strengthened support the services to communities for enhancing AF:

Provision of Advisory and Technical Services: Access to expert guidance on species selection, design, and management practices and enhancing extension services can facilitate the adoption of best practices and improve system productivity.

Financial Support to Farmers/Growers: Access to credit and financial incentives is essential for farmers to invest in AF systems. Programs like the Bhutan Trust Fund for Environmental Conservation (BTFEC) and initiatives under the National Adaptation Plan (NAP) could provide financial resources to support sustainable land management practices (BTFEC, 2023).

Promotion of Green Corridor Concepts in Urban Areas: Integrating green corridors in urban planning can enhance biodiversity, improve air quality, and provide ecosystem services. The development of green infrastructure aligns with Bhutan's commitment to environmental conservation and sustainable urban development.

Expansion and Diversification of Funding Instruments: Utilizing financial instruments like REDD+ and green bonds can mobilize resources for AF initiatives. Bhutan's engagement with REDD+ mechanisms and exploration of green financial instruments reflect efforts to secure funding for climate-

resilient agricultural practices (REDD+, 2022).

Extension and Collaboration: Enhancing knowledge exchange through platforms that share technical knowledge and success stories can inspire and educate farmers. Collaborations with regional partners and international organizations can facilitate the dissemination of best practices and innovations in AF.

Strategic Needs

Strategic vision, planning, and action plans in following areas are required to enable AF as an umbrella plan to reduce technical, financial and facilitative gaps thereby maximizing farmers income, facilitate biodiversity enhancement and ecological services:

i. Research gaps: Agroforestry research in Bhutan remains limited, particularly regarding species selection, system design, and socio-economic impacts. Addressing gaps is critical for evidence-based policies and effective adoption across diverse AEZ (Wangmo, 2025).
ii. Regional Cooperation and GESI: Regional collaboration, especially within South Asia, can enhance knowledge exchange, technology transfer, and capacity building. Integrating Gender Equality and Social Inclusion (GESI) ensures equitable benefits, empowering marginalized groups and promoting socially inclusive AF (BES, 2022).
iii. Exchange of seed and seedling materials: Cross-border exchange of seeds and seedlings improves biodiversity, system resilience, and productivity. Partnerships with neighboring countries strengthen Bhutan's seed systems and promote adoption of improved species (CIMMYT, 2022).
iv. Regional agroforestry strategy: A coordinated regional strategy aligns national and regional priorities, supporting policy harmonization, resource allocation, and climate-resilient practices. Bhutan's participation in regional dialogues reinforces its commitment to collaborative AF (ADB, 2022).
v. Research and capacity building: Investment in research, education, and extension strengthens technical skills and knowledge for farmers and practitioners, enhancing AF productivity. Projects like SLANT demonstrate the value of integrated research and capacity development (CIFOR-ICRAF, 2022).
vi. Joint Market Development and Finance: Developing joint markets and financial mechanisms improves commercialization, market access, and investment in AF. International partnerships, such as those supporting Mountain Hazelnuts, exemplify how coordinated finance and markets can scale sustainable AF initiatives (Finnfund, 2022).

Conclusion, Recommendations and Way forward

It can be concluded that Bhutan has been practicing agroforestry since time immemorial, required by the geological, topography, climate, culture and traditions. Further, due to the vast forest cover Bhutan comfortable to implement AF to further strengthen the resilience of rural communities to impacts of climate change. However, with some alignment of action plan and provision of technical expertise to farmers, the rural community is poised to greatly benefit, thereby contributing to food and nutrition security and contributing to climate resilience. As led by the Department of Forests and Park Services, the development and implementation of the National Agroforestry Strategy could be a way forward. The advantage of agroforestry could be enabled through a strong role played by both the national stakeholders as well as the international partners such as SAARC Agriculture Centre.

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Chapter 4

Role of Agroforestry in Improvement of Rural Livelihood and Build Climate Resilient Communities in Nepal

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Background

Agroforestry refers to the intentional combination of trees, shrubs, or bamboo with agricultural crops and/or livestock on the same piece of land, designed to promote positive environmental and social outcomes. In Nepal, this approach has deep traditional roots and remains a vital part of rural land management. Farmers since long practiced home gardens, boundary plantations, fodder tree cultivation, hedgerows, and mixed crop–livestock systems to sustain their households and protect fragile ecosystems (MoALD, 2019).

Across Nepal, farming systems commonly feature home gardens near dwellings-especially in the hills and Terai regions along with fruit and fodder trees on private lands, contour and boundary plantations, and alley cropping on sloped terraces. The specific forms of agroforestry differ by geographic region, from the Terai plains to the high hills, reflecting variations in livelihoods, ecology, and available resources (Ghimire et al., 2024).

Agroforestry plays a crucial role in improving food and nutrition security through the production of fruits, vegetables, tubers, and small livestock through supplies of fuelwood and fodder, supports income diversification and enhances the resilience of farming systems against climate fluctuations. Moreover, it contributes to on-farm biodiversity, enriches soil organic matter, and improves soil fertility relative to monocropping systems. Empirical studies and reviews have confirmed its positive effects on food security and ecosystem sustainability in Nepal (Ghimire et al., 2024).

Acknowledging these multiple advantages, the Government of Nepal formulated the *National Agroforestry Policy* to promote integrated tree–crop–livestock systems, encourage the productive use of marginal and degraded lands, and link agroforestry initiatives with national climate adaptation and livelihood improvement strategies. The policy highlights the involvement of several partners—including government agencies, ICIMOD, NGOs, and the private sector—in advancing pilot initiatives, mapping tree species, and expanding extension services to scale up agroforestry practices (MOALD, 2019).

Rural and Socioeconomic Profile of the Country

Nepal is a landlocked nation located in South Asia, sharing its borders with China in the north and India in the south, east, and west. As the country's population stands at 29,164,578, with 66.20% residing in urban areas and 33.80% in rural regions (NSO, 2025). A large proportion of the rural population depends on small-scale agriculture and livestock farming for their livelihoods. Agricultural landholdings are mostly small and fragmented, often less than one hectare in size. In many hilly and mountainous regions, access to essential infrastructure such as roads, electricity, and markets remains limited. Rural communities also face lower literacy rates and have fewer healthcare services than those in urban areas. Moreover, a substantial number of young people migrate abroad mainly to Gulf countries and Malaysia in search of employment, and the remittances they send back home play a crucial role in supporting the national economy. Despite these contributions, poverty continues to be a major issue in rural Nepal.

The NSCA (2021/22) indicates that around 62% of households in Nepal are involved in agricultural production. According to the EcS (2081/82)**,** the agricultural sector contributes about 25.16% to the national Gross Domestic Product (GDP) at an estimated annual growth rate of 3.28%.

Table 1 presents the major aspects of Nepal's rural and socio-economic profile. (It highlights key statistics, ongoing trends, and disparities across regions and demographic groups (NLSS, 2022/23).

Table 1. Socioeconomic Indicators of Poverty, Land, and Nutrition

Indicator	Value / Description	Notes / Trends
Poverty Rate (National)	About 20.27% of the population lives below the national poverty line.	(NSO, 2024)
Rural vs. Urban Poverty	Poverty remains higher in rural areas (24.66%) compared to urban areas (18.34%).	(NSO, 2024)
Provincial Variation	The Sudur Paschim Province reports the highest poverty rate (~34.16%), while Gandaki Province shows the lowest (~11.88%).	(NSO, 2024)
Land Ownership	Around 34.56% of households are landless, and approximately 19.66% own less than 0.2 hectares of land.	(NSO, 2024)
Poverty and Land Size	Households with less than 0.2 hectares of land have a poverty rate of around 23.32%,	(NSO, 2024)

Indicator	Value / Description	Notes / Trends
	compared to 11.38% among those owning more than 2 hectares.	
Household Size	Poverty tends to rise with household size—about 10.54% for families with three members and 28.59% for those with more than six members.	(NSO, 2024)
Nutrition and Food Security (ADS Targets for 2025)	• Stunting among children under five: ~20%, down from 37.4% in 2015. • Underweight children (under five): ~13%, down from 30.1% in 2015. • Wasting: ~2%, reduced from 11.3% in 2015. • Women with low BMI (<18.5): ~13%, lower than 2015 levels.	(MoAD, 2015)
Inequality	The national Gini coefficient stands at approximately 0.30, indicating moderate income inequality.	(NPC, 2024)
Regional Disparities	Persistent socio-economic gaps remain between provinces, with far-western and highland regions experiencing higher poverty and limited infrastructure development.	(NSO, 2024

Climate Challenges in Nepal

Changing Temperature and Precipitation Patterns

Nepal is experiencing a significant rise in average temperatures, particularly across the hill and mountain regions. This warming is accompanied by earlier seasonal transitions, more frequent heat waves in the Terai plains, and accelerated melting of snow and glaciers posing significant threat to water availablity (WB, 2022). Research indicates a consistent warming trend with both maximum and minimum temperatures increasing across many locations (Shrestha et al., 2016), temperature rise is most pronounced at higher elevations (above 3,000 meters (Ghimire et al., 2025). In the Gandaki River Basin, the warming rate differs by ecological zone: the hill region records the highest increase approximately 0.0921 °C per year followed by the mountain region with about 0.0254 °C per year, and the Terai with around 0.0042 °C per year during 1990–2020 (Paudel et al., 2022). Future climate projections suggest that, under high-emission scenarios (SSP585), average temperatures

could rise by 4–6 °C by the end of the 21st century (Dhital et al., 2023).

Precipitation patterns are becoming increasingly erratic, with unpredictable monsoon onset, more frequent dry periods, and intense rainfall events (MoFE, 2021), exhibit substantial spatial variability. Western Nepal has seen a decline in seasonal mean precipitation since around 1980, with rising rainfall events of short duration (Pokharel et al., 2019). In the Gandaki Basin, historical and projected data (2015–2100) indicate increases in both annual and monsoon rainfall. The frequency of extreme rainfall events is expected to rise, while dry spells may shorten, particularly toward the latter part of the century (Sigdel et al., 2022). Localized studies, such as those in Pokhara Valley, show seasonal variability: some months experience increased rainfall, others a decrease, but overall, precipitation is becoming more variable (Niraula & Pokhrel, 2022).

Impact on Agriculture and Food Security

Nepal climate change heavy reliance on rain-fed agriculture makes crop yields highly susceptible to climate variability. Yields of staple crops such as maize, millet, rice, and wheat have been declining or becoming increasingly unpredictable in many areas. Variations in monsoon timing, rainfall, and temperature extremes significantly reduce productivity, affecting the majority of farmers dependent on rain-fed systems (MoFE, 2021). Rising maximum and minimum temperatures, particularly in the Terai and warmer regions, adversary affected rice production (Pant, 2013).

Extreme weather events, including droughts, floods, hailstorms, and landslides, contribute to substantial losses, with some areas experiencing 10–30% declines in crop production (Central Department of Environmental Science, Tribhuvan University (TU, 2011). Livestock are also affected by climate change through heat stress, feed and forage shortages, and increased incidence of diseases and pests (MoFE, 2021). Freshwater aquaculture faces challenges from elevated water temperatures, fluctuating water availability, and potential disease outbreaks.

Due to decreasing reliability of agricultural incomes, many households are diversifying their livelihoods away from solely farming (Hussain et al., 2018). In Nepal's mid-hills, such as Kaski district, temperature and precipitation significantly influence yields of paddy, maize, wheat, millet, barley.

Extreme Events of Floods, Landslides, and Droughts

Nepal is experiencing more frequent and intense floods, particularly during the monsoon season, leading to loss of agricultural land, damage to infrastructure, and displacement of communities. Heavy rainfall in steep terrains often triggers landslides, causing soil erosion and declining soil

fertility (WB, 2022). Droughts and prolonged dry spells are also becoming more common, especially in the Terai and mid-hill regions (Smeltz, 2025).

Recently in October 2025, extreme rainfall caused flash floods and landslides in eastern Nepal, particularly in Ilam district, resulting in at least 47 fatalities and numerous people reported missing. These events disrupted transportation networks and overwhelmed emergency response systems (Reuters, 2025). While floods remain a frequent hazard, droughts are emerging as a growing concern, particularly in the southern plains and hilly areas. Rising temperatures and changing precipitation patterns have contributed to water shortages, adversely affecting agriculture and water supply (Amadio et al., 2023). For example, in traditionally arid districts such as Manang and Mustang, drying water sources and reduced crop yields have highlighted the increasing threat of drought in these regions (Pathak, 2023).

Socioeconomic and Institutional Issues

The Ministry of Forests and Environment (MoFE, 2021) highlights that rural populations heavily rely on agriculture and other climate-sensitive natural resources, yet their capacity to adapt-technologically, financially, and institutionally—is limited. Factors such as remoteness, inadequate infrastructure (roads, irrigation, weather information, early warning systems), and restricted access to credit and markets further constrain adaptive capacity (Smeltz, 2025).

Gaps in governance and coordination mean that climate change considerations are not consistently integrated into development planning (Bhandari, 2024). Nepal's economy, being largely dependent on agriculture, is highly vulnerable to climate variability. Erratic rainfall, prolonged droughts, and shifting seasonal patterns have reduced crop yields, threatening both food security and livelihoods.

Economic Costs and Development Impacts

The World Bank's Country Climate and Development Report (2022) highlights that Nepal's agricultural sector already incurred losses equivalent to approximately 1.5–2% of GDP in 2020 due to climate-related impacts. If climate risks remain unaddressed, future projections suggest substantial setbacks in economic growth and poverty reduction (WB, 2022). Agriculture, a key pillar of Nepal's economy, is particularly vulnerable to climate variability. Research indicates that climate-induced events, such as floods and droughts, account for a large share of crop losses—around 90%, with roughly 40% attributed to droughts and 23% to floods (KC, 2025).

Extreme weather events, including intense rainfall and landslides, have also caused significant damage to infrastructure. Hydropower generation, crucial

for Nepal's energy supply, is affected by erratic rainfall and glacial melt, resulting in reduced electricity production during dry periods, increased dependence on energy imports, and economic strain. The World Bank estimates that without mitigation, climate impacts could reduce Nepal's GDP by at least 7% by 2050 due to flooding, heat-induced reductions in labor productivity, and adverse effects on agriculture and infrastructure (WB, 2022).

Climate change also deepens social inequalities, disproportionately affecting marginalized groups. Women, indigenous populations, and rural communities are particularly vulnerable due to limited access to resources and adaptive capacity. Additionally, climate-induced disasters have triggered internal displacement, with affected communities relocating to urban areas, further straining infrastructure and services and posing challenges for sustainable development (WB, 2022).

Agroforestry in Nepal

In Nepal, agroforestry integrates trees with crops and/or livestock on the same land unit. Common practices include home gardens, boundary or contour planting, fodder strips, silvo pastoral systems, alley cropping, and commercial tree–crop combinations such as fruit, timber, and annual crops. While home gardens represent traditional systems, several other practices are promoted as improved or commercial agroforestry models (MOALD, 2019).

In 2019, Nepal became the second country worldwide to adopt a National Agroforestry Policy. The policy aims to facilitate the development, expansion, and commercialization of agroforestry systems to support national economic growth and livelihoods (MOALD, 2019). The policy seeks to reduce regulatory barriers, such as restrictions on tree registration, felling, and transport on non-forest lands, while promoting better coordination between sectors. Key stakeholders include the Ministry of Forests and Environment, the Ministry of Agriculture and Livestock Development (MOALD), the National Agriculture Research Council (NARC), ICIMOD, World Agroforestry (ICRAF), FAO, and numerous NGOs and private partners operating at provincial and district levels (MOALD, 2019).

Agroforestry practices in Nepal have contributed to higher household incomes, improved food security, and greater women's empowerment. For example, community forestry initiatives have reduced the time women spend collecting firewood, enabling them to participate more in income-generating activities and pursue education (Nuberg et al., 2018).

Typology of Agroforestry Practices in Nepal

Agroforestry in Nepal involves a variety of land-use systems that combine

trees with crops and livestock, adapted to the country's diverse ecological regions. These systems can be broadly classified into traditional subsistence models and emerging commercial practices, each offering unique advantages. The following are common types of agroforestry systems in Nepal, grouped by their key characteristics Table 2.

Table 2. Agroforestry Systems and Practices in Nepal

Type / System	Key Characteristics	Typical Species / Components	Regions & Ecological Zones	Key Benefits / Features
Home gardens / Homestead agroforestry	Multi-layered system around households integrating trees, vegetables, herbs, and small livestock; combines perennial and seasonal crops to meet household needs.	Fruit trees, timber trees, fodder trees, vegetables, herbs, NTFPs; some home gardens host over 130 species (Pandey, 2001).	Terai, mid-hills, across most zones; especially common in mid-hills and Terai (Pandey et al., 2021).	High species diversity; supports nutrition and biodiversity; flexible, low external input; suitable for small plots.
Agri silviculture / Crop–Tree combinations	Crops grown alongside or in rotation with trees; trees planted along field edges, terraces, bunds, or intercropped when young.	Fast-growing timber (Eucalyptus, Poplar, Teak), fruit trees, crops like maize and millet (Ghimire et al., 2024).	Mid-hills, Terai; terraces, slopes, field edges (Paudel & Shrestha, 2022).	Controls soil erosion; provides shade; gradual tree-based income; reduces forest dependency; improves microclimate.
Silvi pasture / Silvi-pastoral systems	Integration of trees with livestock forage; animals graze under trees while trees provide fodder and shade.	Fodder and timber trees, grasses, shrubs, livestock (goats, cattle) (Ghimire & Bolakhe, 2020).	Hills and mid-hills where livestock are significant and pasture is limited.	Provides fodder; reduces grazing pressure; combined livestock and tree income; enhances carbon stock and biodiversity.
Agri-silvo-pastoral	Combines crops, trees, and livestock on a	Mix of trees, crops, forage grasses, and	Mid-hills; areas where farmland,	Highly multifunctional; spreads risk;

Type / System	Key Characteristics	Typical Species / Components	Regions & Ecological Zones	Key Benefits / Features
	single land unit (e.g., crops on terraces, trees on bunds, livestock on slopes).	animals (Paudel & Shrestha, 2022).	livestock, and trees are integral to livelihoods (Magar & Kafle, 2025).	diversifies income; requires more management.
Alley cropping / Hedge-row intercropping	Fast-growing or leguminous trees/shrubs planted in rows; crops grown in alleys; pruned for mulch, fodder, or green manure.	Leucaena (Ipil-Ipil), fodder trees; crops like maize and millet (Forest Research and Training Centre, 2020).	Mid-hills, terraces, slopes.	Improves soil fertility; reduces erosion; provides mulch/fodder; suitable for slopes.
Taungya system	Early-stage intercropping of annual crops with plantation trees; crops removed as tree canopy closes.	Plantation trees + temporary crops; applied in Terai/inner Terai (Paudel & Shrestha, 2022).	Terai and inner Terai for plantation establishment.	Provides short-term farmer income; reduces establishment costs; engages communities.
Shelter belts, windbreaks, riparian buffers	Trees/shrubs planted along field edges, roads, or riverbanks to reduce wind, soil erosion, and flood impacts.	Wind-tolerant or riparian species; dense rows of mixed species (Paudel & Shrestha, 2022).	Terai, inner Terai, riverbanks, roadsides; also in hilly slopes.	Protects crops; conserves soil; regulates water; creates biodiversity corridors; mitigates extreme weather damage.
Silvi-fishery / Aqua-silviculture	Integration of trees around ponds or water bodies with fish farming; trees provide shade, leaf litter, and stabilize banks.	Fish species + surrounding trees (fruit, timber, shade) (Paudel & Shrestha, 2022).	Terai / inner Terai wetlands or ponds.	Diversifies income; efficient land use; combines fish protein with tree products.

Type / System	Key Characteristics	Typical Species / Components	Regions & Ecological Zones	Key Benefits / Features
Shifting cultivation (slash & burn / rotational fallows)	Alternating periods of cultivation and fallow to allow forest regrowth; sometimes retains trees; declining practice.	Local tree species, subsistence crops, mixed forest regrowth (Paudel & Shrestha, 2022).	Mountains, high hills, remote upland areas.	Allows soil and vegetation recovery if fallow periods are sufficient; low-intensity system; challenged by population pressure.
Forest-based agroforestry	Agroforestry activities integrated in or near forests, including leasehold forests, forest edges, or forest patch plantations; may include grazing.	Tree seedlings, NTFPs, fuelwood, fodder; sometimes small crops under forest canopy (Magar & Kafle, 2025).	Mid-hill forest areas; community and leasehold forests.	Provides alternatives to deforestation; supplies forest products; supports community livelihoods; promotes forest conservation.

Agroforestry Linked to Dominant Land-Use Categories

Agricultural Land

Agri-silviculture (Crop–Tree Integration): This approach combines trees with crops to enhance biodiversity, improve soil fertility, and generate supplementary income. It is commonly practiced in the Terai and hill regions of Nepal (Ulak et al., 2021). The specific species and crop combinations vary by region and ecological zone. In the Terai, fast-growing exotic trees such as *Eucalyptus camaldulensis*, *Tectona grandis* (teak), and *Populus* species are integrated with crops like ginger, turmeric, yam, and colocasia. In the mid-hills, both indigenous and exotic trees are used, for instance, tea (*Camellia sinensis*) grown under *Albizia procera* and *Dalbergia sissoo*, or cardamom under *Alnus* species. These systems aim to increase overall productivity without compromising the yield of either component (Ulak et al., 2021).

Agri-silvo-pastoral Systems: This system combines crops, trees, and livestock, allowing for diversified income and more efficient resource use. It is particularly common in Nepal's mid-hills (Ulak et al., 2021). In eastern Nepal, terrace risers—often underutilized spaces—are planted with fodder

species alongside crops such as maize and millet. This practice provides additional livestock feed while utilizing otherwise idle land, thereby improving overall farm productivity (Barakoti & Sah, 2019).

Alley Cropping: This method involves planting trees in rows at wide intervals, with crops grown in the spaces between ("alleys"). Alley cropping is widely used in Nepal's sloping terrains, especially in the mid-hills, to reduce soil erosion and improve soil fertility (Ulak et al., 2021). Common tree species include *Eucalyptus camaldulensis*, *Leucaena leucocephala*, and *Bauhinia variegata*, while crops such as maize, millet, and vegetables are grown in the alleys (Dhakal & Rai, 2020).

High-Value Cash Crop Integration: Planting high-value crops, such as broom grass (*Thysanolaena maxima*), within agroforestry systems—particularly on marginal lands- provides additional income opportunities and contributes to soil conservation (ICIMOD, 2019).

Forest Land

Community Forestry and Agroforestry: In Nepal's mid-hills, community-managed forests are combined with agroforestry practices to support both livelihoods and forest conservation (Gilmour et al., 2014). The Community Forestry Program, launched in the 1970s, has played a pivotal role in decentralizing forest management. By 2020, around 2.58 mhaes- approximately 23% of the country's total forest area- had been transferred to local communities for management (Laudari et al., 2024).

Taungya System: This traditional agroforestry practice involves cultivating crops in newly established forest plantations during their early growth stages, providing short-term income while promoting forest regeneration (Gilmour et al., 2014). Introduced in Nepal in the early 1970s, the system allows farmers to grow crops such as maize and mustard between tree seedlings like *Eucalyptus camaldulensis*, *Dalbergia sissoo*, and *Tectona grandis* for three to four years. It was implemented by the Department of Forests and the Sagarnath Forestry Development Project in Tamagadhi, Bara district, aiming to protect remaining *Shorea robusta* forests and associated biodiversity in central Nepal (Ulak et al., 2021).

Forest-Based Agroforestry: This system integrates trees within or adjacent to forested areas alongside agricultural activities, enhancing biodiversity, resource utilization, and local livelihoods (Gilmour et al., 2014).

Peri urban Areas

Urban Agroforestry: In Kathmandu, Nepal's capital, agroforestry practices are gradually being incorporated into the urban landscape. Rapid urbanization has led to the conversion of agricultural and forest lands into built-up areas. Nevertheless, urban green spaces such as Tundikhel and the Garden of

Dreams exemplify how urban agroforestry can help maintain ecological balance and provide environmental benefits within the city (Aryal et al., 2022).

Ecosystem Services Delivered in Nepal

Community-Managed Forests and Ecosystem Services

A study by Paudyal et al., (2015) in central Nepal examined changes in ecosystem service provision from 1990 to 2013 within community-managed forests. The study found that restoration of degraded lands through community forestry significantly enhanced multiple ecosystem services. Key services highlighted included timber, firewood, freshwater, carbon sequestration, water regulation, soil conservation, scenic beauty, and biodiversity. The perceived value of these services differed across local communities, experts, genders, and income groups.

Willingness to Pay for Water Ecosystem Services

Bhatta et al.,(2024) conducted a study to assess public willingness to pay for water as an ecosystem service in Dhankuta and Dasarath Chand municipalities. The findings indicated that the average annual willingness to pay per household was NPR 473.55, with the total annual value of water as an ecosystem service estimated at NPR 7,916,364 (approximately US$ 67,088). The study also found that factors such as gender, education, family size, household income, landholding, and age of the respondents significantly influenced their willingness to pay.

Economic Valuation of Wetland Ecosystem Services

Baral et al., (2016) conducted a study to estimate the total economic value of ecosystem services provided by the Ghodaghodi Wetland Complex. The study found that the wetland's total annual economic value was approximately NPR 94.5 million, with the option and existence values contributing the most to this overall valuation.

Governance and Policy Aspects

Nepal et al., (2025) conducted a study analyzing governance related to the provision of ecosystem services in Nepal. The study identified gaps and barriers that limit effective management of these services and discussed policy recommendations to strengthen the governance framework for ecosystem service delivery.

Economic Returns from Agroforestry

Agroforestry systems in Nepal's mid-hills have been shown to improve household income and food security. These systems integrate trees with crops and livestock, diversifying income sources and reducing vulnerability to

market fluctuations and climate variability. Studies indicate that households practicing agroforestry have better access to food and increased resilience against economic shocks (ACIAR, 2013)

Social Upliftment Through Agroforestry

Agroforestry can enhance agricultural productivity and generate income, thereby reducing the pressure for rural-to-urban migration. This is especially relevant in Nepal's mid-hill regions, where migration has resulted in abandoned farmland. By providing viable livelihood opportunities, agroforestry helps retain young people in rural communities and supports the preservation of local social and cultural structures (McGunnigle et al., 2023a).

Agroforestry in National Education Curricula

In Nepal, agroforestry is gaining recognition within the education sector, especially in higher education and specialized training programs. Although it has not yet been fully incorporated into the national school curriculum, initiatives are underway to introduce agroforestry education across different educational levels.

Current Initiatives in Agroforestry Education

Kathmandu Forestry College (KAFCOL)

Kathmandu Forestry College (KAFCOL) supports agroforestry advancement through its academic programs, research initiatives, and practical skill-building workshops. Its efforts emphasize sustainable land management, promoting the integration of trees and shrubs with crops to improve food security and rural livelihoods. The college also provides training for students and faculty, frequently partnering with other organizations to implement innovative technologies and research findings in addressing agroforestry challenges.

Developing Agroforestry Education and Training Materials

Advancing agroforestry education and training in Nepal is essential for promoting sustainable land-use practices and improving rural livelihoods. Various institutions and development projects have developed tailored resources that address the country's diverse agroecological zones and socio-economic conditions. Key examples of agroforestry education and training resources in Nepal.

Prominent Agroforestry Business Models

Projects such as Varaha's Agroforestry, Reforestation, and Regeneration (ARR) initiative operate across seven districts in Nepal, focusing on the cultivation of native fruit and nut trees, including *Taxus wallichiana*, *Malus domestica*, *Citrus sinensis*, *Elaeocarpus ganitru*, *Shorea robusta*,

Zanthoxylum armatum, *Actinidia deliciosa*, *Dalbergia sissoo*, and *Citrus limon*. These initiatives enable smallholder farmers to earn carbon removal credits by implementing scientifically guided agroforestry practices, thereby contributing to climate change mitigation while creating an additional source of income.

The RASFN project advances regenerative farming through agroforestry, with the goals of improving farmers' livelihoods, strengthening climate resilience, and empowering communities. By integrating carbon credit markets, the project enhances economic stability for farmers while promoting environmental sustainability. Social inclusion is also a key focus, with particular attention to empowering women and marginalized groups (FFN, 2023).

The "Advancing Women in Agroforestry Business Enterprise" (AWABE II) project has empowered more than 430 women in the Jumla and Nuwakot districts. Participants receive training in post-harvest processing, product management, digital marketing, and leadership. By facilitating access to agricultural technologies and support from local government, the project enables women to establish sustainable agroforestry-based enterprises, promoting both economic independence and gender equity (AAP, n.d.).

Community Based Tree Nurseries Agroforestry Business Model

Community-based tree nurseries (CBTNs) in Nepal have emerged as pivotal components of agroforestry business models, integrating environmental sustainability with economic opportunities. These nurseries serve as hubs for producing quality seedlings, promoting biodiversity, and fostering local entrepreneurship. Some key community-based tree nursery models in Nepal are given below.

Kalapani Community Forest User Group (CFUG), Kavrepalanchowk

Kalapani CFUG exemplifies a successful community-managed nursery model managed by the Kalapani CFUG in Bethanchok Rural Municipality. This nursery produces a variety of native tree species, including timber and fruit-bearing trees. The community actively participates in nursery operations, ensuring the production of quality seedlings for both reforestation and agroforestry purposes. This initiative not only supports local biodiversity but also generates income for the community through the sale of seedlings (EnLiFT Nepal, 2020).

EnLiFT2 Project: Nursery Management and Certification

The Enhancing Livelihoods from Improved Forest Management in Nepal (EnLiFT2) project provides comprehensive training on nursery management and certification. The project's manual outlines best practices for establishing

and operating community-based nurseries, emphasizing the importance of quality seedling production, proper nursery management techniques, and adherence to certification standards. These guidelines aim to enhance the sustainability and profitability of community nurseries (FAN, 2023)

Medicinal Agroforestry in Bagmati Province

In Bagmati Province, community-based nurseries specialize in growing medicinal plants that are incorporated into agroforestry systems. These nurseries produce seedlings of various medicinal species, which are then interplanted with agricultural crops. This strategy diversifies farmers' income, supports the conservation of important plant species, and helps preserve traditional medicinal knowledge (reNature, 2024).

Red Panda Network's Forest Conservation Nurseries

In Taplejung district, the Red Panda Network works closely with local communities to develop forest conservation nurseries. These nurseries cultivate native tree species that are crucial for restoring forests and protecting red panda habitats. By engaging community members in nursery management and tree-planting activities, the project promotes environmental stewardship while also generating economic benefits through the sale of seedlings and other forest products (Shrestha, 2025).

Public Private Partnership in Agroforestry Business Model

Public-private partnerships (PPPs) in agroforestry have become an effective approach in Nepal, encouraging cooperation among government bodies, private companies, and local communities. These partnerships focus on promoting sustainable land management, improving livelihoods, and supporting environmental conservation. The following are some notable public-private agroforestry initiatives in Nepal.

Dabur Nepal and ICIMOD in the Kailash Sacred Landscape

In 2018, Dabur Nepal and ICIMOD signed a Memorandum of Understanding to launch an agroforestry project in the Kailash Sacred Landscape. The initiative aims to tackle forest degradation, poverty, and the impacts of climate change in the region. The project is implemented in collaboration with the Ministry of Industry, Tourism, Forests and Environment (MoITFE), the Regional Forest Directorate (RFD), Sudurpaschim Province, and local stakeholders. Timmur (*Zanthoxylum armatum*) was selected as a suitable species for planting in community forests and on fallow lands.

Public-Private Community Alliances in Kawasoti Municipality

In Kawasoti Municipality, a Public-Private Community Alliance (PPCA) has been established to promote sustainable local development. The alliance

supports strategic planning and coordination among local stakeholders involved in eco-tourism and agroforestry. This collaborative approach seeks to strengthen biodiversity conservation and enhance the resilience of ecosystems and forest-dependent communities (International Climate Initiative [IKI], 2021–2024).

Agroforestry Based Value Chain

Agroforestry value chains in Nepal include a range of high-value products, such as honey, mushrooms, medicinal herbs, and nuts. These value chains combine sustainable land management practices with income-generating opportunities, contributing to improved rural livelihoods while supporting environmental conservation. The following sections provide an overview of each sector, drawing on relevant research and reports.

Honey Value Chain in Agroforestry

In Nepal, honey production largely relies on traditional beekeeping methods, involving both managed and wild bee populations. The value chain encompasses beekeepers, collectors, processors, and marketers. Growth in the sector is constrained by factors such as inconsistent product quality, limited processing infrastructure, and restricted market access. Initiatives like the UNIDO-supported Market Access Program are working to strengthen market linkages and enhance the quality of honey (UNIDO, 2024)

Mushroom Value Chain in Agroforestry

Mushroom cultivation, especially of species such as oyster and shiitake, is becoming increasingly popular within Nepal's agroforestry systems. The value chain includes substrate preparation, cultivation, harvesting, processing, and marketing. Research suggests that incorporating mushrooms into agroforestry practices can diversify farmers' income and enhance food security (Raut, 2019).

Medicinal Herb Value Chain in Agroforestry

Nepal's diverse biodiversity provides a strong foundation for cultivating and collecting medicinal and aromatic plants (MAPs) within agroforestry systems. The value chain encompasses cultivation, harvesting, processing, and marketing. The sector faces challenges such as overharvesting, limited processing facilities, and market volatility, which can affect sustainability. Initiatives like the Medicinal and Aromatic Plants in Regenerative Agriculture project work to promote production through regenerative farming practices (Resilient Landscapes Luxembourg, n.d.).

Ecotourism and Bamboo Village Agroforestry Business Model

Combining bamboo-based agroforestry with ecotourism offers a promising

business model in Nepal, supporting sustainable development goals while improving rural livelihoods. Nepal's varied climatic zones are home to more than 53 bamboo species, primarily found in the Hill region. Bamboo's fast growth and ecological benefits make it a key component of agroforestry systems, contributing to soil conservation, carbon sequestration, and biodiversity enhancement (Ayer et al., 2023).

The *National Bamboo and Rattan Development Strategy* (2025) highlight the creation of local employment opportunities through the conservation, management, sustainable use, and commercial cultivation of bamboo and rattan. The strategy aims to strengthen the economy by promoting both bamboo farming and processing. Complementing this, the Ten Million Bamboo Project targets the Kamala and Kankai river basins in eastern Nepal, with the goal of rehabilitating 25,000 hectares of land through bamboo agroforestry, thereby supporting environmental sustainability and boosting local economies (FRTC, 2025).

The Madi Eco-Village project in Chitwan demonstrates a community-based approach to ecotourism. The initiative promotes regenerative tourism by establishing village-level business units, including homestay cottages and communal facilities equipped with solar power and safe drinking water, fostering sustainable livelihoods and environmental stewardship (REPIC, 2018). Some business model frameworks for bamboo developed in Nepal are depicted below.

Table 3. Business Model Framework

Component	Description
Bamboo Cultivation	Set up bamboo nurseries and plantations to produce timber, edible shoots, and craft materials.
Agroforestry Practices	Combine bamboo cultivation with other crops and livestock to diversify income sources.
Ecotourism Infrastructure	Build eco-friendly accommodations and facilities for tourists.
Community Engagement	Engage local communities in decision-making processes and ensure equitable benefit-sharing.
Market Linkages	Develop connections to local and international markets for bamboo products and tourism services.

Barriers and Strategic Pathways of Agroforestry

Agroforestry in Nepal encounters several challenges, though targeted strategies can help improve its adoption and effectiveness. A significant

number of farmers lack knowledge and skills in cultivating, managing, and harvesting agroforestry species, which limits successful implementation (Thapa & Regmi, 2023). Key barriers to agroforestry are illustrated below.

Technical Constraints

Mismatches between species and site conditions, limited access to high-quality seedlings, insufficient guidance on silvicultural practices (such as spacing, pruning, and rotation), and a lack of applied research hinder the adoption of agroforestry and reduce productivity. Reviews. To address these challenges, it is important to invest in applied research, including species trials, strengthen nursery accreditation systems, enhance extension services for silviculture, and expand community-based nurseries that adhere to quality standards (Pandit et al., 2020).

Land-Tenure and Institutional/Policy Fragmentation

Uncertain tenure rights over trees on different types of land, overlapping responsibilities between forestry and agriculture agencies, and complex regulations regarding tree felling and transport discourage farmers from planting and investing in long-lived tree species. The *National Agroforestry Policy* (2019) and related policy briefs emphasize the issue of institutional fragmentation, with multiple ministries and unclear roles, and stress the need to clarify tree ownership and administrative rules to encourage investment. Recommended actions include defining legal and administrative ownership of trees on private and community lands, harmonizing forestry and agriculture mandates through inter-ministerial coordination, and simplifying permitting procedures for smallholder tree products, as outlined in the 2019 policy.

Knowledge and Skills Gaps

Many farmers and local extension agents lack the practical skills required for profitable agroforestry, including tree management, pruning, integrated pest management, and postharvest handling. The shortage of trained trainers (ToT) and limited hands-on training opportunities restrict the spread of effective practices. Field studies and project evaluations highlight the limited reach of extension services and the need for targeted training programs, including nursery manuals and farmer-to-farmer approaches, which have shown success but are not yet widely adopted (Ghimire et al., 2024).

To address these gaps, it is recommended to expand Training-of-Trainers programs, establish farmer field schools, and promote participatory extension approaches such as farmer-to-farmer learning.

Financial Barriers

Tree crops often require long payback periods and entail substantial upfront costs, including expenditures on seedlings, fencing, and soil amendments.

Smallholders face additional financial challenges due to a lack of credit products tailored to their needs, limited access to insurance, and weak incentives, such as unclear benefit-sharing arrangements from payments for ecosystem services (PES) or carbon schemes. The World Bank's CCDR report and sector reviews highlight these financing constraints in climate-resilient agriculture and agroforestry, emphasizing the need for blended finance, concessional credit, and mechanisms to channel carbon or ecosystem service payments directly to smallholders (WB, 2022).

To address these challenges, it is recommended to develop credit products aligned with tree crop cash flows, including grace periods; reduce investment risks through public guarantees or blended finance instruments; pilot PES and carbon payment schemes that reach smallholders; and support aggregation through cooperatives to improve borrower viability (WB, 2022).

Market Access and Value-Chain Constraints

Weak connections between producers and buyers, limited processing and quality-control capacity, inadequate cold-chain and value-addition infrastructure, and insufficient market information result in low returns for agroforestry products. Sectoral market studies, including those on honey and medicinal and aromatic plants (MAPs), as well as UNIDO market-access initiatives, indicate that challenges in product quality standards, processing, and certification are major constraints to scaling agroforestry value chains (UNIDO, 2024).

To overcome these barriers, investments should focus on value-chain development, including processing, grading, and certification. Additionally, strengthening producer cooperatives, improving market linkages, and supporting market access programs through quality infrastructure, branding, and export assistance can enhance returns and promote the growth of agroforestry products.

Farmers' Hesitation and Mindset as a Barrier

Many smallholder farmers tend to focus on short-term gains, giving preference to annual crops that offer quick income rather than tree-based systems with longer payback periods. Trees are often viewed as uncertain or "risky" investments because of concerns about competition with crops and delayed financial returns (Paudel et al., 2022).

In addition, limited local demonstrations and the absence of immediate benefits often lead farmers to doubt the relevance of research or extension recommendations, which slows the adoption of new agroforestry practices even when they are scientifically sound (Buyinza et al., 2022). Some farmers engage in "pseudo-adoption," planting trees mainly to obtain external support or incentives without long-term commitment to their management (Buyinza

et al., 2022).

Labor shortages and widespread male outmigration also discourage participation in agroforestry, as these systems demand sustained care and effort. Without available youth or family labor, tree planting appears less practical or appealing (McGunnigle et al., 2023b). Furthermore, many farmers lack adequate knowledge about the long-term ecological and economic benefits of agroforestry—such as the potential value of timber, non-timber forest products (NTFPs), and carbon markets—which causes them to undervalue its future returns (Agroforestry Network, 2018).

Drivers of the Mindset

Previous experiences of low profits and frequent crop failures have made many farmers risk-averse, encouraging them to focus on short-cycle crops (Paudel et al., 2022). Limited and top-down extension services have also hindered local demonstrations, leaving farmers unconvinced about adopting new practices. Research in the mid-hills suggests that changes in farmers' perceptions occur gradually and only when they witness clear, local benefits (Paudel et al., 2022). Moreover, unclear land tenure and complex regulatory procedures create uncertainty about tree planting, discouraging long-term investments. National policy reviews further emphasize that such institutional barriers continue to reinforce farmers' hesitation toward agroforestry adoption (Agroforestry Network, 2018).

Lack of Skills and Knowledge

Agroforestry systems demand specialized technical knowledge, including skills in nursery management, appropriate species selection, tree–crop–livestock integration, pruning, harvesting, and post-harvest handling. In Nepal, however, many farmers—and even some local extension workers—lack adequate expertise in these areas. As a result, seedling survival rates are often low due to improper planting and maintenance practices. Weak integration between trees, crops, and livestock frequently leads to competition rather than mutual benefit, reducing overall productivity and limiting marketable outputs.

Moreover, many farmers remain hesitant to adopt improved or innovative agroforestry techniques. In several mid-hill and Terai regions, they continue to rely on traditional systems, largely because of limited training opportunities and the absence of practical field demonstrations (Paudel et al., 2022; McGunnigle, 2023).

Evidence from Nepal

Studies reviewing agroforestry systems emphasize that inadequate extension services and limited farmer training remain key barriers to widespread

adoption (Ghimire et al., 2024). Farmer assessments from eastern Nepal reveal persistent knowledge gaps regarding suitable species selection, silvicultural practices, and market opportunities, all of which hinder effective implementation (Paudel et al., 2022). Furthermore, project evaluations indicate that in the absence of community-based capacity-building and peer learning, adoption rates stay low, and a significant number of trees established through development programs experience poor survival rates (Forest Action/EnLiFT2, 2023).

National Agroforestry Policy in Nepal as an Enabling Framework

Policy Context

Agroforestry has been an integral part of traditional farming practices in Nepal for generations, though it lacked a formal national framework until recent years. In 2019, the Government of Nepal introduced the *National Agroforestry Policy* to promote the systematic integration of trees, crops, and livestock with the goal of enhancing livelihoods, ensuring environmental sustainability, and strengthening climate resilience (MOALD, 2019). This initiative also aligns with Nepal's global commitments, including the Paris Agreement, the Sustainable Development Goals (SDGs), and the UN Decade on Ecosystem Restoration (2021–2030).

Key Objectives of the Policy

The *National Agroforestry Policy (2019)* offers a supportive framework for advancing agroforestry development in Nepal. Its key objectives include promoting agroforestry-based livelihoods and income opportunities, enhancing the sustainable production of food, fuel, fodder, timber, and non-timber forest products (NTFPs), supporting climate change adaptation and mitigation through landscape restoration, and fostering public–private–community partnerships to strengthen agroforestry enterprises (MOALD, 2019; FAO, 2021).

Action Plan and Strategic Interventions

The *Agroforestry Action Plan* provides a strategic roadmap for implementing the national agroforestry framework. It focuses on institutional development by strengthening coordination between the Ministry of Agriculture and Livestock Development (MOALD) and the Ministry of Forests and Environment (MoFE). Capacity-building measures include farmer training programs, field schools, and the incorporation of agroforestry into agricultural education curricula. The plan also promotes market and enterprise development by supporting value chains for timber, bamboo, medicinal plants, honey, and nuts. Additionally, it emphasizes research and extension through the promotion of studies on suitable species, silvicultural practices, and climate-smart technologies. Finally, it addresses land use and tenure

issues by integrating agroforestry into the *National Land Use Policy* and removing barriers to tree planting on private land.

Enabling Role in Agroforestry Development

The *National Agroforestry Policy (2019)* plays an enabling role in promoting sustainable land use and rural development in Nepal. It provides policy legitimacy by officially recognizing agroforestry as a key component of national development. The policy promotes cross-sectoral integration, linking agriculture, forestry, environment, and rural development initiatives (Ghimire et al., 2024). It also supports the achievement of the Sustainable Development Goals (SDGs) particularly food security (SDG 2), climate action (SDG 13), and biodiversity conservation (SDG 15). Furthermore, the policy encourages private sector participation in areas such as nursery development, agro-processing, and value chain promotion. Finally, it emphasizes community empowerment by strengthening farmer cooperatives and community-based enterprises engaged in agroforestry production and marketing.

Sectoral Linkage of Agroforestry

Policy Context

Nepal has adopted both the *National Agroforestry Policy (2019)* and the *National Climate Change Policy (2019)*, which together provide a complementary framework for promoting sustainable land management, enhancing climate resilience, and improving livelihoods. The policies explicitly identify agroforestry as a nature-based solution that contributes to food security, strengthens ecosystem services, and supports climate change adaptation and mitigation efforts (MOALD, 2019; MoFE, 2019).

Sectoral Linkages of Agroforestry

Forestry and Land Use: Both the *National Agroforestry Policy* and the *Climate Change Policy* emphasize increasing tree cover and fostering sustainable forest–farm linkages. Agroforestry contributes to Nepal's *Nationally Determined Contribution (NDC)* targets by expanding green cover outside forests, serving as an important climate mitigation measure (MoFE, 2020).

Agriculture and Food Security: Agroforestry promotes climate-smart agriculture through integrated tree–crop–livestock systems. Similarly, the Climate Change Policy prioritizes resilient agricultural practices and mainstreams climate adaptation into agricultural planning (MOALD, 2019; MoFE, 2019).

Energy and Livelihoods: Agroforestry provides fuelwood, fodder, timber, and non-timber forest products (NTFPs), reducing pressure on natural forests. The Climate Policy complements this by emphasizing alternative energy sources

and sustainable resource use to decrease rural household vulnerability.

Disaster Risk Reduction and Ecosystem Services: Agroforestry helps mitigate soil erosion, landslides, and flooding in hill and mountain regions. The Climate Change Policy promotes ecosystem-based adaptation (EbA), where agroforestry directly supports watershed management and biodiversity conservation.

Support Service to the Community

Advisory Support

Several government organizations in Nepal offer advisory and extension services to promote agroforestry. Key organizations area:

Department of Forests and Soil Conservation (DoFSC): Provides technical and extension support to community forestry user groups and promotes agroforestry practices on private lands (DoFSC, 2020).

Department of Agriculture (DoA): Delivers advisory services through Agriculture Knowledge Centres (AKCs) at the district and provincial levels, focusing on integrating trees with crops and livestock systems (MOALD, 2019).

Local Governments (Municipalities and Rural Municipalities): Implement agroforestry promotion activities under the federal system, including subsidized seedling distribution, farmer training, and demonstration programs.

Several NGOs like Forest Action, Nepal Agroforestry Foundation, ICIMOD, Practical Action, LI-BIRD, WWF Nepal play an active role in promoting agroforestry through research, training, policy advocacy, and community-based initiatives.

Technical Services for Farmers

Training and Capacity Building

To strengthen agroforestry development in Nepal, several government agencies, non-governmental organizations, and research institutions have implemented various training, capacity-building, and demonstration programs. These initiatives aim to improve technical skills, promote sustainable land management, and encourage the adoption of agroforestry practices among farmers and local communities. The following table summarizes the major programs and institutions contributing to agroforestry capacity development in Nepal and their key outcomes.

Nursery and Seedling Support

The Department of Forestry (DoF) operates large-scale nurseries across Nepal

to produce substantial quantities of seedlings in line with government targets. Once the seedlings are produced, the DoF distributes them to Community Forest User Groups (CFUGs), which then allocate them to individual households. In some cases, the DoF also provides seeds directly to CFUGs to support the establishment and management of community-based nurseries.

The Ithaka Institute has established a farmer-managed tree nursery network in rural areas of Nepal to ensure a consistent supply of high-quality and diverse tree saplings for project villages. This initiative empowers local farmers to manage their own nurseries, thereby strengthening sustainable agroforestry practices and enhancing local livelihoods (Ithaka Institute, n.d.).

Bajra Samaj Nepal (BSN) collaborates with local communities to develop and manage community nurseries**,** emphasizing the selection of tree species that help prevent soil erosion and conserve water sources. For example, in Ramechhap District**,** BSN facilitated the plantation of tree species such as *Cinnamomum zeylanicum*, *Ficus auriculata*, and *Alnus nepalensis* around natural water sources. This effort actively engages communities in nursery development and plantation activities, promoting ecological conservation and community ownership (BSN, n.d.).

The International Centre for Integrated Mountain Development (ICIMOD) provides seeds and seedlings of valuable plants, including trees, shrubs, and fruit species, to farmers and community groups. These materials contribute to forest regeneration, the development of nitrogen-fixing hedgerows, and various income-generating agroforestry activities (ICIMOD, 2019).

The Peace Corps Nepal supports farmers in establishing and managing nurseries by providing technical training in seedling production and sustainable agricultural practices. Through their guidance, local farmers enhance their skills and capacity for nursery development and agroforestry promotion (Peace Corps, 2022).

Agroforestry Extension Services

A study conducted in the Terai region of Nepal revealed that farmers who had access to agricultural extension services and were members of farmer groups were significantly more likely to adopt agroforestry practices compared to those engaged solely in conventional farming (Dhakal & Rai, 2020). Furthermore, knowledge-sharing platforms and on-farm demonstrations organized through extension programs have proven effective in helping farmers understand the tangible benefits of agroforestry, thereby minimizing hesitation toward adopting innovative land-use systems (Khadka et al., 2021).

In the western mid-hills**,** extension initiatives employing group-based approaches, “mini-kits,” demonstration plots, farmer field schools, and training sessions have shown considerable success in promoting improved

agricultural practices. The IRRI-STRASA project implemented in Lamjung and Tanahun districts utilized various extension tools, including demonstrations, group training, and field visits, which collectively enhanced the adoption of improved crop varieties and agroforestry systems among local farmers (Baral et al., 2018).

Market and Value Chain Advisory

Nepal's National Agroforestry Policy (2019) formally promotes commercialization and scaling of agroforestry — creating policy space for incentives, leasehold agroforestry and use of public/ marginal lands (Government of Nepal, Ministry of Agriculture and Livestock Development, 2019). High market potential exists particularly for bamboo, fruit trees, fuel/fodder trees, and non-timber forest products (NTFPs, e.g., medicinal & aromatic plants). Bamboo & NTFPs show strong livelihood and value-addition potential if value chains are organized and processing is introduced (Kafle et al., 2023). There is also growing demand for tree-based fodder and feed to support commercializing livestock production; feed shortages make fodder tree commercialization an attractive supply-side opportunity (NAFLQML, 2019)

Bamboo (used for timber and small crafts) has high local demand for construction materials, furniture, and craft products. With improved processing and quality standards, it also holds strong potential for export and urban markets. Enhancing value addition can significantly increase farmers' incomes (Kafle et al., 2023).

Fruits and high-value tree crops such as mango, citrus, litchi, walnut, and chestnut have robust domestic markets for both fresh and processed products, along with niche export opportunities to India and other regional processors. However, efficient cold-chain systems and aggregation centers are essential to fully exploit these opportunities (Ghimire et al., 2024).

Non-timber forest products (NTFPs) and medicinal plants possess high per-unit value, but weak market linkages, inadequate quality grading, and unsustainable harvesting practices limit their profitability. Establishing organized collection systems and promoting local-level processing can greatly enhance economic returns (Banjade & Paudel, 2008).

Fodder and forage trees, valued for their leaf biomass as livestock feed, face growing demand from the expanding dairy and poultry sectors. Integrating agroforestry-based fodder production reduces feed costs and can be commercialized through products such as pellets, silage, and leaf meals (NAFLQML, 2019)

Financial Support Mechanisms

Government Subsidies and Grants

The government provides subsidized seedlings and saplings for tree planting (fodder, fruit, timber) through Agriculture Knowledge Centers, Forest Offices, and Rural Municipalities. Farmers get seedlings at reduced cost or free in some development projects. Under National Agroforestry Policy (2019), provisions are made for financial support and incentives for agroforestry enterprises. Trrough Forest for Prosperity Project (FFPP) with sum total US Dollar 24 million community forest were supported in Madhesh and Lumblni proviences. Forest and Farm Facility Program (FFFP) Technical support provided to small farmers. Though many details are delegated to provincial or local governments. Some of the examples are given below.

Credit and Loan

The Forests for Prosperity Project (FFPP)**,** supported by the World Bank, integrates both grant and loan components to foster sustainable forest management and strengthen forest-based enterprises in Nepal. Through the Agricultural Development Bank Limited (ADBL)**,** loan financing is extended to eligible private actors such as forest-sector and agroforestry small and medium enterprises (SMEs). These funds are aimed at promoting the aggregation, processing, and marketing of forest and tree-based products, while also providing essential working capital. ADBL is responsible for identifying potential SMEs, evaluating proposals, and facilitating loans in accordance with FFPP operational guidelines. Stakeholders seeking further information on project procedures may contact ADBL or the Federal Project Management Unit (PMU) (World Bank, 2021).

ADBL provides a range of agricultural loan products, such as Agro Production Loans, Cold Storage Loans, Agro Tools, Livestock Loans, and VITA loans, which can finance inputs, planting, infrastructure, and small-scale processing units. Under FFPP, ADBL also extends loans specifically to forest and agroforestry SMEs. Many ADBL products are suitable for investments in farm forestry and agroforestry, including nurseries, sapling production, agro-processing units, cold storage for tree fruits, and working capital for bamboo enterprises. FFPP helps increase targeted lending to forest enterprises. Interested groups, cooperatives, and SMEs can apply using standard BFI/ADBL procedures, while project-linked lending follows guidance from the PMU and ADBL (ADBL, n.d.).

The Nepal Rastra Bank (NRB) provides refinance facilities at subsidized rates to licensed BFIs for priority sectors and issues directives to enhance the share of agricultural credit, including setting targets for agricultural lending. NRB's refinance programs allow BFIs to offer lower-cost loans to farmers and

enterprises. Borrowers receive loans through BFIs that have obtained NRB refinance, and local banks can provide information about refinance-supported agricultural loans and interest-subvention schemes (NRB, 2020).

Project-Based Funding

Projects supported by ACIAR (EnLiFT project), FAO, ICRAF, and World Bank include financing components: seedling distribution, technical assistance, demonstration plots, matching grants for farmer groups. Carbon finance / Payment for Ecosystem Services (PES) pilots are being explored in some agroforestry interventions (e.g., projects linking agroforestry with carbon credit markets).

World Bank -Forest for Prosperity Project (FFPP): Project financing (loan + grant) targeted at sustainable forest management, forest enterprises and benefits from forests — includes on-lending/modalities relevant for agroforestry and forest enterprise development in selected provinces (World Bank, 2020).

International Fund for Agricultural Development (IFAD) — Leasehold & Hills Forestry Projects

IFAD has long supported leasehold forestry, fodder and household forestry projects (blended grant + credit models) that directly inform agroforestry financing and project design (IFAD, n.d.).

Food and Agriculture Organization (FAO) — Forest & Farm Facility (FFF) / technical grants

FAO supports national agroforestry and Forest and Farm Facility grants, small-grants and capacity building for producer organizations and community forestry groups. FAO also facilitates direct beneficiary grants under FFF (FAOUN, 2025).

WWF Nepal: WWF Nepal funds community forest management, restoration, and private/agroforestry initiatives linked to biodiversity and landscape restoration programs; they also partner on large restoration flagships (WWFNN, n.d.).

World Agroforestry/CIFOR-ICRAF: ICRAF (World Agroforestry) runs research-to-project initiatives (pilot agroforestry projects, livelihood enhancement and value-chain research) in Nepal — good partners for evidence-based project design and donor collaboration (Gilmour, et al 2014)

Forest Action Nepal (research & project partner): National research & policy NGO that implements donor-funded projects (often Darwin Initiative, UK funds, GEF partners) on community forestry, governance and restoration —

useful as local implementing partner.

Local Initiatives for Biodiversity, Research and Development (LI-BIRD) is a Nepal-based non-governmental organization with extensive experience in implementing projects funded by GEF/UNDP, the European Union, and various bilateral partners. The organization focuses on integrating agroecology, agroforestry, biodiversity conservation, and market development through applied field-based initiatives (LI-BIRD, n.d.).

UNDP/GEF Small Grants Program (SGP): The Small Grants Program (SGP), supported by UNDP/GEF, provides funding to community-based organizations and NGOs for initiatives focused on agroforestry, ecosystem restoration, non-timber forest product (NTFP) conservation, and small enterprise development. These projects are frequently implemented in collaboration with local partners, such as LI-BIRD, to ensure community engagement and sustainability (LI-BIRD, n.d.).

Darwin Initiative/Royal Botanic Gardens Edinburgh (RBGE) partnerships: Darwin Initiative funds biodiversity-linked restoration and community forestry projects in Nepal (often implemented with Forest Action, RBGE and local partners). These grants support applied restoration and agroforestry that link livelihoods and biodiversity (Darwin Initiative, 2021).

RECOFTC (regional capacity & project support for community forestry): RECOFTC works on scaling community forestry and linking it to climate and biodiversity goals — they support programmatic grants and technical partnerships in Nepal (Suzuki, 2012).

Bilateral & multilateral donors (EU, SIDA/Finland, NORAD, ACIAR, JICA, KOICA): Various donors provide funding for agriculture, landscape restoration, and environmental initiatives in Nepal. A significant portion of these resources is allocated through NGOs and partner organizations to support agroforestry and related value-chain development projects, as reflected in the project portfolios of organizations such as LI-BIRD, GIZ, FAO, and other local partners (Forest Action Nepal, n.d.).

Provincial / Local Government Budgets

After federalism (post-2015 constitution), local governments (rural/municipal) have responsibilities and budgets to support agriculture and forestry; some municipalities allocate funds to agroforestry programs (seedling subsidies, training, small grants).

Promotion of Green Corridor / Green Belt

A green corridor generally means linear strips of vegetation (trees, hedges, green belts) that connect open or green spaces in cities (parks, riversides, streets), helping ecological functions (shade, air filtration, habitat

connectivity), recreation, movement, etc. Green belts serve similar functions around urban perimeters. In Nepal it overlaps with urban greening, green infrastructure, blue-green landscapes etc.

Funding instrument

REDD+ provides results-based payments and project financing to support forest-based mitigation and restoration activities, which can be directed toward community-led and landscape-level agroforestry initiatives. Similarly, green bonds—whether sovereign, municipal, or corporate—can attract large-scale domestic and international investment for landscape-level agroforestry, nursery development, processing infrastructure, and value-chain enhancement. However, the successful implementation of these mechanisms in Nepal requires robust monitoring, reporting, and verification (MRV) systems, clear tenure rights, equitable benefit-sharing arrangements, and inclusive social and environmental safeguards (Shrestha et al., 2014)

REDD+ provides performance-based payments for activities that reduce emissions from deforestation and forest degradation, enhance forest carbon stocks, and promote the sustainable management of forests. Agroforestry initiatives that increase tree cover and carbon storage—such as farm tree planting and community forest enrichment—can qualify for REDD+ benefits when integrated into national or sub-national frameworks with robust monitoring, reporting, and verification (MRV) systems. Nepal has completed the readiness and pilot phases of REDD+ implementation and has adopted a comprehensive National REDD+ Strategy to guide its long-term forest carbon initiatives (Ministry of Forests and Environment [MoFE], 2018).

Green bonds are financial instruments designed to generate capital for projects that deliver measurable environmental benefits. These bonds can finance sustainable land management, reforestation, agroforestry nurseries, processing facilities, and landscape restoration activities. International frameworks, such as the Green Bond Principles established by the International Capital Market Association (ICMA) and the Climate Bonds Initiative, provide guidance on eligible project categories and transparency requirements. In Nepal, the issuance of green bonds between 2024 and 2025 by commercial banks, the Nepal Infrastructure Bank (NIFRA), and IFC-supported institutions demonstrates growing potential to mobilize both domestic and international investments for agroforestry-related projects (ICMA, 2022).

Evidence and Examples from Nepal

Nepal has implemented several REDD+ pilot projects within community forests and advanced its REDD+ readiness through the Forest Carbon Partnership Facility (FCPF). These pilot initiatives—such as the Chepang

Chiuri community project—have demonstrated ecological benefits while also revealing challenges related to social equity. Recently, Nepal updated its *National REDD+ Strategy (2024–2025)* to strengthen forest-based climate mitigation efforts. The lessons learned from these initiatives indicate that REDD+ mechanisms can be effectively expanded to support agroforestry interventions, including farm tree cultivation, enrichment planting, and assisted natural regeneration (Shrestha et al., 2014).

In 2025, Nepal achieved a significant milestone in green finance through landmark green bond issuances and agreements involving banks and the Nepal Infrastructure Bank (NIFRA). These issuances established a foundation for financing renewable energy and green infrastructure projects. The same financial mechanisms can be extended to sustainable land-use initiatives, including forestry and agroforestry projects, when aligned with recognized green bond standards and forestry criteria (IFC, 2025).

Extension and Collaboration for Agroforestry Development

Role of Extension Services

Extension services provide farmers with essential information, training, and advisory support on agroforestry practices. This includes guidance on species selection, system design (tree–crop combinations), nursery management, tree–crop interactions, pruning, and harvest scheduling. Studies in Nepal have shown that access to extension services significantly influences the adoption of agroforestry systems, while a lack of technical knowledge and extension support remains a key barrier to uptake (Khadka et al., 2021). Globally, rural advisory services are recognized for helping farmers acquire new skills, update farming practices, link with markets, and integrate innovative systems such as agroforestry (Forests, Trees and Agroforestry [FTA], n.d.).

Successful agroforestry requires farmers to match tree species with site conditions, design optimal tree–crop spatial arrangements, manage interactions between crops and trees, and plan long-term rotations. Extension agents provide this technical guidance and assist in tailoring agroforestry systems to local biophysical and socio-economic conditions. Research in Nepal's Chure region indicates that improved access to extension services is positively associated with the adoption of diverse agroforestry systems (Khadka et al., 2021).

Extension services facilitate access to quality seedlings, seed sources, and nurseries, which is critical for agroforestry success. They also provide training on nursery establishment and management, supporting the supply of appropriate planting materials. According to the Country Agricultural Extension Profile for Nepal, organizations such as the World Agroforestry Centre (ICRAF) deliver extension training on tree-based farming, nursery

management, and integrated farming systems (Karki, n.d.).

Extension services act as a bridge between research and practice by monitoring agroforestry interventions, collecting farmer feedback, adapting techniques, and disseminating lessons learned. This role is particularly important in long-term agroforestry systems. Effective knowledge transfer regarding species selection and tree-planting techniques has been shown to enhance the successful establishment and growth of agroforestry systems (Khadka et al., 2021).

Collaboration and Knowledge Sharing

Organizations including ICIMOD, ICRAF (World Agroforestry), and NGOs such as LI-BIRD and CARE Nepal have collaborated with local governments to pilot innovative agroforestry systems and share lessons learned (ICIMOD, 2019). Partnerships between universities such as Tribhuvan University and Agriculture and Forestry University and local farmers, through participatory research, have strengthened the development of context-specific agroforestry solutions (Acharya et al., 2021). ICIMOD also promotes cross-border knowledge exchange among Hindu Kush–Himalaya (HKH) countries, showcasing successful initiatives such as walnut-based agroforestry in Jumla and cardamom-based agroforestry in Ilam (ICIMOD, 2019).

Success Stories for Inspiration

Cardamom (*Amomum* spp.) is a high-value spice and a prominent agroforestry crop in Eastern Nepal, particularly in the districts of Ilam, Panchthar, and Dhankuta. It grows well under the shade of existing forest trees or within multi-strata agroforestry systems, making it an attractive option for smallholder farmers seeking to diversify their income while maintaining environmental sustainability. The integration of large cardamom under shade trees has enhanced farmer incomes and contributed to biodiversity conservation, and it is widely recognized as a successful agroforestry model (Paudel et al., 2018).

Strategic Needs for Agroforestry Development

Agroforestry enhances land productivity by integrating trees, crops and livestock on the same farm, providing households with food, fruits, fodder, fuelwood, and timber. This diversified system reduces vulnerability to crop failure and seasonal fluctuations while generating multiple income streams through timber and non-timber products, fruits, and improved livestock yields MOALD, 2019).

By storing carbon in biomass and soils, agroforestry contributes to climate change mitigation and can make smallholders eligible for programs such as REDD+ or green bond–type financing, provided that carbon stocks are

properly measured, credited, and linked to equitable benefit-sharing mechanisms (Maharjan et al., 2024). Planting trees on private and marginal lands such as boundaries, terraces and riparian strips improves soil fertility and reduces reliance on community and national forests for timber and fuelwood, thereby balancing conservation objectives with local resource needs.

Evidence from Nepal indicates that agroforestry reduces pressure on forests and enhances livelihoods (Pandit et al., 2014). When combined with effective market linkages, high-value tree products including fruits, medicinal plants, timber, and fodder can be commercialized, further increasing household income and resilience.

Research Gap Bridging in Agroforestry

Agroforestry in Nepal faces several critical research gaps that need to be addressed to enable scaling, climate finance access, and equitable benefits. Key recurring gaps identified in literature and policy documents encompasses policy and governance, biophysical knowledge, MRV/carbon accounting, markets and value chains, and social inclusion. Addressing these gaps requires targeted, interdisciplinary research linking site-specific agroecology and species placement with robust MRV, inclusive governance, and market analysis.

Unclear rules on tree tenure, ownership, felling and timber transport on private and agricultural lands impede farmer uptake and scaling of agroforestry. Policy fragmentation across ministries and weak implementation are often highlighted MOALD, 2019). To address this, a comprehensive policy audit should be conducted, mapping laws such as the Forest Act, Land Act, and National Agroforestry Policy (2019), along with administrative procedures affecting on-farm trees. Mixed methods including legal review and stakeholder interviews with farmers, local governments, and forest offices can identify contradictions and bottlenecks. The outcomes should include specific legal amendments, administrative guidelines, short legal briefs and draft SOPs for local governments.

There is limited empirical, spatially explicit guidance on which tree species combinations perform best across Nepal's diverse elevations, microclimates, and farming systems (Finlayson, 2020). To fill this gap, multi-site participatory trials should be implemented to test priority species mixes (food, fodder, timber, NTFPs) across elevation gradients. Monitoring should include yield, soil health, and labor requirements for at least three cropping cycles. A spatial decision-support tool (Which tree, where?) integrating GIS layers with trial results can support local extension services.

Lack of standardized, locally calibrated carbon sequestration factors and MRV protocols limits smallholder access to REDD+, carbon, or green finance (Baral et al., 2025). To address this, country-specific allometric equations and soil carbon measurement protocols should be developed for common agroforestry species. Community-level MRV approaches using mobile data collection and periodic sampling should be piloted, along with smallholder aggregation models for carbon projects. A business case demonstrating the viability of smallholder aggregation can facilitate investment.

Disaggregated evidence on how agroforestry affects women, landless households, tenants, and marginalized castes is limited, particularly regarding labor burdens (Thapa & Regmi, 2024). Addressing these gaps requires integrating gender and equity modules into all trials and pilots, conducting gendered time-use surveys, and analyzing benefit distribution. Interventions such as tenure-proof registration, women's nurseries, and improved access to credit should be tested and evaluated.

Most studies on agroforestry are short-term, resulting in a scarcity of long-term monitoring plots and baseline datasets for soil health, biodiversity, and hydrology (Ghimire et al., 2024). To fill this gap, a network of permanent agroforestry monitoring plots should be established across representative agroecological zones. These plots should track ecological and socioeconomic indicators over 10+ years, with open data availability for researchers and policymakers.

Research on agroforestry as a tool for landscape-scale objectives such as flood buffering, landslide stabilization, wildlife corridors, and restoration of abandoned croplands is limited (Ojha et al., 2022). Addressing this requires landscape modeling and pilot projects implementing agroforestry-based restoration on marginal or abandoned lands, measuring both ecosystem services (e.g., runoff reduction, sediment retention) and livelihood impacts.

Regional Cooperation

These brief highlights actionable insights on regional cooperation for agroforestry development, suitable for policy notes, donor proposals, or research initiatives. It outlines the rationale for regional collaboration, key platforms, priority areas, practical mechanisms, and quick-start project ideas.

ICIMOD (International Centre for Integrated Mountain Development): Plays a central convening role in the Hindu Kush Himalaya (HKH) region, supporting agroforestry, landscape restoration, and public–private partnerships across Nepal, India, China, Pakistan, Bhutan and Myanmar (ICIMOD, n.d.).

SAARC / SAARC Agriculture Centre (SAC): Serves as a regional forum for agricultural cooperation in South Asia and hosts expert meetings on

agroforestry and rural livelihoods (Amatya & Adhikari, n.d.-a).

BIMSTEC (Bay of Bengal Initiative for Multi-Sectoral Technical & Economic Cooperation): Provides a platform for Bay of Bengal countries to collaborate on agriculture, trade, and food security, particularly useful for developing value chains and trade linkages (BIMSTEC, n.d.).

CIFOR-ICRAF & FAO Regional Programs: Offer technical support on agroforestry policy, MRV, and the scaling of best practices across Asia (Park et al., 2022).

Bilateral, Provincial, and Private Sector Partnerships: Involving agribusinesses and nurseries is essential for piloting commercialization efforts and expanding nursery networks (ICIMOD, 2022).

Exchange of Seeds and Seedling Materials

The exchange of seeds and seedling materials for agroforestry within Nepal and across the SAARC region is guided by several existing frameworks, yet faces operational challenges. The SAARC Seed Bank Agreement (2011) establishes a framework for Material Transfer Agreements (MTAs) to facilitate the movement of seeds and germplasm among member countries (The Kathmandu Post, 2014). In addition, the "Seeds Without Borders" initiative, coordinated by the SAARC Agriculture Centre, aims to simplify bilateral seed exchanges by providing mechanisms such as designated nodal institutions, phytosanitary permits, and standardized checklists (Pandey et al., 2019).

A recent development includes a Memorandum of Understanding (MoU) in August 2024 between Nepalese seed companies and international partners from India, Bangladesh, Japan, and Thailand. This agreement focuses on custom seed production for cereals and vegetables in Nepal, offering incentives such as exemptions from variety registration to encourage participation and streamline the process (CIMMYT, 2024).

Strengthening the seed and seedling exchange system for agroforestry will require harmonized phytosanitary standards, effective institutional coordination, capacity building for nurseries, and clear regulatory frameworks to support both domestic and cross-border germplasm flow.

Strengthening Regional Strategies

The SAARC region, through the SAARC Agriculture Centre (SAC), has increasingly recognized agroforestry as a regional priority. Initiatives such as regional expert meetings, trainings, and the "Seeds Without Borders" discussions illustrate SAARC commitment. SAC organizes events focusing on agroforestry, carbon trading, and seed exchange, aiming to establish a regional framework for knowledge sharing, capacity building, and harmonized seed policies (SAARC Agriculture Centre, 2024). Technical

leadership and regional programming are provided by ICRAF, CIFOR-ICRAF, and the World Agroforestry Centre through their South Asia Regional Program. These organizations support national agroforestry policies, offer species-placement guidance, and facilitate capacity-building initiatives across South Asia, making them essential partners for any SAARC-level strategy (IMCC, 2018).

Regional policy instruments and declarations like SAARC resolutions, SAC program documents, and FAO/CIFOR reviews highlight the intent to coordinate activities such as species trials, nursery development, MRV and carbon accounting, and seed exchange. Would contribute to knowledge exchange, capacity building, harmonization in MRU and joint project development.

Research and Capacity Buildings

Nepal and the broader SAARC region benefit from strong policy frameworks and active technical partnership, National Agroforestry Policy (2019), Nepal Agricultural Research Council (NARC), Agriculture and Forestry University (AFU), Institute of Forestry (Tribhuvan University), CIFOR-ICRAF, ICIMOD, and the SAARC Agriculture Centre (SAC). Despite these strengths, significant research gaps remain in areas such as species–site matching, MRV and allometry protocols, socio-economic analyses, value-chain development, and long-term ecological monitoring. Capacity limitations also persist, including the need for accredited nurseries, trained MRV technicians, a strengthened extension workforce and harmonized regional phytosanitary systems. Addressing these gaps requires coordinated, interdisciplinary research programs alongside multi-level capacity-building efforts that span national, provincial, community, and regional levels (MOALD, 2019).

National Agroforestry Policy (2019) provides the overarching policy framework; key national institutions engaged in research and capacity development include NARC, AFU, the Institute of Forestry at Tribhuvan University, FAO and various national NGOs and private nurseries. CIFOR-ICRAF and ICIMOD maintain active country programs and technical support offices in Nepal. At the regional level, SAC manages training initiatives such as the “Seeds Without Borders” program, while CIFOR-ICRAF, ICIMOD, and FAO provide technical guidance and leadership. However, regional cooperation remains largely project-based focused on pilot initiatives and exchange trainings—rather than being implemented as a fully harmonized, long-term program (Pandey et al., 2019).

Joint Market Development and Finance

Agroforestry products, including fruits, non-timber forest products (NTFPs), timber, and fodder-linked dairy, are frequently produced by numerous

smallholders on fragmented plots. Aggregating these products regionally and integrating them into broader markets can increase value and create more stable demand (CIFOR-ICRAF, n.d.). Regional cooperation through platforms such as SAARC, BIMSTEC, ICIMOD, and CIFOR-ICRAF helps reduce transaction costs by standardizing procedures, ensuring phytosanitary compliance, and facilitating seedling supply. It also enables cross-border market expansion and supports larger investment opportunities, such as regional processing hubs and blended finance initiatives, which individual districts or countries may struggle to attract independently (SAARC Development Fund Secretariat, n.d.).

The strategic objectives of joint market development include building aggregated supply chains that allow smallholders to access processors, exporters, and larger domestic and regional markets (Kollmair et al., 2011). Other goals are improving product quality, establishing standards, and strengthening post-harvest handling such as grading, cold storage, and processing to meet regional and export market requirements (Rahman et al., 2024). Financial instruments that combine grants, concessional loans, and carbon or green finance can help mitigate risks for private investment in nurseries, processing units, and logistics (CASH Coalition, n.d.). Harmonizing regional regulations, including phytosanitary requirements, seed and seedling exchanges, and value-chain standards, can lower non-tariff barriers and facilitate cross-border trade (SAARC Secretariat, 2020).

Practical interventions for market development involve forming primary producer groups that federate into district- or regional-level aggregators supplying processors and exporters. Evidence from Nepal indicates that cooperative-based value-chain interventions such as those for bay leaf and NTFPs—can substantially increase smallholder incomes (Shah et al., 2018). Establishing small drying units, cold storage facilities, and primary processing centers near production clusters helps capture value locally before products are exported to regional markets. Regional labeling (e.g., origin, organic, forest-friendly), simple quality standards, and shared market intelligence platforms (covering price trends and buyer information) reduce information gaps and enable producers to access higher-value markets.

Linking accredited nurseries with regional germplasm hubs, supported by SAC and ICIMOD, ensures the availability of high-quality seedlings for priority agroforestry species, thereby accelerating scale-up (SAARC Development Fund, n.d.). Mobile applications can facilitate orders, quality reporting, and traceability, meeting buyer requirements and enabling finance through mechanisms such as inventory-backed loans. Examples from CIFOR-ICRAF and ICIMOD illustrate the successful integration of ICT tools in agroforestry value chains (SAARC Development Fund, n.d.).

Conclusion, Recommendations and Way Forward

Conclusion

Agroforestry in Nepal plays a critical role in enhancing food and nutrition security, diversifying incomes, supplying fuelwood and fodder, improving soil fertility, and supporting biodiversity conservation. Traditional practices such as home gardens, boundary plantations, and integrated crop–livestock systems remain effective across the country's diverse ecological zones, from the Terai plains to the mid-hills and highlands.

Rural populations heavily rely on small-scale agriculture and livestock production, often on fragmented landholdings.

Nepal is increasingly exposed to climate-related challenges, including rising temperatures, erratic rainfall, glacier retreat, and more frequent extreme events such as floods, droughts, and landslides, negatively affected crop yields, livestock productivity, and water availability, disproportionately affecting vulnerable populations, including women, indigenous groups, and those in remote regions. Climate-induced economic losses already account for 1.5–2% of GDP, with potential long-term impacts on growth and development.

Agroforestry enhances resilience by integrating trees, crops, and livestock to provide food, fodder, timber, fuelwood, and ecosystem services such as carbon sequestration and soil fertility improvement. Projects such as Varaha ARR, RASFN, and AWABE II demonstrate that these systems increase farmers' incomes, strengthen climate adaptation, and foster social inclusion. Community-based and women-led initiatives, including Community-Based Tree Nurseries (CBTNs) like Kalapani CFUG and medicinal agroforestry nurseries in Bagmati Province.

Public–private partnerships (PPPs), such as those between Dabur–ICIMOD and Kawasoti Municipality, have enhanced technical support, market access, and collaborative resource management, aligning community, private, and government objectives for forest restoration and income generation.

National Agroforestry Policy (2019) provides legal recognition, strategic guidance, and alignment with climate adaptation strategies, carbon sequestration goals, and Sustainable Development Goals (SDGs). Its integration with the National Climate Change Policy and Nepal's Nationally Determined Contributions (NDCs) positions agroforestry as a key strategy for climate resilience.

Training programs, field demonstrations, and participatory learning approaches by Government agencies and private sectors have strengthened farmers' technical knowledge in nursery management, species selection,

contour hedgerows, and climate-smart agroforestry practices. Successful agroforestry models Integrating agroforestry into livelihoods, climate adaptation, and ecosystem management can significantly improve food security, income generation, social equity, and environmental sustainability in Nepal.

Growing domestic and regional demand for agroforestry products underscores the importance of strengthening value addition, processing, and aggregation. Policies, subsidies, concessional loans (e.g., from ADBL), and project-based funding support tree planting, nursery development, and agro-processing. Innovative financing mechanisms, including REDD+ and green bonds, provide opportunities for landscape-level expansion and carbon-based revenue generation.

Recommendations

Scaling Up Agroforestry

Promote integrated tree–crop–livestock systems to optimize land use, enhance resilience, and improve rural livelihoods. Expand extension services, training programs, and pilot demonstrations to accelerate adoption of improved agroforestry practices. Identify and promote region-specific tree species suitable for diverse ecological and livelihood contexts. Encourage commercial and improved agroforestry models alongside traditional home gardens. Promote agri-silviculture, agri-silvo-pastoral, alley cropping, and cash crop integration tailored to specific ecological zones. Expand urban and peri-urban agroforestry to maintain green spaces, biodiversity, and ecosystem services.

Livelihood and Socioeconomic Support

- Provide targeted support for smallholders, women, and marginalized groups through credit access, insurance schemes, and market linkages.
- Promote income diversification via timber, fruit, fodder, and non-timber forest products (NTFPs).
- Support climate risk management and community resilience through local capacity-building.
- Enhance women's participation and leadership in agroforestry enterprises.
- Integrate agroforestry into food security and nutrition programs and promote high-value crop integration for improved household income.
- Offer incentives for implementing sustainable agroforestry on marginal and degraded lands.

Infrastructure and Institutional Strengthening

- Improve rural infrastructure—roads, electricity, and market facilities—to facilitate agroforestry and climate-smart agriculture.
- Strengthen institutional coordination among government agencies to mainstream climate adaptation and agroforestry in development planning.
- Invest in early warning systems and disaster risk reduction mechanisms.
- Support farmer-managed and community-based nurseries for high-quality seedling production.
- Provide technical backstopping for species–site matching, nursery management, and distribution systems.

Research and Monitoring

- Conduct research on agroforestry systems, climate impacts, and adaptive management strategies.
- Establish monitoring frameworks for soil fertility, biodiversity, water resources, and climate trends to guide policies.
- Develop locally suitable species combinations and climate-resilient management practices.
- Implement multi-site species–site trials and develop a GIS-based decision-support tool (Which tree, where?).
- Create locally calibrated allometric equations and soil carbon protocols for robust agroforestry MRV systems.
- Integrate gender and equity analysis into all trials, including labor burden and benefit distribution studies.
- Establish long-term monitoring plots for soil, biodiversity, and hydrology.
- Launch landscape-scale restoration pilots for flood control, erosion reduction, and wildlife corridor creation.

Policy and Regulatory Measures

- Strengthen implementation and public awareness of the National Agroforestry Policy (2019).
- Simplify and streamline procedures for tree registration, harvesting, transport, and trade to attract private investment.
- Harmonize forestry and agriculture mandates to minimize institutional fragmentation.
- Clarify tree ownership rights on private and community-managed lands.
- Enhance policy coordination among ministries, research institutions, NGOs, and private sector actors.
- Support community forestry and agroforestry policies through effective enforcement and incentive mechanisms.

Education, Training, and Awareness

- Integrate agroforestry education into higher education, vocational training, and extension curricula.
- Develop tailored training modules and manuals for farmers, extension agents, and local facilitators.
- Conduct Training-of-Trainers (ToT) programs, farmer field schools, and participatory learning sessions.
- Promote awareness campaigns emphasizing agroforestry's environmental and economic benefits.
- Strengthen nursery accreditation systems and ensure quality seedling production.
- Establish regional training hubs and fellowship programs combining classroom and field learning.
- Deploy ICT and mobile tools for decision support, seedling registries, and market information sharing.
- Encourage collaboration among government, NGOs, universities, and research centers to share innovations.

Financial and Incentive Mechanisms

- Introduce credit products aligned with tree crop cycles, incorporating grace periods and blended finance instruments.
- Pilot Payments for Ecosystem Services (PES) and carbon credit programs targeted at smallholders.
- Support cooperatives and farmer groups for collective marketing and financial viability.
- Improve access to government subsidies, concessional loans, and project-based funding.
- Promote REDD+, PES, and green bond mechanisms for landscape-level and community-based agroforestry.
- Invest in post-harvest facilities, such as drying, grading, and cold storage, with digital traceability systems.
- Facilitate cross-border trade through harmonized standards, certification, and shared market intelligence.

Market and Value Chain Development

- Invest in processing, grading, certification, and branding infrastructure for agroforestry products.
- Strengthen producer cooperatives and establish direct market linkages at domestic and international levels.
- Promote high-value agroforestry commodities such as honey,

mushrooms, medicinal herbs, bamboo, and nuts.

- Establish aggregation centers and value-chain hubs for bamboo, fruits, fodder trees, and NTFPs.
- Develop quality standards and cold-chain facilities to access urban and export markets.

Gender and Social Inclusion

- Promote women-led enterprises through targeted training, financial support, and market access.
- Ensure equitable participation of women and marginalized groups in decision-making and benefit-sharing.

Strengthening Extension Services

- Expand coverage and frequency of training, field demonstrations, and farmer field schools.
- Equip extension agents with knowledge on site-specific agroforestry systems and climate-smart technologies.

Integrating Agroforestry into Urban Green Infrastructure

- Design urban green belts, corridors, and river buffer zones incorporating multi-purpose tree species.
- Engage urban communities in agroforestry initiatives to enhance climate resilience and ecosystem services.

Promoting Demonstration Models

- Highlight successful agroforestry systems such as cardamom-based, fodder tree-based, and CFUG-linked models.
- Facilitate knowledge exchange and replication across Nepal and the Hindu Kush–Himalaya region.

Regional Cooperation

- Strengthen partnerships with ICIMOD, CIFOR–ICRAF, and SAC for technical collaboration and cross-border learning.
- Expand the Seeds Without Borders initiative to include agroforestry species with standardized phytosanitary protocols.
- Develop regional nurseries and germplasm hubs to ensure seedling quality and genetic diversity.
- Standardize MRV, carbon accounting, and smallholder aggregation models regionally.
- Pilot regional value chains for fruits, NTFPs, and timber to enhance cross-

border trade and investment.

Way Forward

Policy Implementation and Governance

- Ensure the effective implementation of the *National Agroforestry Policy (2019)* and related climate adaptation strategies.
- Strengthen coordination among federal, provincial, and local governments for integrated agroforestry promotion.
- Align agroforestry initiatives with national strategies on climate change, land use, and agricultural development.
- Harmonize national policies (Agroforestry Policy, REDD+, and Green Bond frameworks) with local implementation plans.
- Facilitate multi-stakeholder partnerships among government agencies, NGOs, research institutions, and the private sector to scale up interventions.
- Integrate agroforestry modules into vocational training, CTEVT courses, and school curricula to institutionalize knowledge.

Institutional Strengthening

- Build the capacities of government agencies, research institutions, and local bodies to implement agroforestry programs effectively.
- Strengthen public–private partnerships (PPPs) to support the commercialization and scaling of agroforestry systems.
- Promote inter-institutional coordination between agriculture, forestry, and environment sectors to ensure policy coherence.

Community Engagement and Social Inclusion

- Strengthen participatory approaches in agroforestry planning and management to reflect local knowledge and priorities.
- Involve women, youth, and marginalized communities in planning, implementation, and benefit-sharing processes.
- Promote awareness campaigns highlighting the livelihood, nutritional, and environmental benefits of agroforestry.
- Foster community ownership to ensure long-term sustainability of local initiatives.

Investment, Finance, and Incentives

- Mobilize financial resources for agroforestry expansion, climate-resilient agriculture, and rural infrastructure development.
- Leverage climate finance, carbon markets, and blended financing

mechanisms (grants, loans, green bonds, REDD+) to reduce investment risk.

- Encourage public–private partnerships and project-based funding from national and international donors.
- Develop transparent monitoring, reporting, and verification (MRV) systems for ecosystem service and carbon payments.

Integrated Development Approach

- Link agroforestry with water management, livestock development, and rural livelihood improvement for holistic rural development.
- Incorporate climate risk reduction, ecosystem restoration, and social equity considerations into all planning and implementation processes.
- Encourage multifunctional systems such as agri-silvo-pastoral, alley cropping, and silvi-fishery models for productivity and resilience.

Research, Monitoring, and Innovation

- Establish national and provincial systems to monitor agroforestry adoption, productivity, ecosystem services, and socioeconomic impacts.
- Promote research on climate-resilient species combinations, market-oriented value chains, and innovative agroforestry models.
- Strengthen research–practice linkages through collaboration among universities, ICIMOD, LI-BIRD, Forest Action, and other partners.
- Facilitate regular knowledge exchange and replication of successful practices across provinces.

Capacity Building and Education

- Expand agroforestry education across universities, technical schools, and community training programs.
- Develop training manuals, demonstration plots, and farmer field schools to enhance technical knowledge and practical skills.
- Encourage continuous learning through digital platforms, community networks, and participatory extension services.
- Support ongoing programs like RASFN and EnLiFT to disseminate practical innovations and success stories.

Market-Oriented Agroforestry

- Strengthen value chains for high-value agroforestry products such as bamboo, medicinal plants, honey, fruits, and NTFPs.
- Invest in processing, packaging, and marketing infrastructure to increase farmer income and competitiveness.
- Promote entrepreneurship and cooperative-based enterprises for income

diversification and job creation.

Agroforestry Across Land Use Categories

- Agricultural Land: Promote agri-silviculture, alley cropping, and agri-silvo-pastoral systems to enhance productivity and soil fertility—especially in the Terai and mid-hill regions.
- Forest Land: Support community forestry and forest-based agroforestry (e.g., Taungya system) to conserve forests while improving livelihoods.
- Peri-Urban Areas: Integrate urban agroforestry and green corridors into city planning to strengthen urban resilience and ecosystem services.

Ecosystem Services and Environmental Benefits

- Recognize agroforestry as a key contributor to ecosystem services, including soil and water conservation, carbon sequestration, biodiversity conservation, and landscape restoration.
- Promote the integration of agroforestry in wetland and watershed management to enhance environmental and economic outcomes.

Scaling and Replication

- Expand community-based nurseries, cooperatives, and agroforestry enterprises across districts.
- Scale up proven models through multi-stakeholder collaboration, policy incentives, and knowledge-sharing platforms.
- Encourage adaptive management using evidence from pilot projects and research findings.

Way Forward / Strategic Roadmap

Details Way Forward is listed in table below

Phase	Key Actions	Responsible/Partners
Year 0–1: Setup	National research agenda, MRV gap analysis, selection of demo sites, policy audit	MOALD, MoFE, NARC, AFU, ICIMOD, CIFOR-ICRAF, SAC
Year 1–3: Pilots & Training	Multi-site species trials, MRV pilot & allometries, nursery accreditation pilots, regional fellowships, digital decision tools	AFU/IOF, NARC, SAC, CIFOR-ICRAF
Year 3–5: Scale & Finance	Evidence-based scaling, link to carbon/green finance, support market access via co-ops, expand regional seedling hubs, operationalize value-	MOALD, NARC, SAC, SDF, BIMSTEC, ICIMOD, CIFOR-ICRAF

Phase	Key Actions	Responsible/Partners
	chain pilots	
Cross-cutting	Capacity building at all levels, ICT-enabled monitoring, policy harmonization, continuous evaluation & adaptation	National + regional partners, NGOs, private sector

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Chapter 5

Role of Agroforestry in Improvement of Rural Livelihood and Build Climate Resilient Communities in Pakistan

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Background

Pakistan is geographically located in 30.3753°N and 69.3451°E with a total area of 796,000 Km^2 stretch from Hindukush Himalaya in the north and coastline of the Arabian Sea and the Gulf of Oman in the south. Encompassing a wide array of landscape varies from the coastal areas of the south to the lofty mountains of the north plain. The climate varies from tropical to temperate, with arid conditions in the coastal south. June is the hottest month on the plains and July in the mountainous areas, with a mean monthly maximum temperature over 38°C, while the mean monthly minimum is only 2.5°C in January. The average annual precipitation ranges from 100 mm in the Central zone to more than 1250 mm in the Himalayan foothills.

Out of the total 79.6 mha area, 22.74 mha is under cultivation, 80% of total agriculture area is under irrigated agriculture and the rest is rainfed. Forest Forests cover 3.92 mha making 4.92% of the total area, whereas, while 10.28% of the total area (8.19 mha) stands as cultivable waste land (PBS, 2020). More than 70% of Pakistan's land being arid or semi-arid, agriculture relies heavily on access to irrigation (Farooq, Ahmad and Jasra 2007) and 90 percent of agricultural production is supplied by irrigated land (Yu, et al., 2013).

Forestry is one of the most important land use systems in the country and source of ecotourism, wildlife conservation, and source of timber, fuel wood, paper, medicine and food. Consequent upon arid to semi-arid climate, Pakistan has forest cover of less than 5.71% (Table 1).

Table 1. Total Forest area of Pakistan in comparison to Asia and World Forest cover

Parameter	Pakistan	South Asia	Asia	World
Total forest area	3726	897906	622687	4058931
Natural forest	1381	42013	431946	3774805.8
Plantation forst	980	34652	115847	284125.2
% Forest land	~4.8%	~18.82	~22.6	~31,8

FAO, 2000; 2022

Different types of forest found in Pakistan are (i) *Conferous forest*: These forests are located at high altitude and rich of Deodar (*Cedrus deodara*), pindrow fir (*Abies pindrow*), Chir pine (*Pinus roxburghii*), morinda spruce (*Picea smithiana*), and blue pine (*Pinus wallichiana*), juniper (*Juniperous macropoda*) and chilghosa pine (*Pinus geradiana*) at Dir, Malakand, Swatm Mansehra, and parts of Baluchistan province (ii) *Sub-tropical Dry Forests:* These forest are rich of Phulai (*Acacia modesta*), hopbush (*Dodonaea viscosa*), and kau (*Olea cuspidata*) are other dominant species included in sub-tropical dry forests at altitude up to a height of 1,000 m. In Punjab, they are present in Attock, Gujrat, Islamabad, Jhelum, Rawalpindi and Abbottabad, Peshawar, Mardan, Mansehra, and Kohat districts of Khyber Pakhtunkhwa (KP). While in Balochistan, they are widely found in the Sulaiman Mountains and some other hilly areas (iii) *Tropical Thorn Forests*: The forests are characterized by xerophytic scrubs and widely distributed in the plains of Punjab province and confined to some parts in the southern and western regions of Sindh and Balochistan, respectively. Common species included in these forests are kair (*Capparis aphylla*), vann (*Salvadora oleoides*), and khejri (*Prosopis cineraria*) and mostly grazed by animals, used as fuel wood, and in protecting the watershed. iv) *Irrigated Plantation*: With the current forest cover of about 226,000 ha, this forest was first planted in 1866 at Changa Manga, Lahore. Main tree species in this forest area include *eucalyptus, populus, shisham, babul and mulberry/sha*htoot v) *Rivarian Forests:* These forests are common in Sindh and Punjab provinces alongside the Indus River. *Babul, khejri, shisham (Dalbergia sissoo), Populus euphratica, and Tamarax dioica* are common species of the forests mainly used as timber wood vi) *Mangrove Wetlands*: Saltwater wetlands found in the delta of the Indus River and the coastal area of Balochistan, and rich of *Avicennia marina, bamboo and Marsh grasses like apluda and Cenchrus* (Figure 1).

Figure 1. Forest types in Pakistan

Major agroecological zone are (i) Indus Delta having arid tropical and adequate hot summer and warm winter with 75 mm average summer and <5 mm winter rainfall (ii) Southern irrigated plain characterized by arid subtropical and continental climate with 16-20 mm rain during summer low rain in winter (iii) Sandy Desert having arid subtropical with avaerge rain of 32 mm in North to 46 mm in the South (iv) Northern Irrigated plains are

characterized by semi-arid subtropical continental climate with average annual rainfall between 300-500 mm (v) Barani Lands experienced semi-arid with hot summers and cold winter with a short dry season in early summer. Rainfall ranges from 200 mm in summer and 36-50 mm in winter (vi) Wet ountains have humid, mild summer and cold winter. Average monthly rainfall varies from 236 mm in summer to 116 mm in winter (vii) Northern Dry Mountain are covered by snow. With daily temperature fluctuating between 1-7 °C and average monthly rainfall varies from 25-75 mm in winter and 50-100 mm in spring (viii) Western Dry Mountains have semi-arid highlands with mid-summer and cold winter and limited winter snowfall, 15-95 mm rainfall in the northern part, dry Western Plateau have arid tropical climate with persistent dry season and inadequate rainfall (ix)Sulaiman Piedmont has sub-tropical continental climate with arid and hot conditions with 13 mm winter rainfall and 21-38 mm summer rainfall.

Rural and Socio-Economic Profile of the Country

According to 7th population census (2023), population of Pakistan is 241.5 million comprising 51.4% male and about 48.50% females, over 60% population is living in rural areas. Rural areas are hit by substantial poverty as 4 out of 5 poor living there. The least contribution of agriculture sector to alleviate rural poverty can be ascribed to low farm productivity, and commercialization of agriculture sector in the country.

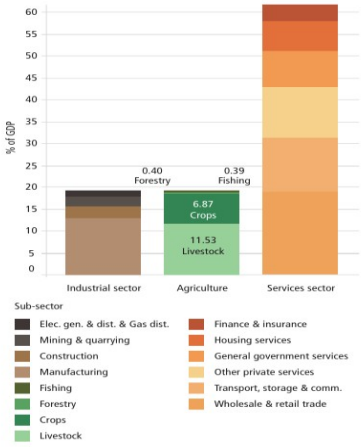

Figure 2. Contribution of various sectors to GDP

Land ownership is highly skewed, with many rural households being landless, impacting their access to credit and resources.

Rural-Urban migration and overseas shifting are also dominant demographic features. According to Pakistan Demographic and Health Survey (PDHS) 2017-18, half of out-migrants (52%) migrated to cities, 29% moved abroad, and 19% migrated to a rural area within Pakistan.

Pakistan's agriculture sector continues to play a pivotal role in economic resilience and rural livelihood, contributing 23.5 percent to GDP and employing over 37 percent of the labour force. Agriculture sector recorded growth of 0.56 percent, primarily led by a 4.72 percent rise in livestock, sub-sectors include fisheries and forestry, which grew by 1.42 percent and 3.03 percent, respectively (PBS, 2025).

Agriculture though has a low contribution to overall GDP, but remained a major contributor of rural livelihoods and food security (Figure 2; Economic survey, 2021-22).

Climate change challenges

Pakistan faces significant climate change challenges and stands as a stark example of escalating climate risks. In 2022, the country suffered the world's costliest flood in history, exacerbated by record-breaking monsoon rainfall and GLOFs from June–September 2022, affecting more than 33 million people including more than 1,700 fatalities, and US$ 15 billion damage. The floods, presumably caused by climate change and amplified by extreme monsoon rainfall increase by 243 percent (PMD, 2022), followed a lethal heatwave with temperatures reaching 49.5°C (Climate Index, 2025). Thus, the country faces a deepening climate emergency, due to heatwaves and glaciers bursting, drought and water scarcity. Pakistan ranks 8th most vulnerable country on climate risk index 2021. Pakistan is predominantly arid to semi-arid with significant spatial and temporal variability in climate parameters: scarcity of water due to shriking precipitation, ever increasing melting of glaciers, and heat waves. The country classified as 3rd most water stress country in 2024, would likely to influence the agriculture sector, a predominetly irrigated agriculture. Other issues like salinization, sodification and other climate change induced challenges are major issues. Thus, Pakistan is bearing catastrophic climate impacts although most of the greenhouse gas emissions are from large, industrialized countries.

Agroforestry sector in Pakistan

Agroforestry is an important sector in Pakistan and plays a vital role in enhancing agricultural productivity, conserving natural resources, and improving rural livelihoods. With nearly 80% of the population directly or indirectly dependent on agriculture, agroforestry provides a sustainable land-use system by integrating trees, crops, and livestock. In addition to meeting household fuelwood and timber needs, agroforestry contributes significantly to soil fertility improvement, biodiversity conservation, carbon sequestration, and climate change adaptation.

Prominent Agroforestry Systems in Pakistan

Pakistan has following dominant agroforestry system:

Farm-Based Tree Plantations (Agri-silviculture)

This is the most widespread form of agroforestry in Pakistan, particularly in the irrigated plains. Farmers integrate trees into their agricultural fields, along canals, and on field boundaries. This system is primarily agri-silvicultural, combining crops like wheat, cotton, or fodder with trees. The most common

tree species include Shisham (*Indian Rosewood*), Kikar (*Acacia nilotica*), Poplar, and Eucalyptus. These trees provide timber, fuelwood, fodder, and help in water table regulation. The income from timber sales, particularly from fast-growing species like Poplar, serves as a "living bank" for farmers, providing a significant financial cushion. Studies indicate that tree-based farming can reduce soil erosion by up to 30% while increasing organic matter and water retention, particularly in rain-fed areas of Punjab and Khyber Pakhtunkhwa (Figure 3).

Agro-pastoralism integrates trees with livestock grazing systems, providing fodder and shade, particularly in arid regions like Baluchistan and Sindh, where over 60% of rural communities depend on livestock as a primary source of income.

Figure 3. Agri Silviculture system

Silvo-Pastoral Systems

Silvopasture, which incorporates trees into grazing lands, enhances biodiversity and livestock health by providing shelter from extreme weather conditions. Research suggests that well-managed silvopastoral systems can increase milk yields by 10–15% due to improved animal welfare and nutrition. These systems are crucial in the rangelands of Balochistan, KPK, and the Potohar plateau. Trees and shrubs are maintained or planted to provide shade for livestock, reduce wind erosion, and produce fodder, especially during lean periods. Key species include Kikar, Phulai (*Acacia modesta*) and Jujube (*Beri*). The integration of cactus as a climate-resilient forage is being promoted in arid regions of Balochistan, providing vital moisture and nutrients for livestock during droughts. These systems are essential for sustaining the livelihoods of pastoral communities (Figure 4).

Figure 4. Agri Pastoral system

Forest Farming

Forest farming supports the cultivation of high-value crops such as medicinal plants, spices, and honey under tree canopies, creating alternative income sources. Pakistan's agroforestry sector contributes nearly 2% to the national GDP, with timber, fuelwood, and fruit production generating substantial revenue.

Riverine and Farm Forestry

The forests along the Indus River and its tributaries are a unique ecosystem where natural tree stands and agricultural practices often intermingle. Additionally, government-led block plantations of fast-growing hybrid species like Poplar and Eucalyptus have been established on state land to meet wood demand and control waterlogging. Shelterbelt technology (Figure 5), involving rows of trees planted as windbreaks, is used to protect farmland from wind erosion and sand dune movement, particularly in the Thar desert and other sandy areas.

Figure 5. Agri Pastoral system

Mountain and Terrace Agroforestry

In the northern mountainous regions (e.g., Gilgit-Baltistan, KP), traditional agroforestry is practiced on terraced farms. Farmers integrate fruit trees such as apricots, apple, walnut, and mulberry with seasonal vegetables and fodder crops. This agroforestry integration helps stabilize the terraced slopes, improves soil health, and provides a diversified income from both fruit and crop harvests (Figure 6).

Figure 6. Mountain and Terrace Agroforestry

Ecosystem Services Deliverables

Agroforestry systems in Pakistan provide critical environmental benefits. By integrating trees, these systems significantly enhance soil and water conservation. Practices like Sloping Agricultural Land Technology (SALT) using contour hedgerows stabilize soil on slopes, reduce runoff, and improve fertility. The presence of deep-rooted trees improves soil structure, boosts organic matter through leaf litter, and aids in groundwater recharge. Agroforestry also plays a crucial role in carbon sequestration, capturing atmospheric carbon in biomass and soil, thereby contributing to climate change mitigation. Systems like mangrove plantation in the Indus Delta not only sequester large amounts of "blue carbon" but also protect coastlines from erosion and storms, while serving as nurseries for fish. By providing fuelwood and fodder from farmland, agroforestry alleviates pressure on the remaining natural forests.

Details of ecosystem services are given below:

Environmental Benefits

Biodiversity conservation is another critical benefit, as tree-based farming systems provide habitats for pollinators, birds, and pest-controlling species, reducing reliance on chemical pesticides. Research suggests that diversified farms with agroforestry elements support up to 50% more beneficial insect populations compared to monoculture systems. Additionally, trees in farmland act as windbreaks, protecting crops from extreme weather conditions.

Water conservation is particularly crucial for Pakistan’s arid and semi-arid regions, where agroforestry enhances groundwater recharge and regulates soil moisture. Tree roots improve water infiltration and reduce surface runoff, mitigating the risks of drought and soil degradation. Studies show that

agroforestry can improve water-use efficiency by 10–30%, making it an effective strategy for sustainable water management.

In arid regions like Tharparkar and Cholistan, incorporating native trees like *Propopis cineraria* (jand), *and Acacia nilotical* (babul) support livestock, improve soil organic matter, and reduce land degradation (IUCN Pakistan, 2023).

Agroforestry also contributes to climate resilience by sequestering atmospheric carbon dioxide and reducing greenhouse gas emissions. Estimates suggest that agroforestry systems in Pakistan have the potential to sequester up to 1.5 tons of carbon per hectare annually. By providing diversified income sources and stabilizing farm productivity, agroforestry reduces the vulnerability of smallholder farmers to climate shocks, making it a key solution for sustainable agriculture.

Economic Contributions

Agroforestry significantly contributes to rural economic development by creating multiple revenue streams, generating employment, and enhancing market integration. Farmers engaged in agroforestry benefit from diversified income sources, including timber, fuelwood, fodder, fruits, nuts, and medicinal plants. This reduces their dependence on single-crop farming and enhances financial resilience against market fluctuations. In Pakistan, agroforestry contributes substantially to the rural economy, with farm-based tree plantations generating an estimated PKR 100 billion annually through wood and non-wood products.

Agroforestry results in long-term economic gain. According to Pakistan Agricultural Research Council reports a 4-acre agroforestry plot has a benefit-cot ratio (BCR) 2.1, substantially higher than 1.3 in case of monoculture.

The employment generation is another key economic advantage. Agroforestry creates job opportunities in tree planting, nursery management, harvesting, processing, and value-added industries. According to estimates, the agroforestry sector in Pakistan provides direct and indirect employment to over 1.5 million people. The demand for skilled labor in nursery operations and agro-processing continues to grow, supporting rural livelihoods and reducing migration to urban centers.

Market integration further strengthens the economic viability of agroforestry. Value-added products such as honey, essential oils, and medicinal extracts improve profitability for small-scale farmers. Beekeeping integrated within agroforestry systems has shown promising results, with honey production increasing by 30–40% in regions where trees like Acacia and Ber (*Ziziphus mauritiana*) are cultivated. Additionally, essential oils extracted from agroforestry species such as eucalyptus and lemongrass have growing

demand in domestic and international markets. Strengthening supply chains and providing market access for agroforestry products can significantly boost rural income and contribute to Pakistan's sustainable agricultural development.

Agroforestry in the National Education Curriculum

Knowledge of agroforestry in Pakistan has traditionally been passed down through generations. However, it is not a core subject in the primary or secondary school curriculum (e.g., up to Matric or Intermediate level). Its formal teaching is primarily confined to the university level, where it is offered as a specialization or specific course within degree programs in forestry, agriculture, and environmental sciences at universities. There is a strategic need to incorporate basic concepts of agroforestry, soil conservation, and climate-resilient agriculture into the national curriculum at an early stage. This would foster a sustainability mindset and equip the next generation with the knowledge to manage integrated, resilient land-use systems.

Business Model in Agroforestry

Agroforesty provides diverse business models for rural upleft. Some of the main business models are summarized as below

Nursery Enterprises

The demand for certified plants and high-quality seedlings of timber, fruit, and fodder species creates a significant opportunity for nursery establishment. This can be a sustainable micro-enterprise for rural families, farmer cooperatives, and NGOs. Upgrading small-scale nurseries with modern technologies like poly-tunnels and drip irrigation can enhance their profitability and sustainability.

Public-Private Partnerships (PPPs)

PPPs are emerging as a key driver for scaling agroforestry. For example, paper and pulp industries (e.g., Century Paper) partner with farmers to promote block plantations of fast-growing species to secure their raw material. Corporate entities are also increasingly engaging in mangrove plantation projects in the Indus Delta as part of their Corporate Social Responsibility (CSR) and carbon offsetting initiatives.

Value Chain Development

- Honey Production: Beekeeping in agroforestry landscapes, especially those with flowering trees like Kikar and fruit orchards.
- Medicinal Herbs: Cultivating high-value medicinal plants under the shade of trees.
- Fodder Production: Commercial hay production from systems integrating Rhodes grass or other fodder species.

- Fruit and Nuts: Developing value-added products from fruits grown in mountain and farm agroforestry systems (e.g., apricot jam, walnut oil).
- Community based tree nurseries
- Public private partnership
- Agroforestry based value chain (honeybee, mushrooms, medicinal herbs, nuts)
- Ecotourism-bamboo village etc.

The business model in agroforestry is diverse and community-centric, focusing on sustainable development and economic growth.

Community Based Tree Nurseries

Community-based tree nurseries are vital components of agroforestry business models, empowering local communities to produce and manage seedlings for reforestation, agroforestry, and conservation efforts. These nurseries provide affordable, high-quality planting materials adapted to local ecological conditions. By involving community members in nursery management, they create job opportunities, foster local ownership, and encourage sustainable land use practices. For example, in Nepal and Kenya, community nurseries have successfully supplied seedlings of native tree species and agroforestry trees, contributing to forest restoration and income generation through seedling sales.

Public Private Partnership

Public-private partnerships in agroforestry combine resources and expertise from government bodies, private companies, NGOs, and local communities to scale up agroforestry projects efficiently. Governments may provide policy support, technical assistance, and infrastructure, while private partners contribute investment capital, market access, and innovation. This collaboration reduces risks and enhances the sustainability of agroforestry ventures. An example is the partnership between private honey producers and government forestry departments in countries like Ethiopia, which supports sustainable honey production linked to agroforestry landscapes, improving livelihoods and conserving forest ecosystems.

Agroforestry based value chain

Agroforestry value chains integrate diverse products (honeybee, mushrooms, medicinal herbs, nuts) that enhance the economic viability of farming systems. Honeybee farming, for instance, benefits from the floral diversity of agroforestry systems, producing high-quality honey while aiding pollination. Mushroom cultivation can utilize agroforestry residues, such as tree bark and leaf litter, turning waste into income. Medicinal herbs grown under tree canopies offer valuable products for traditional medicine and global markets.

Nut trees like cashew or chestnut add long-term income sources through harvests that complement annual crops. Countries like India have developed successful agroforestry value chains for turmeric (medicinal herb) and honey, connecting farmers to markets and increasing profitability.

Ecotourism-bamboo village concept

Ecotourism initiatives in agroforestry, such as bamboo villages, combine environmental conservation with cultural and economic benefits. Bamboo villages are designed around the sustainable cultivation and utilization of bamboo, showcasing eco-friendly construction, handicrafts, and agroforestry practices. Visitors experience local traditions, learn about sustainable forestry, and contribute to the local economy through tourism spending. For example, in China and parts of Southeast Asia, bamboo villages attract tourists interested in nature and culture, generating income for rural communities while promoting the conservation of bamboo forests and associated biodiversity.

Barriers and Strategic Pathways

The Agroforestry development in Pakistan is hampererd by several challenges related to technical, capacity building and knowledge gaps, land tenure, finance and market access.

Agroforestry faces multiple challenges that hinder its widespread adoption and effectiveness. Technical challenges include selecting appropriate tree species, managing tree-crop interactions, and addressing pest and disease control within complex systems. Land tenure insecurity is a critical barrier—when farmers lack clear ownership or long-term rights to their land, they are less likely to invest in long-term agroforestry practices. Financial constraints limit farmers' ability to purchase seedlings, inputs, or tools necessary for agroforestry development. Additionally, many farmers struggle with insufficient knowledge and skills to manage agroforestry systems effectively. Market access also poses a challenge; without reliable buyers or value chains for agroforestry products such as timber, fruits, or honey, farmers cannot generate steady income, reducing motivation to adopt these practices.

Farmer hesitation, mindset

A significant barrier to agroforestry adoption is the hesitation among farmers, often rooted in mindset and cultural norms. Many farmers are accustomed to conventional monoculture farming and may perceive agroforestry as risky or labour-intensive with delayed returns. The uncertainty about the benefits of integrating trees with crops or livestock can lead to resistance. Some farmers may fear losing valuable agricultural land to trees or worry about negative impacts on crop yields. Changing deeply ingrained farming habits and scepticism requires effective awareness campaigns, demonstration sites, and

trust-building measures to showcase the tangible benefits of agroforestry.

Lack of skills and knowledge

The lack of technical knowledge and practical skills is a major constraint for farmers interested in agroforestry. Many smallholder farmers have limited access to training on tree selection, nursery management, planting techniques, and integrated pest management. Extension services may be weak or unavailable, especially in remote areas, leaving farmers without the support needed to implement agroforestry successfully. Furthermore, knowledge gaps exist in post-harvest processing, value addition, and marketing of agroforestry products. Addressing this barrier requires comprehensive capacity-building programs, farmer-to-farmer learning platforms, and the involvement of local institutions to provide ongoing technical assistance.

Enabling Frameworks and Initiatives

- National Agroforestry policy and action plan
- Sectoral linkages of Agroforestry with national climate policy etc.

The successful promotion and scaling of agroforestry depend significantly on supportive enabling frameworks and initiatives at the national level.

National agroforestry policy and action plan

At present in the Pakistan lacks agroforestry policy and however initial work and action plan has been completed in this direction. The successful promotion and scaling of agroforestry depend significantly on supportive enabling frameworks and initiatives at the national level. A National Agroforestry Policy and Action Plan provide a clear and structured roadmap to mainstream agroforestry as a sustainable land-use practice. This policy typically includes provisions for legal recognition of agroforestry systems, secure land tenure for farmers, access to quality inputs and financial services, capacity building, and research and development support. It also emphasizes institutional coordination and monitoring mechanisms to ensure effective implementation.

Sectoral linkages of agroforestry with national climate policy

Agroforestry is strongly linked with the national climate policy**,** as it contributes to multiple sectors including forestry, agriculture, environment, and energy. Agroforestry aligns with the country's Nationally Determined Contributions (NDCs) under the Paris Agreement by serving as a climate mitigation and adaptation strategy—enhancing carbon sequestration, improving soil health, and increasing resilience to climate change. Through integration with national climate frameworks, agroforestry also supports ecosystem restoration goals, watershed protection, and sustainable

livelihoods, making it a vital component in the transition toward climate-smart and nature-based solutions.

These challenges can be seummazed as absence of standalone national agroforestry policy leading to uncoordinated activities across ministries: agriculture, climate change, and provincial forest departments, unequal and insecure land tenure, particularly for tenant farmers, discourages long-term investments in tree planting. Abiotic strees like water scarcity and other climate change impacts, lack of acees to market due to weak value chains, lack of storage facilities, and price volatility limit profitability and limited technical Knowledge and awareness. All these challenges constraints the development of agroforestry sector in Pakistan.

Strategic Pathways

To cope with these challenges following strategic pathways are proposed

- Develop a National Agroforestry Policy to provide a coherent framework.
- Promote carbon sequestration techniques like reduced tillage and organic composting to access carbon financing.
- Strengthen extension services and provide training programmes for farmers and officers on sustainable agroforestry models.
- Facilitate access to financial support and certified plants.
- Promote joint market development for agroforestry products.

Strategic Needs

To promote agroforesty sector in Pakistan following strategic actions are needed to be taken

- Bridging research and capacity gaps
- Enhanving regional cooperation and GESI
- Exchange of seed and seedling materials
- Developing regional agroforestry strategy
- Joint Market Development and Finance

Bridging research and capacity gaps

Key research gaps in agroforestry systems include the need for more comprehensive socio-economic data and analyses, better-designed and standardized biophysical and environmental quality research, improved understanding of human-environment interactions for climate-smart agroforestry systems (CSAF), and the development of enabling policy, legal, and institutional frameworks to support wider adoption and scaling-up of agroforestry practices. Bridging the gap between knowledge and action is crucial, requiring robust public-private partnerships and the integration of

knowledge into practical, locally appropriate solutions. Research and capacity building involves enhancing the skills, resources, and infrastructure of individuals, organizations, and systems to improve their ability to conduct and sustain high-quality research for societal benefit. It operates on multiple levels—individual (training), organizational (funding and management), and environmental (policies and resources) to foster a robust research ecosystem that can address complex problems and contribute to economic and social development.

Provision of advisory and technical services to farmers

Providing advisory and technical services is essential to empower farmers with the knowledge and skills needed for successful agroforestry implementation. These services include guidance on selecting suitable tree species, nursery management, planting techniques, pest and disease control, and sustainable land management practices. Technical support helps farmers optimize productivity and improve system resilience. Advisory services often come through extension officers, NGOs, or specialized agroforestry experts who can offer tailored solutions based on local ecological and socio-economic conditions, ensuring that farmers can make informed decisions and overcome technical challenges effectively.

Financial support to farmers/growers

Projects are the only option as financial support to community to develop various agroforestry practices on their land to improve their livelihood. Access to financial resources is critical for farmers to invest in agroforestry, which often requires upfront costs for seedlings, tools, labour, and maintenance before benefits are realized. Financial support can come in various forms such as grants, low-interest loans, subsidies, or input vouchers. Microfinance institutions and cooperative societies can also play a role by providing flexible credit tailored to smallholder needs. By easing financial constraints, these support mechanisms enable farmers to adopt agroforestry practices with greater confidence and reduce the risk associated with long-term investments.

Enhancing regional cooperation and GESI

Regional cooperation and GESI (Gender Equity and Social Inclusion) are intertwined because regional integration projects, such as ADB's in South Asia, are increasingly incorporating GESI principles to ensure that growth benefits all groups and individuals. Regional cooperation benefits from GESI by creating more inclusive economic opportunities, and GESI is more effective when supported by regional frameworks that share knowledge, resources, and address systemic barriers for marginalized communities.

Exchange of seed and seedling materials

The exchange of seed and seedling materials involves the sharing of seeds and young plants, most commonly at seed swaps or fairs, where gardeners and farmers trade seeds, plants, and bulbs to share genetic diversity, discover new varieties, and promote local seed saving. This practice supports food security, helps reduce seed costs, and fosters a community among growers by sharing cultivation knowledge.

Developing regional agroforestry strategy

A regional agroforestry strategy is a coordinated plan for a specific geographical area that integrates trees into farming systems to promote sustainable land use, increase food security, and enhance environmental benefits, such as improved soil health and biodiversity. These strategies often involve policy reforms, stakeholder engagement, market development for tree products, and the implementation of appropriate technologies to address local challenges like climate change, poverty, and degraded land.

Joint Market Development and Finance

Joint Market Development and Finance" refers to collaborative financial and strategic initiatives between two or more entities to expand a market, often involving shared funding and marketing efforts, such as joint ventures (JVs), joint development agreements (JDAs), and market development funds (MDFs). These strategies aim to increase brand visibility, reach new customers, and drive sales through shared resources and marketing campaigns

Conclusion, Recommendations, and Way Forward

Agroforestry in Pakistan holds transformative potential for building climate-resilient, productive, and sustainable land-use systems. To unlock this potential, a multi-pronged strategy is essential:

1. Policy and Institutional Integration: Enact a National Agroforestry Policy and integrate agroforestry into national climate strategies (e.g., National Adaptation Plan).
2. Capacity Building and Technology Transfer: Scale up training for farmers and extension agents on proven techniques like SALT, silvo-pastoral systems, and water-efficient practices. Promote the use of certified plants.
3. Market-Led Development: Strengthen value chains for timber, fodder, fruits, and non-timber forest products. Develop business models around hay production and nursery enterprises.
4. Climate Finance and Incentives: Develop mechanisms to provide incentives for ecosystem services, such as payments for carbon sequestration through mangrove and block plantations.

5. Research and Collaboration: Foster public-private partnerships and international collaboration to pilot, refine, and scale successful agroforestry models across Pakistan's diverse agro-ecological zones.

By strategically investing in agroforestry, Pakistan can simultaneously address its challenges of food security, environmental degradation, and rural poverty, paving the way for a greener and more prosperous future.

Economic Gain and Climate Resilience through Agroforestry

Agroforestry is a transformative economic model to ensure financial return and ecological services in Pakistan. Integration of trees with annual crops and livestock, farmers diversify income sources such as vegetable and cereals crop as short term, fruit-bearing and fodder as medium-term, while timber and medical tress species as long- term return. In comparison to monoculture system, practicing agroforestry can contribute 25-40% more income to small farmers (FAO, 2023). Besides economic return, agroforestry enhances land-use efficiency by up to 80% and reduce reliance on chemical fertilizers by up to 40% particularly planting nitrogen-fixing species like *Leucaena leucocephala.*

In site specific context, traditional agroforestry model comprises native trees like *proscopis cineraria* (jand), and Acacia nilotica (babul) in Tharparkar and Cholistan areas, on only support livestock feed, but also improve soil organic matter contents, and reduce land degradation (IUCN, Pakistan, 2023). A study by Pakistan Agricultural Research council showed that a 4- acre agroforestry plot has a benefit-cost ratio (BCR) of 2.1, substantially higher than 1.3 for monoculture.

Besides economic return agroforestry is the most potential system to cope with climate change challenges. Pakistan as frontline and among top ten climate vulnerable country in the world is most exposed to climate shocks like growing heatwaves, and temperatures, torrential rainfall and cloud burst induced flood, and landsliding, and recurring drought and land degradation. Global Climate Risk Index (2023) reported that 2022, and 2023 severe flood cost Pakistan as much as $30 billion loss and resulted in mass human displacement. Agroforestry is the most effective sector to counter these challenges through preventing soil erosion by up to 70%, enhancing water infiltration by 30%, and storing 35-50 tons of Carbon/ha land (ICIMOD, CIFOR, and World Agroforestry center, 2023). Through carbon sink and can storing significant amounts of CO_2 in biomass and soils (Handa, et al., 2020) and can sequester up to 2.2 Pg C by 2050 at global level (Murphy, et al., 2025). Remote sensing data

estimated that tree cover contributed at least 75% of the 45.3 GtC on agricultural lands in 2010 (SOFO 2022). In this way agroforestry can be instrumental in climate change mitigation and adaptation.

Practices typology of Agroforestry:

Agroforestry in Pakistan includes practices such as growing fodder and cereal crops with fruit orchards, poplar and bamboo along canals and farm boundaries, scattered trees like Acacia nilotica for multipurpose use, fruit and walnut trees in mountainous regions, date palms in desert areas, and home gardens with medicinal plants. These systems are categorized as boundary, bund, scattered, Agri-horticulture, and Agri-horticulture-cum-horticulture systems, providing benefits like increased biomass, carbon stock, and soil health while reducing erosion and providing diverse income streams for farmers. The most important crops are wheat, sugarcane, cotton, and rice, which together account for nearly more than 75% of the value of total crop output. Pakistan's largest food crop is wheat. There are four types of agriculture are Pastoralism, Shifting Cultivation, Subsistence Farming, and Intensive Farming. The most profitable farming in Pakistan includes high-demand crops like tea, saffron, cannabis, sugarcane, and certain vegetables such as onions and avocados. Livestock farming, particularly poultry and dairy, and fish farming (aquaculture) are also highly lucrative. Modern agricultural techniques like greenhouse farming, hydroponics, and organic farming are also showing significant profit potential.

Agroforestry practices linked to dominant land use categories (agriculture, forest, or peri urban)

In Pakistan, agroforestry practices are linked to different land use categories: they are most prominent in agricultural lands where farmers integrate trees with crops and livestock for income, fodder, and soil conservation. In peri-urban areas, agroforestry is gaining traction for improving urban food security and providing ecosystem services, though faced with land tenure and policy integration challenges. In forest zones, particularly in arid areas like the Thal desert, agroforestry helps stabilize incomes and provides essential resources like firewood and timber, demonstrating a practical application of blending trees with land use.

Promoting Agroforestry at School level education/National curricula

Agroforestry content is largely lacking in high school agriculture science classrooms, despite its relevance to modern advancements in agricultural sustainability for economic, environmental, and social resilience. Due to the contextual nature of content adoption by agricultural educators, the curriculum implementation process for novel content is dependent on an understanding of teacher learning, teacher self-efficacy, professional

development, and curriculum modification. This collective case study of agroforestry professional development for and content adoption among participating Missouri high school agricultural educators provides insight into the potential for the integration of agroforestry content in high school agriculture programs using a mixed methods approach. While substantial growth in expected classroom hours dedicated to agroforestry resulted from these professional development events, identified complexities of the teacher and student learning context necessitate alternative approaches to engage teachers and students in previously unfamiliar agroforestry content. The importance of teacher-learning support networks and experiential learning in curriculum and professional development emerged as major themes for effective agroforestry content implementation.

Developing education and training materials:

Developing agroforestry training materials involves creating content based on a defined curriculum that addresses the specific needs of trainees, such as farmers, students, or development workers. Key steps include forming networks of institutions to share information, collaborating with subject matter specialists to generate and adapt knowledge, and utilizing participatory methods to ensure materials meet specific job requirements. The materials should cover agroforestry principles, practices, and their benefits, and may include various formats like publications, audio-visual resources, and practical tools, with a strong focus on adapting existing materials to local contexts and training trainers to maximize outreach.

National Agroforestry Day

There is no record of a designated National Agroforestry Day in Pakistan; however, the country actively promotes agroforestry due to its arid climate and high dependence on agriculture. Agroforestry integrates trees into farming systems to improve soil and water management, provide sustainable food and fuel resources, enhance farm income, and build resilience against climate change, all of which are critical for Pakistan's economy and environment.

Funding instruments (REDD+ and green bonds) to promote agroforestry

Innovative funding instruments such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation) programs and green bonds provide vital financial support for agroforestry projects focused on climate mitigation and sustainable land use. REDD+ initiatives offer incentives for conserving forests and integrating trees into farming landscapes, thereby reducing carbon emissions. Green bonds allow governments and private investors to raise capital specifically for environmental projects, including agroforestry development. These financial tools mobilize significant investments, encourage private sector participation, and

promote scalable, long-term agroforestry solutions that align with global climate goals.

Extension and collaboration (enhance knowledge exchange, successes stories)

Extension services and collaboration among stakeholders play a crucial role in facilitating knowledge exchange, sharing best practices, and scaling agroforestry innovations. By connecting farmers, researchers, NGOs, and government agencies, extension programs foster an enabling environment for learning and adaptation. Sharing success stories and demonstration sites builds farmer confidence and motivates wider adoption. Collaborative platforms, such as farmer cooperatives and online knowledge hubs, encourage peer-to-peer learning and the dissemination of practical solutions, ultimately strengthening the agroforestry sector and enhancing community resilience.

Conclusion, recommendation and way forward

Agroforestry is a win-win strategy when strategically integrated can offers Pakistan a vibrant, economical viable and environmentally sustainable pathway to rural development and climate resilience. Agroforestry not only enhances farm income, but also resilience against climate shocks most critical, as Pakistan is among top ranking climate vulnerable countries in the world. Provision of income diversification and econolgical services make agroforestry as the most desirable and profitable barrier against market and environmental uncertainties observed mostly by small farmers.

However, scaling up requires policy support, capacity building, secure land tenure, and market linkages. Case studies from Africa, Latin America, and Pakistan demonstrate its potential, but overcoming adoption barriers is crucial for widespread impact. It is seen integration of agroforestry into agriculture and climate change policy incentivized market development and capacity building can facilitate in quick adoption.

Recommendation

Recommendations in agroforestry include the introduction of fast-growing hybrid plants into farmlands for sustainable production, implementing climate-resilient systems, and establishing plant nurseries to supply the necessary trees. Additionally, promoting agroforestry requires supportive policies, financial incentives, and community engagement to overcome challenges like farmer conservatism and land scarcity.

Way forward

The way forward for agroforestry involves integrating scientific research with integration knowledge through inclusive co-design, developing supportive government policies and schemes, improving market access and farmer

training, and promoting diverse, climate-resilient systems through species selection and spatial planning. Key efforts include investing in research and development, building farmer capacity with effective extension services, establishing clear land tenure, and creating a favorable regulatory environment to scale up agroforestry practices for greater socioeconomic and environmental benefits.

In Pakistan embracing agroforestry can not only offer an environmental strategy, but also part of economic development agenda of the country. It can contribute to more resilient, gender and social inclusive and sustainable development of rural communities.

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Chapter 6

The Role of Agroforestry in Improvement of Rural Livelihood and Building Climate-Resilient Communities in Sri Lanka

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Background

Sri Lanka has a tropical climate characterized by hot and humid conditions throughout the year, shaped by its equatorial location, seasonal monsoon patterns, and diverse topography. The island experiences a bimodal rainfall pattern driven by two major monsoons: the Southwest Monsoon (May to September) and the Northeast Monsoon (October to January), along with two inter-monsoon periods. The temperature of the country varies significantly with altitude, ranging from an average of 15.8 °C in the Central Highlands to around 29 °C in coastal lowlands. Based on rainfall, elevation, and topography,

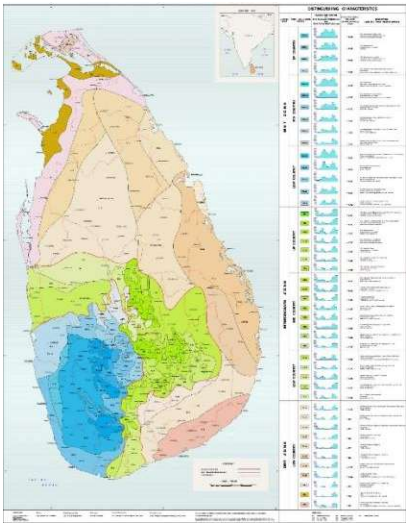

Figure 1. Agro Ecological Zones of Sri Lanka

Sri Lanka is divided into three main agro-climatic zones: the Wet Zone (mean annual rainfall over 2,500 mm), the Dry Zone (less than 1,750 mm), and the Intermediate Zone (between 1,750 mm and 2,500 mm) (Punyawardena, 2009) further subdivided into 46 agro-ecological regions, each defined by specific combinations of altitude, seasonal rainfall patterns, soil types and properties, temperature regimes and type of land use and vegetation (Punyawardena, 2009; Figure 1).

Biodiversity of the country is deeply influenced by these agro-ecological regions, which support a wide range of ecosystems and agricultural systems of lush rainforests rich in endemic flora and fauna, dry scrub forests,

grasslands and diverse cropping systems adapted to local climatic conditions.

Rural and Socio-Economic Profile of the Country

The total population of Sri Lanka is approximately 22 million, with an average annual population growth rate of 0.5 percent. The population density is estimated at 349 people per square km. More than 75% of the population live in rural areas, where agriculture remains the mainstay of the economy. About 26% of the total labor force is engaged in agricultural activities. Gross Domestic Production of the country is around 3.3% while Government Revenue increased due to tax reforms and improved collection, reaching 12.5% of GDP in 2024. Unemployment rate has been hovered around 4.8% while Poverty rate is at 13.7%. Sri Lanka maintains a medium Human Development Index (HDI) (Department of Census and Statistics, 2025).

Climate Change Challenges

Sri Lanka, a tropical island in the Indian ocean, is highly vulnerable to the impacts of climate change (NDC, 2016) due to its geographical location. Although the country contributes minimally to global greenhouse gas emissions, it faces severe consequences of climate change. The Average temperature of the country has steadily increased, with more frequent heatwaves and warmer nights. Rainfall patterns have become unpredictable, leading to both droughts and intense flooding. Sea levels around Sri Lanka have risen (Climate Change Secretariat, 2010; De Zoysa and Inoue, 2014), threatening low-lying coastal zones. These more frequent and severe climate-related disasters, including floods, landslides, and droughts have disrupted livelihoods and displaced communities. Coastal erosion and saltwater intrusion have affected agriculture and freshwater supplies, especially in the Northern and Western Provinces. Crop yields have declined due to erratic weather, especially in rice and tea cultivations and Biodiversity hotspots, including coral reefs and endemic species, face stress from warming seas. Sri Lanka has committed to climate adaptation and mitigation, including reforestation, renewable energy expansion, and disaster preparedness. Agroforestry serves as a one of fundamental method to reduce climate change impact (Raveendra et. al., 2021; Udumann et. al. 2023).

Agroforestry Sector of the Country

Agroforestry, one of the most promising and ecologically sustainable land use systems in Sri Lanka is deeply rooted in the island's cultural and ecological heritage. Except the area covered by natural forests (28%) and paddy lands (9%), Agroforestry systems are distributing among the other land use of Sri

Lanka. Topology of agroforestry in Sri Lanka can be identified as three main categories; Homegardens, Plantation based Agroforestry and Chena cultivation. These three systems may be Agrisilvicultural, Silvopastoral or Agrosilvopastoral according to the integration of crops, trees and livestock within the system (Figure 2).

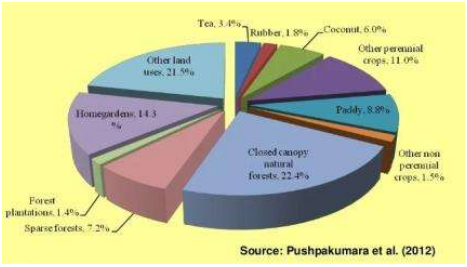

Figure 2. Land cover percentages

Homegardens

The most prominent and elaborated form of agroforestry in Sri Lanka is the multi-storied, complex and sustainable land use system associated with a homestead mimic to natural tropical forest. Home gardens are the oldest land use activity, next to chena cultivation (Kumar and Nair, 2004). Also, homegardens are classified as highly adapted agroforestry systems in Sri Lanka, covering approximately 14-15% of the country's total land area (Marambe et. al. 2011, Weerahewa et. al. 2012, Mattsson et. al. 2013). It integrates multiple components like annual and perennial crops, livestock, and sometimes fish to provide environmental services, meet household needs, and offer opportunities for employment and income generation (Weerahewa et. al. 2012, Mattsson et. al. 2013). Diverse range of crops include perennial food crops, fruits, vegetables, roots, tubers, medicinal plants, sugar crops, spice crops, and timber crops (Pushpakumara et. al. 2010). Livestock are also occasionally integrated into this system. Home gardens are an effective system that enhances biodiversity, productivity and serving as a powerful tool for ecosystem restoration and resilience. Based on Agro ecological variation, homegardens in Sri Lanka can be classified in to two types as Kandyan Homegardens (KHG) and Dry & Intermediate Zone homegardens.

Kandyan Homegardens (KHG) are complex, multi-strata (layered) agroforestry land use systems comprising various perennial, annual crops, shrubs, and multipurpose trees on the same piece of land often surrounding the house found primarily found in the mid-country wet zone in the district of Kandy Matale, Kegalle, part of Kurunagala and Rathnapura districts (Pushpakumara et. al. 2010). The distinct canopy layers of KHG include tall timber/fruit trees (Jackfruit, Mango etc.), mid-canopy spices (Clove, Cinnamon etc), and ground-level vegetables and herbs. KHG are highly biodiverse, featuring a plant species density that ranges from 654 to 5,663 individuals per hectare meet nutritional and diet diversity, with medicinal

species, spices, and tree products offering a source of substantial supplementary income to the family (Figure 3 a).

Dry zone homegardens (Figure 3 b) often featuring species that tolerate drought and focusing on food and fuel production with lower overall biomass and species diversity compared to wet zone systems use and for home consumption (Marambe et. al. 2013).

Plantation based agroforestry

Plantation based agroforestry systems in Sri Lanka primarily involve the integration of other crops, timber & fruit trees, and sometimes livestock with three major plantation crops tea, rubber and coconut. This approach is being promoted to address challenges in monoculture plantations land degradation, low productivity, and economic vulnerability.

Coconut Based Agroforestry System

Traditionally, coconuts are planted as monoculture with relatively low returns (Peiris et al.,2003a). However currently coconut monoculture to Coconut Based Agroforestry Systems (CBAS). CBAS generates higher financial and economic returns (Samarakoon et. al. 2023). Semi perennial crops such as banana, pineapple, betel and perennial crops such as cinnamon, cocoa, cashew, mango, guava and pepper are cultivated along with coconut. Timber trees are allowed to grow randomly within coconut lands. Livestock, including cattle, buffalo, goats, and poultry, is integrated beneath the coconut palms. This silvi-pastoral system provides farmers with additional income and the animal manure enriches the soil (Figure 3 c).

Tea Based Agroforestry Systems

Many species of shade trees are integrated into tea lands for their benefits in modifying the microclimate, specifically by decreasing incident radiation, temperature, and wind speed while increasing relative humidity (Mohotti et. al., 2020). Furthermore, these shade trees contribute to climate change mitigation and offer valuable ecosystem services (Figure 3 e).

Figure 3. Agroforestry systems of Sri Lanka

Rubber Based Agroforestry Systems

In rubber plantations, farmers have wait for cash inflow during the 6-7 years immature period. Therefore, most of the farmers adopt rubber-based agroforestry as a subsidiary source of income (Sankalpa et al.,2020). Some of the crops included in this agroforestry system are groundnut, pepper, cocoa, and banana (Figure 3 d).

Chena cultivation

Chena also known as hena, shifting or slash and burn cultivation an oldest farming system in Sri Lanka (Dharmasena, 2010, Gunasena and Pushpakumara, 2015). It involves the temporary use of forest land for growing a variety of crops, after which the land is left fallow to regenerate naturally promoting biodiversity and soil fertility. This cyclical method has traditionally supported subsistence farming, especially in the dry zone, and is closely tied to rice cultivation and home gardening systems. Indigenous farmers have developed sustainable management practices over generations through Chena cultivation, including minimal use of agrochemicals, crop

rotation, and reliance on seasonal rainfall. However, the traditional Chena cultivation has shifted into semi-intensive sedentary type cultivation. The improved chena cultivation use improved varieties, apply modern land preparation and establishment methods and high number of inputs. Increase of cultivable time with reduced fallowing period reduces soil fertility. Despite its ecological benefits, Chena cultivation faces pressures from modernization, land-use changes, and policy shifts (Figure f; Figure g).

Ecosystem services deliverables

Agroforestry systems provide a suite of environmental benefits vital to Sri Lanka's ecological sustainability, primarily by enhancing biodiversity, improving soil and water conservation, and increasing carbon sequestration. By integrating trees into agricultural landscapes, these systems significantly enhance soil health and water retention, especially in erosion prone and degraded areas. Senarathne and Udumann (2019) reported that agroforestry practices are demonstrably effective for land rehabilitation.

Agroforestry also plays a crucial role in carbon sequestration, capturing atmospheric carbon in both above and below ground biomass, thereby contributing to climate change mitigation and resilience (Kumar, 2006, Mattsson, 2013). Moreover, by reducing dependence on natural forests for fuel, wood, fodder, and other resources, agroforestry alleviates pressure on remaining forest ecosystems.

Economic Return and Social uplift due to Agroforestry

Agroforestry also improves food and nutritional security by promoting the cultivation of diverse edible plants of fruits, vegetables, nuts, and medicinal species within integrated landscapes. It reduces the reliance on external food sources and thereby enhances self-sufficiency within the system. The poverty remains concentrated in rural areas of the country, where many households depend on low return activities and social assistance to survive. The farming practice of agroforestry generates multiple agricultural products including timber and fruits and fodder that lead to rural development alongside food security (Dissanayaka et. al. 2023). This crop diversification offers a lifeline by diversifying income sources, thereby reducing economic risk and enhances financial stability of rural livelihoods, especially in regions affected by climate variability. The contribution of home gardens for food security in Sri Lanka is ranging between 17% in low country dry zone to 29% in mid country wet zone (Marambe et. al. 2013).

Agroforestry in National Education Curriculam

Agroforestry is an ancient practice with traditional knowledge in Sri Lanka for centuries (De zoysa, 2022). Knowledge of agroforestry has traditionally

been transmitted from one generation to the other and has empowered by educational programmes conducted by government and non-governmental organizations (Kumara et. al., 2003). However, these conventional educational approaches must be refined to successfully address the demands of current climate change conditions. Marambe et. al.2011 have reported that the majority of the homegardens, a major component of agroforestry in Sri Lanka is consisted with low-income farmers, mainly with primary education and possessed on prior experience in agricultural activities. Thus, Agroforestry of Sri Lanka should be incorporated with comprehensive knowledge of three scientific disciplines which include agriculture, forestry and environmental sciences (Udumann et al., 2025) and dissemination Agroforestry technologies towards the society.

Agroforestry is not typically offered as a compulsory subject in the general school curriculum (primary or secondary) leading up to the G.C.E. Ordinary Level (O/L) or Advanced Level (A/L) examinations in Sri Lanka. Including Agroforestry as a primary subject across the curriculum in primary and secondary education in the national education will be a strategic step to manage and expand its role as a powerful solution for climate change mitigation and the enhancement of rural livelihoods. This strategic inclusion is necessary to create a sustainable mindset from an early age. By adapting the educational framework in this manner, the next generation will be equipped with the interdisciplinary knowledge and practical appreciation required to manage and sustain integrated, resilient, and biodiverse land use systems.

Agroforestry is recognized as an important, multi-disciplinary field in university level of Sri Lanka and is taught as a specific or specialization subject in the degree programs related to agriculture, forestry and environmental science and agro-technology. These degree programs should be collaborated with practical aspects of Agroforestry so that learners can achieve direct system experience as well as stakeholder connections. Similarly, agroforestry curriculum improvement should be integrated with new technologies such as remote sensing, GIS and data analytics technologies (Udumann et al. 2025).

Business Models in Agroforestry

Community based tree nurseries

Community-based tree nurseries are a critical component of successful agroforestry programs efforts across Sri Lanka, providing the essential plant stock. These nurseries, are often run by single owner, farmer cooperatives, governmental departments like Department of Export Agriculture and Department of Agriculture, non-governmental organizations (NGOs) or

community groups. Although large scale nurseries are commercialized, small scale nurseries should be upgraded with facilitating new technologies for sustainable micro business model to generate supplemental income for rural families. This approach is effective in supporting the diversification of traditional plantations and the crucial maintenance of diverse home gardens.

Public private partnership

Public private partnerships on agroforestry systems are collaborated with farmers, government, international donor and development organizations and non-government organizations. Siyabalagaswewa Forest Restoration project was initiated in Sri Lanka in 2021 by Hongkong and Shanghai Banking Corporation Limited (HSBC) with the collobaration of Department of Forest Conservation, Sri Lanka and IUCN and continued. The focus of the project is restoration of 100 hectares of adjoining community land through regenerative agricultural practices such as food forest gardens, silvopastoral systems and live fencing.

Lead partners of Netherlands Enterprise Agency (RVO), GRO (Territorial Development Team) started Dutch Sri Lankan Agroforestry Partnership project on degraded tea and coconut plantations in 2022 with Sri Lankan stakeholders. This project emphasizes on diversifying monoculture systems with tree crop combinations, land restoration, rural livelihood diversification, improve soil health, climate resilience, promote business models, value chain development and scaling agroforestry in commercial agriculture.

Dilmah, a leading tea company in Sri Lanka, has initiated conservation Projects where agroforestry models are being piloted in their tea estates. These models aim to enhance biodiversity and soil health by integrating species such as Garcinia, Pepper, Durian, and Rambutan into the existing tea plantations.

CIFOR-ICRAF (Center for International Forestry Research – World Agroforestry Centre) plays a pivotal role in advancing sustainable land use and climate resilience in Sri Lanka. Its work focuses on four key areas: First, in Agroforestry Development and Policy Support, it identifies and addresses institutional and policy barriers to scaling agroforestry, collaborating with national ministries to enhance climate policy, agroecology, and land restoration efforts. Second, through Climate Resilience and Ecosystem-Based Adaptation, CIFOR-ICRAF implements ecosystem-based adaptation (EbA) projects aimed at reducing climate vulnerability across communities and landscapes. Third, as a delivery partner for Sri Lanka's Green Climate Fund (GCF) readiness program, it supports the implementation of the National Adaptation Plan and the country's Nationally Determined Contributions (NDCs). Finally, its Capacity Building initiatives promote knowledge sharing

and technology transfer to empower local institutions and communities, fostering long-term sustainability and innovation.

Agroforestry based value chain (honeybee, mushrooms, medicinal herbs, nuts)

Agroforestry in Sri Lanka provides a foundation for diverse value chains, offering supplementary income streams for rural livelihood. These systems, particularly traditional home gardens are crucial for integrating various products like honeybee products, mushrooms, medicinal herbs, and nuts. In wet zone of Sri Lanka, 30-50% of household income is provided by Kandyan homegardens (Pushpakumara et al., 2010). A study conducted by Kumara et al., 2003 revealed that most of the household need including food, fodder, firewood, timber and traditional medicine are supplied through the agroforestry systems in dry zone.

Barrier and Strategic Pathways

Agroforestry in Sri Lanka faces a complex array of challenges that hinder its full potential for sustainable development and rural prosperity. Sri Lanka does not currently have a standalone national Agroforestry policy. Instead, agroforestry is woven into several major national frameworks and strategies of National Climate Change Policy (2023), National Adaptation Plan (NAP), National Land Use Policy National Agricultural Policy and National Forest Policy. As these policies belonged to different ministries, there is an overlapping mandate on Agroforestry systems among ministries. This policy gaps and institutional conflicts undermine coordinated support as Agroforestry is not fully integrated into national agricultural or forestry strategies. This is a drawback in allocating financial incentives, such as subsidies or carbon credits which encourage adoption. Thus, it is very essential to have strong National Agroforestry policy to upgrade agroforestry system of Sri Lanka.

One of the most pressing issues is land tenure insecurity, where fragmented land holdings are and unclear ownership rights. Informal tenancy and encroachments further complicated land management and reduce incentives for sustainable practices. Weak value chains and inadequate infrastructure limit profitability and make poor market access to regional and global markets. Price volatility further destabilizes farmer incomes. Climate related risks of increasing droughts, floods, and pest outbreaks threaten productivity, especially in dry zones. Water scarcity due to shifting rainfall patterns adds to the vulnerability. Additionally, limited technical knowledge among farmers poses a significant barrier. Existing training programs are not sufficiently widespread or accessible to remote communities and contribute to the low adoption of innovative agroforestry models. Also, Lack of

communication or shared goals among government agencies, NGOs, and private sector prevents effective implementation.

Enabling Frameworks and Initiatives

Addressing these challenges requires a strategic blend of land reform, capacity building, market development, climate adaptation, and coherent policy frameworks. To unlock the full potential of agroforestry in Sri Lanka, a multi-pronged national strategy is essential. One that builds on proven models, it should be integrated with climate goals, empowered with farmers, and motivated innovation and partnerships. These models should be expanded across agroecological zones using participatory design and farmer-led adaptation. These efforts should be scaled through mobile platforms, farmer field schools, and youth engagement by conducting Training programmes for extension officers and Farmers on Agroforestry, Sustainable land use, land restoration, and integrated farming. Incentives like carbon credits, biodiversity payments, and subsidies for tree planting and intercropping can further boost adoption. Agroforestry must also be embedded into Sri Lanka's national climate strategies. It is already a key component of the National Adaptation Plan and the Climate-Smart Agriculture Investment Plan, with targets to increase green cover by 32% by 2030. Also, Agroforestry should be integrated into climate finance mechanisms and land-use planning frameworks. Establishing a national agroforestry research hub that links universities, plantations, and farmer networks would accelerate knowledge transfer and model refinement. Finally, public-private partnerships (PPPs) through both national and international collaboration are vital for scaling agroforestry. Creating agroforestry PPP platforms would mobilize investment, share risks, and scale innovation, bridging the gap between policy and practice.

Support Services to community

A concerted effort to bolster support services to the community on agroforestry in Sri Lanka is vital for scaling up this sustainable land-use system. This effort is grounded in enhanced extension and collaboration to share success stories and new knowledge, demonstrated by pilot projects such as the Sri Lankan-Dutch collaboration on tea and coconut plantations that have successfully established agro-ecological, social, and economic benefits and led to the creation of practical implementation guidelines (Agroberichten Buitenland, 2025; ResearchGate, 2024). A key pillar of support is the systematic Provision of Advisory and Technical Services to farmers, delivered by both government agencies and private sector entities like Hayleys Agriculture and CIC Holdings, who provide comprehensive agronomic consultancy, soil testing, and farmer training to ensure the adoption of best management practices and quality planting material for

sustainable yield improvements (Hayleys Agriculture, 2025; CIC Holdings, 2025). Furthermore, Financial Support to farmers/growers must be expanded through access to specialized credit schemes and new Funding instruments, such as leveraging Green Bonds and pursuing mechanisms like REDD+ (Reducing Emissions from Deforestation and Forest Degradation) for carbon financing, which is essential for mobilizing investment towards climate-resilient agroforestry as outlined in the Sri Lanka Green Finance Taxonomy and the Sustainable Finance Roadmap (Central Bank of Sri Lanka, 2022; CIFOR-ICRAF, 2022). Complementing rural efforts, an integrated strategy should Promote the Green Corridor concept in urban areas, recognizing the role of urban home gardens in enhancing food security, providing essential ecosystem services, and creating green pathways that link urban and peri-urban spaces for both human and ecological well-being (Sabaragamuwa University, 2021; Sri Lanka Green Building Council, 2022).

Strategic Needs

The strategic needs for advancing agroforestry in Sri Lanka are multifaceted, requiring a comprehensive approach across policy, research, cooperation, and market development to ensure sustainability and resilience (World Agroforestry, 2022; Dissanayaka et. al. 2023). A regional Agroforestry Strategy is essential to guide coordinated efforts, focusing on overcoming existing research gaps, particularly in scientifically validating traditional systems like the Kandyan homegardens and developing context-specific, climate-smart agroforestry models for different agro-ecological zones (De Zoysa, M. (1997); World Bank, 2019). This strategic framework must integrate Research and Capacity Building programs, collaborating with national institutions and international partners like ICRAF, to strengthen technical assistance, extension services, and farmer training on system management, product processing, and value addition (CIFOR-ICRAF, 2022; Dissanayaka et al., 2023).

Crucially, Regional Cooperation and GESI (Gender Equality and Social Inclusion) must be prioritized, recognizing the significant role women play in managing homegardens and ensuring that benefits, knowledge, and opportunities are equitably accessible to all vulnerable populations, particularly smallholder farmers (WB, 2019; De Zoysa, M. (1997). This cooperation should facilitate the regulated Exchange of Seed and Seedling Materials to ensure farmers have access to high-quality, genetically diverse, climate-resilient germplasm of both local and improved varieties, which is vital for maintaining agro biodiversity and productivity (Agroforestry.org.com 2013; Calvet-Mir et al., 2012). Finally, achieving widespread adoption requires addressing economic constraints through Joint Market Development and Finance initiatives, which focus on improving infrastructure, strengthening market linkages, reducing post-harvest losses,

and developing business models for high-value tree-based products (CIFOR-ICRAF, 2022; Kelani Valley Plantations PLC, 2024). This includes integrating financing solutions and promoting compliance with international quality and sustainability standards to enhance market competitiveness (Dissanayaka et al., 2023).

Conclusion, Recommendations and way forward

Agroforestry in Sri Lanka presents a transformative opportunity for climate resilience, sustainable land use, and rural development, but unlocking its full potential requires a strategic blend of land reform, capacity building, market development, climate adaptation, and coherent policy frameworks. A multi-pronged national strategy must build on proven models, align with climate goals, empower farmers, and foster innovation and partnerships. Expanding these models across agroecological zones through participatory design and farmer-led adaptation is crucial, supported by mobile platforms, farmer field schools, and youth engagement. Training programs for extension officers and farmers on agroforestry, sustainable land use, and integrated farming should be scaled, while incentives such as carbon credits, biodiversity payments, and subsidies can boost adoption. Agroforestry must be embedded into national climate strategies and integrated into climate finance and land-use planning frameworks. Establishing a national agroforestry research hub and promoting public-private partnerships will accelerate knowledge transfer and innovation.

A regional strategy is essential to address research gaps, validate traditional systems like Kandyan homegardens, and develop climate-smart models tailored to diverse zones. Collaboration with international institutions will strengthen technical assistance and financial support, while prioritizing Gender Equality and Social Inclusion ensures equitable access for women and smallholder farmers. Facilitating regulated seed and seedling exchanges will enhance agro biodiversity, and joint market development initiatives must improve infrastructure, reduce post-harvest losses, and promote high-value tree-based products through sustainable business models and financing solutions.

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Invited Papers

Agroforestry as a Strategy for Addressing Climate Change Impacts, Promoting Inclusive and Fostering Sustainable Development

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Background

The role of trees or tree cover is well recognised to significantly reduce the risk of climate change, and make the environment more conducive to humans, livestock, and agriculture. As the forest cover in most of the countries of the region is constant, or even decreasing, the only effective way to increase the green cover of the countries to achieve the desired optimum cover is to promote and mainstream agroforestry. SAARC nations have an estimated 27% of their agricultural land under agroforestry, where farmers and other stakeholders currently practice agroforestry and depend upon its products and the environmental services. Thus, planting trees through agroforestry is the way to protect and compensate the loss of forest cover; provide the benefits that otherwise will be obtained from already over-exploited forests; increase environmental sustainability; enhance the production of food (fruits & vegetables) fodder, fuel wood, and timber; reduce soil erosion and degradation; assists in rehabilitation of degraded lands; enhance soil organic matter; remove atmospheric carbon through sequestration; supports biodiversity and provide many other social, religious and aesthetic benefits (Rizvi and Dhyani, 2020).

Agroforestry (AF) is recognized as the ultimate tool to enhance resilience to climate change & reduce the carbon footprint of developmental activities. To achieve their Intended Nationally Determined Contributions (INDCs), 23 countries recognize agroforestry as a priority for mitigation, and 29 countries for adaptation.(https://ccafs.cgiar.org/agricultures-prominence-indcs-data-and-maps#.Wfa1uohx200).

Agroforestry in South Asia

The South Asian region is home to AF, as integration of trees into agricultural and social landscapes has been an integral part of the socio-ecological fabric of the South Asian farming community for centuries. Farmers of the region develop AF practices to meet their basic needs of food, fuelwood, fodder, fibre, plant-based medicines and in times of need, cash income. Not surprisingly, traditional knowledge of integration of trees on farms is

extensive in the SAARC region, even though the eight SAARC Member States cover a wide range of agro-ecological zones which include Hilly and Mountainous (Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka); Indo-Gangetic Plains (Bangladesh, India, Nepal, Pakistan); Semi-Arid and Arid (Afghanistan, India, Pakistan); and Coastal Humid (Bangladesh, India, Maldives, Sri Lanka) region. Across the region's diverse climatic conditions, AF has always been seen as a means of not only improving people's income through the supply of fruits, timber, fodder, fuel wood, and fertilizer, but also stabilizing erosion, replenishing soils, storing carbon, moderating the micro-climate (as in shelterbelts in arid zones) and enhancing on-farm biodiversity. The prominent agroforestry systems of South Asia (Kumar et al., 2012; 2018) include agrihorticultural-; agrisilviculture-; silvi-pasture-; alley cropping-; multistoried-; homegardens-; and other systems. The traditional taungya and shifting-cultivation, where trees play an important role, are still practised in many countries of the region. Country-specific examples of agroforestry systems in the eight countries, as mentioned below.

- Afghanistan: Agrisilviculture, agrosilvopastoral systems and multi-storied homegardens.
- Bangladesh: Multistoried agroforestry systems (AFs) with various trees and plants, often on small land holdings.
- Bhutan: Traditional shifting cultivation, integrating crop production, grazing, and forest areas.
- India: Employs a range of traditional and research-based AFs, including trees on farmland boundaries.
- Maldives: Adopts AF practices with diverse homegardens often incorporating coconut and palms.
- Nepal: Follows both traditional and research-based systems, including growing trees on crop boundaries.
- Pakistan: Primarily focuses on farm-based AFs.
- Sri Lanka: Diverse home gardens and coconut-based AFs.

The diverse AFs practiced over centuries in this region also have undergone transformations in response to changing pressures. Although such transformations reflect the great potential of agroforestry in resolving many of the world's challenges, the level at which it is applied needs more thrust and encouragement. The indigenous knowledge and experiences from these practices can be helpful to address the land management challenges, such as climate change, biodiversity decline, food and nutritional insecurity, and land degradation a common phenomenon in SAARC countries.

Agroforestry also provides important above-and-below-ground environmental services, including improving soil health, contribute to climate

change mitigation through carbon sequestration is of particular relevance as countries develop mechanisms for Reducing Emissions from Deforestation and forest Degradation (REDD+).

Emerging threats and challenges in South Asia

The South-Asian region is facing several threats and challenges that require an urgent and yet sustained response from decision makers. The climate change from anthropogenic causes is already threatening the region with higher temperatures and increased variability in precipitation, directly leading to a higher frequency of droughts and/or floods in the region. As per IPCC 5th Assessment Report (IPCC, 2014), over the mid-term (2046-2065), an increase of 2-4^0 C is projected for South Asia with daily maximum temperatures to increase by 4-7^0 C. Recent reports from Afghanistan, Pakistan, India, and Nepal, with a wide diversity of geographic and climatological regimes, are in line with IPCC predictions, high inter- and intra-seasonal variability in rainfall distribution, rainfall events and extreme temperatures is causing crop damage and loss to farmers. Consequently, average temperature increases of 2-4^0 C by the 2050s would be disastrous for the region, and the agriculture sector would be affected by increased risk of drought-related water and food shortages. It can be expected that irrigation water demand will increase due to warming.

Agroforestry Potential for Meeting Climate Change effects

Agroforestry is an integrated response to the threat of climate change by supporting mitigation and adaptation. Planting trees and shrubs also increases carbon sequester both above and below ground, thereby contributing to GHG mitigation (Verchot et al., 2007). Much of the livestock population and a large portion of the cropped area in the SAARC countries are in rainfed land characterised by low input use and low yield levels (Kumar et al., 2012). For rainfed areas, diversification of land use systems with agroforestry is a necessary strategy for providing a variety of products for meeting the requirements of the people, insurance against risks caused by weather aberrations, controlling erosion hazards and ensuring sustainable production on a long-term basis. The AFs with integration of crops, livestock, and woody perennials at the farm level offer high potential for alleviating the nutritional malady, which is quite prevalent in this region, by incorporating essential nutrient-containing crops and fruit trees in the farming and the household level consumption patterns.

At present, AF meets the demand for fuel wood, and the timber demand for wood-based industries, such as plywood and raw material for paper pulp, and provides significant quantities of the green fodder, besides meeting the subsistence needs of households for food, fruit, fibre, medicine, etc. Thus, it

is helping in checking the degradation of forests. In India, 90% of the forests in the country are performing the critical functions of protecting fragile watersheds and are not exploited for commercial exploitation (Dhyani et al., 2007). Agroforestry is also contributing to reaching the national goal of desired tree cover in these countries, which can only be achieved by planting trees on farm fields/bunds, as bringing more areas under forests is not possible.

It is now accepted that land use under AF increases livelihood security and reduces vulnerability to climate and environmental change. There is ample evidence to show that the overall (biomass) productivity, soil fertility improvement, soil conservation, nutrient cycling, microclimate improvement, and carbon sequestration potential of an AFs are generally greater than those of an annual system (Dhyani et al., 2009). Agroforestry has an important role in reducing vulnerability to weather extremes, increasing resilience of farming systems and buffering households against climate-related risks and also provides ecosystem services. Therefore, the importance of developing and implementing a SAARC Agroforestry Program cannot be delayed.

Agroforestry Policy and Advocacy

In the South Asian countries, most of the forests are owned by the State (Dhyani, 2017). However, in India and most of the SAARC countries, AF is practised on private land, mostly agricultural land. Therefore, the enabling environment for the implementation of AF is affected by the respective National Forest Policies and state-specific regulatory regimes for felling and transit of wood from trees. In 2014, India became the first country in the world to adopt a national agroforestry policy (NAP). The policy was designed to resolve bottlenecks with other policies on agriculture, forestry, water and environment, recognizing that land use by its very nature must be integrative (Rizvi et al., 2024), effective in upgrading the national research and development institution, bringing AF into the Corporate Social Responsibility Act, establishing the National Sub-Mission on Agroforestry to promote adoption and freeing farm-grown tree species from counterproductive felling and transit regulations. The NAP helped in catalysing 2.66 million ha of forest area annually during the last decade (FAO, 2024). This secures India in the third spot among the top 10 countries with the most significant forest area gains during this period (FAO, 2024). The process of NAP development has been recognised as a valuable lesson and is being used in neighbouring countries in South Asia (FAO, 2024). In 2014, supported by ICRAF, Nepal launched a NAP process and in 2019, became the second country to launch a NAP (MOALD 2019a; MOALD 2019b), to leverage the benefits of AF to manage land more sustainably, improve livelihoods, and strengthen environmental resilience. Similar efforts are ongoing in other SAARC countries.

Development of a coordinated program on Agroforestry in SAARC

To benefit from the large number of workshops, training programs, and consultations on AF (List 1) organized during 2004-2015 and attended by researchers, administrators, and policymakers from SAARC countries, it was decided to document the technological advancement in AF practices and assess their relevance as climate-smart technologies (Gurung and Temphel, 2015). A SAARC regional consultation was organized by the SAARC Agriculture Centre (SAC) and SAARC Forestry Centre (SFC), in collaboration with the Indian Council of Agricultural Research (ICAR) and the World Agroforestry Centre (ICRAF) during June 2015. The consultation identified the following challenges that must be overcome for the benefits of agroforestry to be realized:

- Limited awareness about the benefits of AF across social, economic, and environmental domains,
- No dedicated service for AF in the agricultural extension system and similarly a shortage of extension personnel with expertise in agroforestry,
- Unorganized structure of AF institutions and agriculture departments,
- Poor technology dissemination and adoption,
- Absence of policies specific to AF in most Member States,
- Need for a network on SAARC AF for promoting a community of practice and technology dissemination to support a growing user community.

A draft program was developed as a direct follow-up on the above consultation and was intended to address these challenges and bring social, economic, and environmental benefits to farmers. The program was discussed during the Inception Meeting to 'Develop a SAARC Coordinated Program on Agroforestry' organized jointly by the SAC, Nepal, Ministry of Agriculture, Government of Nepal, ANSAB and World Agroforestry, ICRAF at Kathmandu, Nepal on June 1-5, 2016. Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka nominated an agroforestry specialist to represent the country. During the Inception Meeting, Country Focal Point people and institutions to serve as a nodal point for the Programme were also identified (Figure 1). At the end of the Inception meeting, a SAARC Resolution on Agroforestry entitled 'SARCOPA for Accelerating Agroforestry in South Asia' was issued.

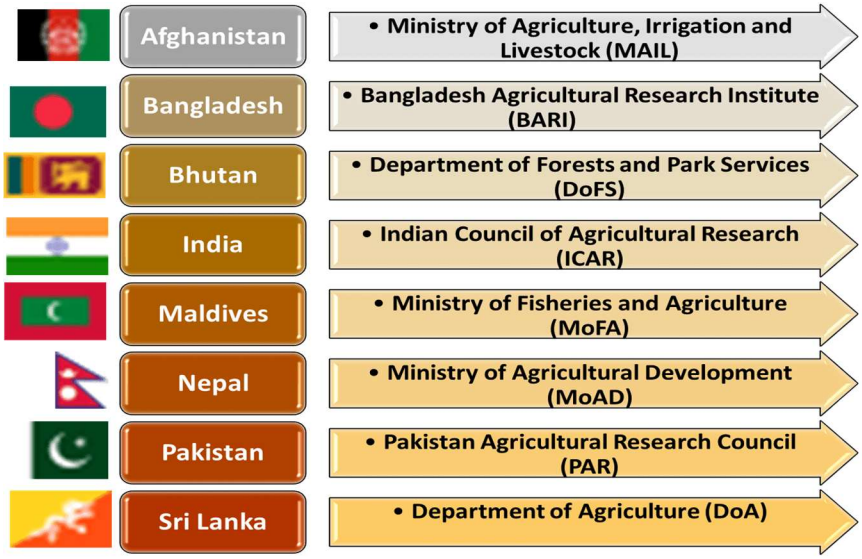

Figure 1. Focal Institution for Agroforestry development in SAARC member state

1. Enhancing farmers' knowledge in agroforestry for sustainable livelihood and environment, 12 – 14 July 2004, held at the World Agroforestry Centre-South Asia NASC Complex, Pusa, New Delhi. Organized by ICRAF and Action Green Earth (NGO).
2. A regional workshop-cum-training programme on tree domestication, 9 - 10 March 2005, held at the Postgraduate Institute of Agriculture University of Peradeniya, Peradeniya, Sri Lanka. Organized by CARP-ICRAF Tree Domestication Project, ICRAF Regional Programme for South Asia.
3. New frontiers in agroforestry planting material utilization, 28 August-2 September 2006, held at ICRAF South Asia, New Delhi. Organized by ICRAF's South Asia Regional Programme.
4. Improving strategies for tree germplasm supply, 29 October-3 November 2007, held at ICRAF headquarters, Nairobi, organized by ICRAF.
5. International workshop on improving strategies for tree germplasm supply, 29 October-3 November 2008, held at ICRAF headquarters, Nairobi, organized by ICRAF.
6. Level 2 certificate training programme for Maldives, 14 March-8 May 2010, held at Agriculture Centre, Hanimadhhoo, Maldives. Organized by ICRAF-South Asia Regional Programme.
7. Carbon footprint assessment training workshop and climate change research planning workshop, 23-27 April 2012, held at ICRAF headquarters, Nairobi. Organized by ICRAF.
8. Training workshop on field sampling for monitoring and reporting of

carbon stocks of mangrove ecosystems (conducted by the experts from CIFOR, Indonesia and USAID, USA), 15- 17 May 2013, held at Bhubaneswar, Odisha, India. Organized by ICRAF-South Asia Regional Programme and Orissa University of Science and Technology.

9. On-the-job training on the use of the carbon stock toolbox, carbon measurement and stock assessment and field visits to active sites in Southeast Asia, 8 -15 July 2013, held at ICRAF-Southeast Asia Regional Programme, Los Banos, the Philippines. Organized by ICRAF-South Asia Regional Programme.
10. Workshop on ICRAF's capacity development strategy and South Asian partners' capacity development needs, 30-31 January 2013, held in Dhaka, Bangladesh. Organized by ICRAF-South Asia Regional Programme in collaboration with Bangladesh.
11. The 3rd World Agroforestry Congress, held in Delhi, India, on 10-14 February 2014. Organized by ICRAF, ICAR, the Indian Society of Agroforestry, and Global Initiatives (GI). Participants from more than eighty countries, including those from SAARC countries, participated.
12. Training Program on 'Research Methods in Agroforestry' organized at ICAR-CAFRI, Jhansi on 1-5 December 2014- participants from 4 SAARC countries [Bangladesh, India, Nepal and Sri Lanka] attended.
13. Design of agroforestry experiments (an international training workshop), 1-5 December 2015, held at the Central Agroforestry Research Institute (CAFRI), Jhansi, India. Organized jointly by ICRAF-South Asia Regional Programme and ICAR-CAFRI.
14. Consultation Workshop on Present Status and Future Prospects of AF in Nepal, 26 -28th March 2015, Kathmandu, Nepal- participants from 4 SAARC countries [Bangladesh, India, Nepal and Sri Lanka] attended.
15. SAARC Consultation on "Strategy for climate smart Agriculture technologies in SAARC Countries" organised at ICAR-CAFRI, Jhansi on 16-18 June 2015, participants from 8 SAARC countries participated.
16. Regional Consultation on Agroforestry, New Delhi, Oct. 8-10, 2015- participants from 6 SAARC countries [Afghanistan, Bangladesh, Bhutan, India, Nepal, Sri Lanka] participated.
17. SAARC Regional Training on Smart Practices for Climate Resilient Agriculture: AF Options, New Delhi, Nov. 15-20, 2015- participants from 7 SAARC countries, except Afghanistan, participated.

Conclusion

The review presented above clearly brings out the following points, which can be followed in each country to mainstream agroforestry in country agriculture policies and strategies.

- De-notify tree species from felling, transit and processing regulations- use of digital technologies
- Incorporate tree plantation in government-supported programs
- Link producers with industry and the development of the value chain
- Endorse and facilitate CSR investment in AF
- Production, certification and supply of high-quality planting material- create an institutional mechanism
- Promote R&D in AF
- Set up Network Nursery Ecosystem- Promote *village-level nurseries, women aggregators, etc.,* to address livelihood options for tribal communities. There would generate employment generation potential in agroforestry of 53 and 108 days in the farm and non-farm sectors.
- Establish Tree-Based Enterprise Incubation Centres (TBEICs) at suitable places to encourage entrepreneurship among local youth, women and self-help groups (SHGs).
- Focus on bamboo-based products and agro-produce processing for food, feed, and fodder.
- Primary processing & value addition of fruits, seeds, medicinal herbs, vegetables, etc. from agroforestry presents opportunities for post-harvest loss reduction, income augmentation and employment generation.
- Implementing gender-sensitive & community-owned AF models ensures long-term adoption and impact.
- Promote PPP & deal with tree and land tenures
- Exchange of case studies and experience in the SAARC countries

Key messages

- Agroforestry is a potent driver to address challenges related to food, nutrition, industrial products; and C-sequestration, soil rehabilitation, water conservation, biodiversity, and helps in employment and livelihood generation.
- A new paradigm should be considered in intersectoral planning and policy in each country to practice agroforestry at scale, leading to transformative impacts
- Awareness and capacity development of stakeholders (policy makers, researchers, practitioners, development partners, farming communities and private sector) is imperative to achieve the transformative impacts.

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Agroforestry and Ecosystem Services: A way to mitigate climate change impact in Bangladesh perspectives

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Climate Change and Bangladesh

Climate change refers to the change in temperature and weather patterns, and the result of extreme weather events. It is mainly caused by human-induced greenhouse gas emissions, such as CO_2, CH_4, N_2O, resulting from deforestation, fossil fuel combustion, and industrial processes.

Bangladesh faces significant challenges in the context of climate change and shows its vulnerability in ecological and socio-economic field. Being a low-lying delta, Bangladesh is prone to floods and salinity intrusion also occurs in the coastal areas which affects freshwater and agricultural production negatively and is responsible for major losses of lives and assets and projections indicate a sea-level rise of up to 1 meter by 2100, threatening to submerge 18% of the country's land and displace millions. Further, the loss of biodiversity and livelihoods becomes apparent in the endangered Sundarbans ecosystem. In the socio-economic context, an agriculture-dependent economy experiences a decline in production and is projected to reduce yields of key crops like rice and wheat by up to 30%, posing risks to food security. Moreover, limited adaptive capacity hinders sustainable livelihoods of people and leades to poverty. These climate-induced disruptions are expected to decrease Bangladesh's GDP by over 6% by 2050, with significant effects on agriculture and livelihoods.

Agroforestry

Agroforestry is a land-use system where trees, crops, and/or animals are deliberately integrated on the same land unit, either simultaneously or sequentially, to optimize ecological and economic interactions. It features the combination of woody perennials (trees, shrubs) with crops and/or livestock, practiced in spatial arrangements or temporal sequences. Enhancing biodiversity, soil fertility, and carbon sequestration, it aims at sustainable land management and increased productivity.

In Bangladesh, major agroforestry systems are homestead agroforestry, silvopastoral systems, alley cropping and cropland agroforestry.

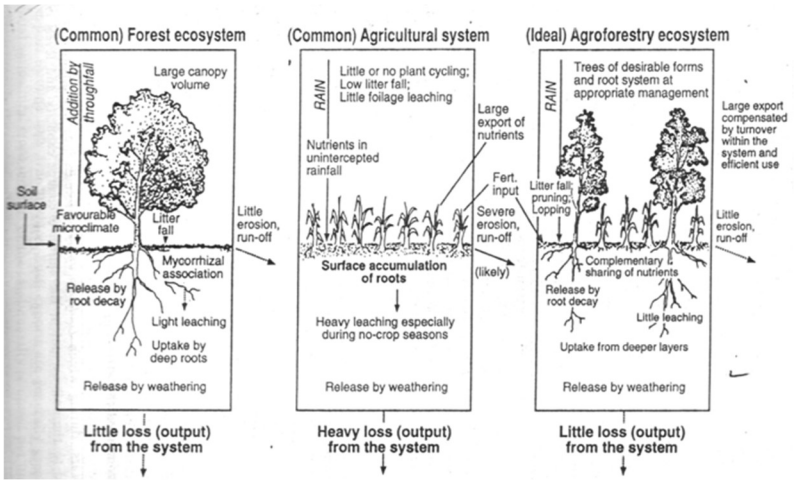

Figure 1. Comparative nutrient cycling among the Forest ecosystem, Agricultural system and Agroforestry system (Nair, 1993)

Agroforestry and Ecosystem Services

Ecosystem services (ESS) are the benefits that are derived by humans from ecosystems essential for sustainable life, economic development, and environmental stability. ESS are composed of four categories, such as provisioning (for example, food, fodder, timber), supporting (including soil health enhancement and nutrient cycling), regulating (like carbon sequestration and water purification in riparian systems), and cultural (for instance, spiritual enrichment, recreation, and aesthetic value). In terms of soil fertility enhancement, tree-based cropland agroforestry in Dinajpur showed increased SOC from 0.31% in 3-year-old plantations to 1.99% in 23-year-old plantations. Besides, water retention and erosion control tree roots in agroforestry systems enhance water infiltration and reduce surface runoff, controlling soil erosion and improving water quality. The benefits of agroforestry are also evident in economic output and biodiversity conservation, in Madhupur Sal forest, tribal farmers cultivated 22 tree and 33 crop species, contributing to species richness and habitat diversity.

Carbon Sequestration

Carbon Sequestration is the process of capturing and storing atmospheric carbon dioxide (CO_2) in various carbon pools such as forests, soils, oceans, and geological formations occurs through biological, physical, and chemical pathways, and human interventions can enhance this process. In terrestrial ecosystems, like forests or agroforestry systems, plants act as sinks and can absorb CO_2 through photosynthesis and store it in plant biomass and organic matter. In marine ecosystems, carbon is sequestrated in large amounts through

CO_2 dissolution and by the marine organisms involved biological pump mechanism. In terms of climate change mitigation, this process plays a significant role and contributes in sustainable development pathways by aligning with carbon neutrality goals. Various allometric equations have been reported in table 1.

Table 1. Allometric equations for measuring biomass towards Carbon sequestration

Researchers	Allometric Equation Above ground biomass (AGB)	
Chave et al, (2005)	$0.0509 \times (\text{Wood Density} \times \text{DBH}^2 \times \text{Height})$	(1)
Basuki et al, (2009)	$\text{EXP}((2.196 \times \text{LN(DBH)}) - 1.201$	(2)
Kettering et al, (2001)	$\text{EXP}((2.59 \times \text{LN(DBH)}) - 2.75$	(3)
Kenzo et al, (2009)	$0.0829 \times \text{DBH}^{2.43}$	(4)
Chave et al, (2014)	$0.0559 \times (\text{wood density} \times \text{DBH}^2 \times \text{Height})$	(5)
Kato et al, (1978)	MS : $0.0313 \times (((\text{DBH2}) \times \text{Height})^{0.9733})$ $MB: 0.136 \times (MS)^{1.07}$ $1/M1 : 1/((0.124 \times (MS^{0.794})) + (1/125))$ $M1 : 1/(1/M1)$ $AGB : MS + MB + M1$	(6)

British Methods

- D<11, W=0.25D²H
- D>11, W=0.15D²H

W=bove-ground weight in pounds
D=Dameter of the trunk in inches
H= Height of the tree in feet

Above Ground+ 20% Root biomass = Total Green Weight of trees

- 72.5% Dry matter
- 27.5% Moisture

Dry weight of the tree= weight of the tree x 72.5%

Average carbon content is generally 50% of the tree's total volume
Weight of carbon in the tree= Dry weight of the tree x 50%

Agroforestry and Carbon Sequestration (Bangladesh Cases)

In the Madhupur Sal forest, Sal species can sequester up to 49.80 lbs/year. A study in Mymensingh district showed that agroforestry plantations with *Albizia saman* and *Swietenia* sp., are major carbon contributors. Besides, fruit tree-based agroforestry in Khulna, Satkhira, Rajshahi, and Dinajpur has economic viability and carbon sequestration potential. In terms of soil fertility, agroforestry systems in Dinajpur enhance soil organic carbon (SOC) levels.

Agroforestry for livelihood

Research conducted in Char Kali Bari shows improved socioeconomic conditions through diversified income sources, as well as enhanced food security and environmental benefits. In the Sal Forest, community involvement in managing Sal (*Shorea robusta*) has played a crucial role in poverty alleviation and generating diversified income through timber and non-timber forest products. Study shows that in Coastal Belt of Sundarbans, 76.25% of respondents perceive agroforestry positively, with 68.7% having a favorable attitude toward adoption and 47% being interested in agro-aquaculture. In addition, in Capasia village, poverty levels have been reduced, as well as natural resource management has improved, leading enhanced resilience against environmental degradation.

Case Study at Madhupur Sal Forest

AF/PAF	Area (acre)	Remarks
1. Woodlot	3415.08	Cash income
2. Agroforestry	1296.60	Subsistence and cash income
3. Sal coppices management	1733.94	Totally failure (Stopped)
4. Buffer zone management	623.56	Mostly failure (Stopped)
Total participants **3327** (50% ethnic + 50% Non-ethn.)		

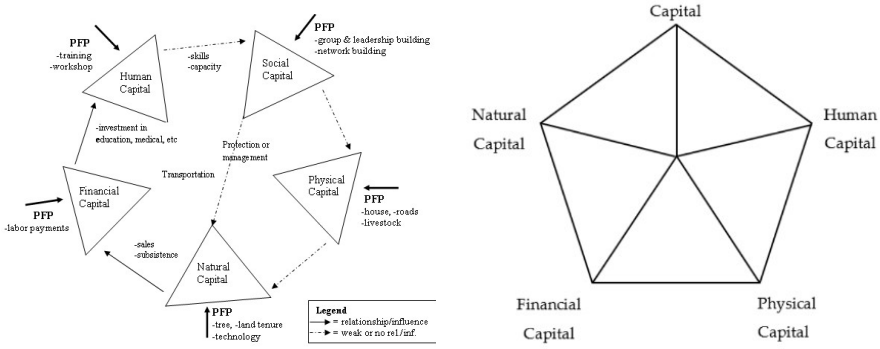

Figure 2. Improvement of Livelihood Capitals of Pro-Poor Farmers

Agroforestry and Biodiversity

Agroforestry enhances species diversity, as homegardens often match the structural and compositional complexity of natural forests. It restores habitats in degraded areas, such as the Madhupur Sal forest, facilitating ecological recovery. Additionally, agroforestry systems provide wildlife corridors that enable species' movement and promote gene flow between fragmented habitats. These systems also improve soil health and support microbial diversity, contributing to overall ecosystem resilience. Furthermore, they boost ecosystem services, including erosion control and water regulation, which are essential for environmental stability. Importantly, community involvement in agroforestry practices supports sustainable biodiversity conservation by integrating local participation with ecological restoration efforts.

Different Government Policies and Programs are-

- National Agroforestry Policy (in Progress)
- Social Forestry Rules (2004, 2010 Am.)
- Co-management Plan
- Sixth Five Year Plan
- 7^{th} Five Year Plan
- 8^{th} Five Year Plan

Challenges to Agroforestry Expansion

Challenges, like lack of awareness among rural people and inadequate programs for capacity building, create hindrance towards agroforestry expansion and its success. Besides, land tenure issues often become problematic in this context. In addition, market access constraints for the rural people and marginal farmers reduce the opportunities to be sustainably resilient against any economic and environmental stresses. Moreover, failure in agroforestry expansion often becomes significant due to gaps in policy implementation.

Opportunities for Scaling Up

The National Agroforestry Policy provides a framework for integrating trees into farming systems, and improved livelihoods. This agroforestry approach enhances resilience to climate change by improving soil health, increasing biodiversity, and sequestering carbon. Further, agroforestry systems offer higher returns compared to monocropping, with increased crop yields and diversified income sources. Projects or programs like, community-based nurseries, provide quality planting materials, generate income, and build local capacity for sustainable agroforestry practices. In terms of research and development, institutions like Bangladesh Agricultural University are

actively involved in developing and disseminating agroforestry technologies tailored to local needs.

Role of Youth and Communities

Study shows that young farmers (20–30 years) show a strong interest in agroforestry for livelihood improvement, middle-aged farmers (42.7%) are the primary adopters, while younger farmers (23.95%) are increasingly engaged. Participatory forestry programs involve local communities in agroforestry activities, particularly in degraded forest areas, which enhances sustainability in ecological and socio-economic contexts. Yet, limited access to training and extension services hinders youth and community involvement. Socio-economic barriers, such as land tenure issues and lack of market access, affect adoption rates. In this regard, policy alignment; research, monitoring and incentive provision; and community-based and participatory approaches can be the solutions to overcome the challenges.

Conclusion

Agroforestry depicts a win-win situation for people and the planet. It shows strong potential in Bangladesh for climate mitigation and adaptation. Therefore, letting trees grow with crops and/or animals could be the best strategy for a climate-resilient future.

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Agroforestry in the mountain ranges of Pakistan: Socio-Economic impacts, conservation and climate change mitigation potential

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Background

According to United States Department of Agriculture (USDA) "*Agroforestry is the intentional integration of trees and shrubs into crop and animal farming systems to create environmental, economic, and social benefits*." As an integrated and sustainable land-use system, agroforestry focusing on the socio-economic and environmental needs. The common mood of agroforestry includes silvorable, silvopastoral, agropastoral, hedgerows, shelterbelts, riparian buffer strips, homestead, alley cropping and forest farming.

In the current era of anthropocene, agroforestry is considered to be a cost-effective and sustainable approach that provide multiple ecosystem services, particularly in developing economies of South Asia including Pakistan. In Pakistan, natural resources like forests, grassland and agriculture are highly exposed to climate change, land use change, urbanization and population pressures (Baig et al., 2022). Pakistan's economy is largely dependent on agriculture which shares about 20%-24% to country GDP, employees 38% of labor and provides 70% of living to total population, particularly in rural areas (Ali et al., 2022; PESR, 2024). As per digital census report of 2023, about 61% of the total population in Pakistan is living in the rural areas (PBS, 2024), highly dependent on the natural resources for their livelihoods. Due to development issues like population growth, urbanization, land use change and climate change, the rural areas are facing greater threats. The shrinking of agriculture land as a result of climate change and land use change induced disaster, urbanization and settlement expansion, will lead severe food shortage in future (Ali et al., 2022). Thus, counter approaches such as promotion of agroforestry and restoration of micro watershed in both urban and rural areas are required.

The Hindu Kush, Karakoram and Himalaya (HKH) Mountain ranges in Pakistan are the backbone of country's economy. These mountain ranges are rich in natural resources like forest, grassland, agriculture land, water bodies, and glaciers. HKH ranges contains about 67% of natural forest in Pakistan, share more than 80% water to Indus basin, and contribute 30% power (Khan et al., 2016; Baig et al., 2022; PESR, 2024), and producing 10 million tons of agriculture crops, fodder, fruits and non-timber forest products (NTFPs) as

well sequester huge amount of carbon (Ahmad et al., 2017; Ahmad et al., 2022c PESR, 2024; Ahmad et al., 2025). About 90% of the local people in these ranges are dependent on forest, rangeland and agriculture land for fuel wood and timber (Ahmad et al.,2022a; Baig et al.,2022) and fulfilling country timber and fuel wood demands.

Despite powerhouse of ecosystem services, HKH region is facing climate change vulnerability, land use change, demograhic challenge, built land expansion and pollution. By the end of 2021, a 1.5 ^{o} C raise in temperature is expected over the region (Wester et al., 2019). Similarly, it is expected low winter precipitation and increase in summer precipitation will happen (Khan et al., 2016). Annual deforestation rate ranges 0.2% to 1.4%, with annual settlement expansion varied between 1% and 3% (Ahmad et al., 2015; Qamar et al., 2015; Ahmad et al., 2018; Ahmad et al., 2022b). These challenges increase vulnerability as manifested by floods in 2010, 2012 and 2024, GLOFs and land slides.

To counter climate change and land use change related social, economic, environmental impacts, nature based & cost-effective solutions are required. Agroforestry in this regard is a cost-effective approach to cope with the existing ecological, social and economic problems over the region.

Common mood of agroforestry

The common mood of agroforestry in the region including silvorable, silvopastoral agropastoral, agrosilvopastoral, hedgerows, shelterbelts, riparian buffer strips, homestead, alley cropping and forest farming. In silvorable type, trees are planted at wider spaces either in rows or irregularly for timber, fodder, fuel wood and nuts production. Common species for timber and nuts includes *Pinus roxburghii, Pinus wallichiana, Cedrus deodara*, *Juglans regia, Pinus geordiana* and *Dalbergia sissoo.* Species like *Poplus ciliata*, *Robinia pseudoacacia*, *Quercus baloot*, *Ailanthus altissima*, *Morus alba*, Apple, Pears, Peach, Apricot, parceman, plums, Pomegranate are grown for fodder, fuel wood and fruits. Silvopastoral type integrates trees, grassland and livestock in the region. The most common tree species includes *Cedrus deodara*, *Pinus wallichiana*, *Pinus roxburghii*, *Monotheca buxifolia* and Poplus species. Trees are integrated either on the natural grassland or with fodder species like trifolium alfalfa. In some areas, fruits like plums, apricots, and apples are integrated with fodder crops. In agropastoral system integrate livestock and grassland. Under this system along the agriculture field fodder crops and trees are either sown or the natural fodder producing herbs, grass and shrubs are managed for livestock. Similarly, on the alpine pasture, temperate and sub-alpine grass land agriculture crop like maize and potato are grown. The agrosilvopastoral in the region combines trees, livestock and agriculture. Trees are grown for fodder, timber, fuel wood. It is a common

practice on the communal grassland and pastureland, where trees, with cops like maize and potato are grown on grassland.

Besides the above agroforestry systems, hedgerow systems also exist in the region. Around the agriculture filed species like *Salix tetrasperma*, *Rebus fruticosus*, Poplus, *Morus alba* and tall grasses are grown around the agriculture fields for fodder, protection and fuel wood. Trees like Poplus, eucalyptus are also plated in linear form along the edges as Shelterbelts and Windbreaks for fodder, protection form animals, wind and erosion. Trees are also grown between the floodplains and agriculture land as riparian buffer strips. At lower elevation Poplus is the most common tree, while at higher elevation Poplus, Salix and *Alnus nitida* are the common trees. Homestead is a common practice in the upper elevation, where trees, crops and livestock are integrated in fields around the home. In Alley cropping, crops are integrated between the rows of fruit trees. Forest farming is mostly common in the temperate regions, where potato crops are grown in canopy gaps.

Figure 1. Some Common Practices of Agroforestry in the region

Socio-economic benefits of trees on agriculture and rangeland

In HKH ranges, natural resources play an important role in the local livelihoods. Forest land in area provides 10% of livelihoods, while agriculture, livestock and rangeland contribute 31%, 13% and 3% respectively (Mannan, 2001; Ahmad et al., 2022a). Forest, farm and fruit trees on the range land provides multiple benefits such as fodder, fuel wood, nut and fruits. Trees on the rangeland and agriculture land bears a total growing stock volume of 17.70 million m^3 with a total biomass of 18.26 million Mg (Table 1; Figure 2). The annual fuel wood consumption in the region is about 5 Mg per house hold, of which 23% and 8% are fulfilled from trees on agriculture and rangeland respectively (Mannan, 2001; Ghani, 2017; Ahmad et al., 2022a). The per household timber requirement in the region is 9 to 15 m^3 (Ahmad et al., 2018; Ahmad et al., 2022a).

Though, local community extract their timber requirements form forest, farm trees are equally important in fulfilling timber needs. Similarly, trees, grass, and fodder crops on range and agriculture land fulfill 76% of fodder

requirements (Mannan, 2011; Ghani, 2017; Ahmad et al., 2022a). Fruits and nut trees provide about 0.08 million Mg of fruits and 0.03 million Mg of nuts each year (PESR, 2024).

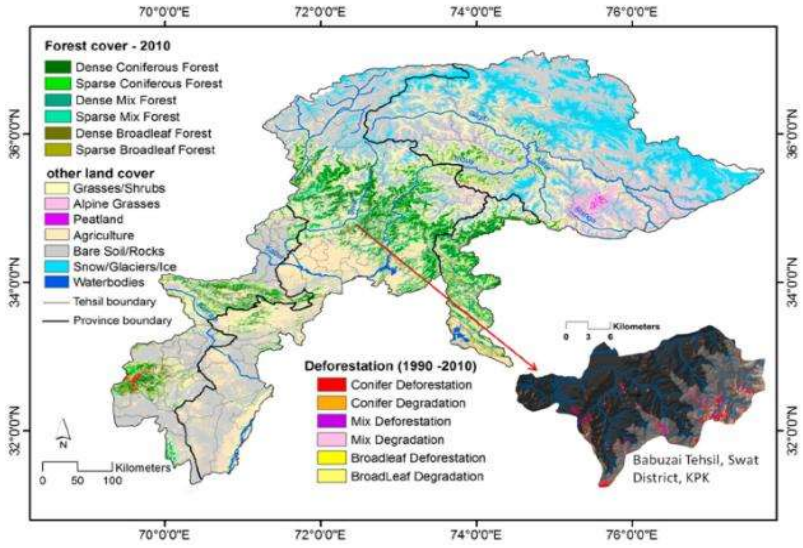

Figure 2. Land cover distribution (Qamar et al., 2016)

Table 1. **Land uses HKH ranges**

Land uses	Area million ha	%
Forest land	2.1	11.67
Agriculture land	2	11.11
Rangeland	4.1	22.78
Bare soil	7.3	40.56
Snow/Glaciers/ice	2.3	12.78
Water bodies	0.1	0.56
Total	18	100

Source: Qamar et al.,2016

Table 2: **Stocking and growing stock**

Land uses	Density ha^{-1}	Volume m^3 ha^{-1}	MAI m^3 ha^{-1}	T. MAI Million m^3	T. Trees Million	T. Volume Million m^3	T. Biomass Million Tons
Agriculture	37	4.4	0.2	0.4	74	8.80	9.08
Rangeland	17	2.17	0.1	0.41	69.7	8.90	9.18
Total	54	6.57	0.3	0.81	143.7	17.70	18.26

Source: (Ahmad et al., 2024; Mannan, 2011); MAI= Mean annual increment

Climate change mitigation potential

Growing farms, fruits and farm trees on AL and RL in the region is sequestrating and store large amount of carbon, thus playing crucial role in climate change mitigation. Collectively, trees on AL and RL sequester about 0.83 million Mg of carbon each year (Table 3). The total biomass carbon of the AL and rangeland is about 22.18 million Mg (Table 3), of which about 50% is contributed by trees (Table 3). Agriculture land in the area stored about 30 Mg C ha^{-1} in their soil, while rangeland hold about 36 Mg C ha^{-1} soil carbon (Ahmad et al., 2018). However, it is to note that rangeland and agriculture land without trees bears 13% less carbon soil as compared to rangeland and agriculture with trees (Shah et al., 2015). Besides carbon benefits, trees on the rangeland and agriculture land are important for stabilizing land surface temperature through cooling effects.

Table 3. Carbon sequestration and stock.

Land uses	Carbon sequestration	Biomass carbon	Soil carbon	Total carbon
	Million Mg per year		Million Mg	
Agriculture	0.41	7.83	62.58	70.41
Rangeland	0.42	14.35	146.083	160.43
Total	0.83	22.18	208.663	230.84

Source: Ahmad et al., 2018, Mannan, 2001

Conservation benefits

Natural resources in the region is a major livelihoods source. Forests in the region provide 10% to 15% of livelihoods (Mannan, 2001; Ahmad et al., 2022a). Similarly, local people get 50% of fuel wood form the forest, while 22% to 36% livestock feeding is carried out through grazing in the forests, and about 15% of fodder requirement are meet form forest (Mannan, 2001; Ahmad et al., 2022b). Forests in the HKH ranges also stored huge amount of carbon (Ahmad et al., 2022b; Baig et al., 2022). Although, forests in the area are under extreme biotic pressures, but agroforestry is subsidizing the local needs, thus play effective role in forest conservation. Agroforestry is playing an important role in the promotion and conservation of diversity in the region. Introduction of forests, farm and fruits trees on communal, agriculture and range land is not only enhancing species diversity, but also protecting natural diversity in the region by reducing biotic pressures on natural resources.

Agroforestry is also crucial in the controlling of deforestation and conservation of forest carbon in the area. In the region, deforestation is responsible for 55% of forest carbon lose, while wood harvest (commercial

and domestic) share 45% of total carbon loss (Ahmad et al., 2018; Ahmad et al., 2022b). Agriculture and settlement expansion, livestock grazing, blackwood marketing, and fuel wood harvesting are considered to be major drivers of deforestation (Ahmad et al., 2018; Zeb et al., 2019; Ahmad et al., 2022b). Agroforestry in the region makes a major contribution in meeting local needs for timber, fuel wood and fodder. Without agroforestry, deforestation and carbon forest loss will be even more.

Conclusion and recommendations

Agroforestry in the region provides enormous social, economic and environmental benefits and is important for the sustainable conservation of natural resources. Agroforestry is also security to local livelihoods, carbon diversity conservation, controlling of deforestation and rehabilitation of natural resources. Therefore, promotion of agroforestry in the region is required to secure maximum benefits. Increasing tree stocking on agriculture, rangeland and communal land, growing fruits and nuts will further enhance their benefits. Introduction of shorter rotation forestry and associated bye products/ services management like ecotourism, NTFPs, and small industries will also be useful to maximize their benefits.

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Scaling up Non-Timber Forest Products Enterprises for Sustainable Livelihoods and Climate Resilience in Khyber Pakhtunkhwa, Pakistan

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Background

Khyber Pakhtunkhwa (KP) is one of the most beautiful provinces of Pakistan, blessed its mountains, rivers, valleys, and rich culture. Around 40 million people live here, speaking different languages like Pashto, Hindko, Kohistani, Chitrali, and Urdu and known for their hospitality, crafts, music, and strong traditions. The economy of KP depends a lot on agriculture, forests, hydropower, tourism, and natural resources. Tourists from all over the country and the world visit valleys like Swat, Kaghan, and Chitral to enjoy their scenic beauty. At the same time, forests and mountains are the backbone of livelihoods for local people, providing fuel, food, fodder, and income.

Among these resources, Non-Timber Forest Products (NTFPs) include medicinal plants, fruits, nuts, honey, resins, and many other products are very important. These resources not only support rural families but also help in protecting forests and building resilience.

A Brief History of Forest Management in Khyber Pakhtunkhwa

Forest management in KP has a long history. It started during the British era in 1867, when forests were mainly seen as a source of timber for railway tracks and army camps. Over time, the system changed. In the 1970s, the government stopped the contractor system and set up the Forest Development Corporation. Later, new approaches such as Joint Forest Management and Community-Based Forest Management were introduced to involve local people. In 2007, the management of NTFPs became a formal part of the Forest Department's work. This step was important, as people realized that forests are more than timber; they provide many other resources that can improve lives without destroying forests.

Forest Types

Khyber Pakhtunkhwa (KP) is home to a wide range of forest types, from pine forests in the lower mountains to moist temperate forests in Swat and Hazara, and high-altitude sub-alpine forests in Dir and Chitral. There are also oak forests, olive groves, and riverine forests in the plains. Each type of forest supports different plant species and provides different NTFPs. For example:

1. Chir Pine forests give timber, resin, and fuelwood.

2. Dry temperate forests in Chitral and Dir provide valuable trees like deodar and juniper.
3. Oak and wild olive forests are used for fodder, firewood, and soil protection.
4. High mountain forests support unique plants like birch and yew.

Consequent upon this diversity, KP province is rich in NTFPs.

The Role of NTFPs in Livelihoods Support

For rural families, NTFPs are not just small side products, but the main source of cash income. Medicinal and aromatic plants are collected from the mountains and sold to traders. Chilghoza nuts from Chitral and South Waziristan are sold at high prices in national and international markets. Honey, resins, gums, and wild fruits also contribute to family earnings.

Importantly, when people earn from NTFPs, they cut fewer trees for timber and firewood. This reduces pressure on forests and allows them to regenerate. In this way, NTFPs link conservation with livelihoods.

Community-Based Enterprises

One of the best approaches introduced by the NTFPs Directorate is the idea of Community-Based Enterprises (CBEs). These are small businesses run by local communities, focusing on NTFPs.

How do they work?

1. Local collectors are trained in sustainable harvesting, so plants and forests are not damaged.
2. Communities learn how to clean, dry, and process products to increase their value.
3. They are supported in packaging and marketing so they can sell directly to customers instead of middlemen.
4. NTFPs outlets are established to connect them with bigger markets.

This system gives people fairer income, reduces over-harvesting, and builds local capacity.

Challenges in Scaling NTFPs

Despite their potential, there are many challenges in expanding NTFPs:

1. Markets are not well organized, so producers often depend on middlemen.
2. Communities lack access to finance, modern tools, and technology.
3. Policy and institutional gaps.
4. Lack of awarness and capacities.

These issues slow down the growth of NTFPs-based enterprises.

Opportunities Ahead

On the positive side, there are also many opportunities:

1. Strengthening value chains can connect producers to bigger, fairer markets.
2. Agroforestry models can integrate NTFPs with farming systems.
3. Supportive policies can encourage sustainable practices.
4. Community enterprises can be promoted across districts, giving people ownership and benefits.

By focusing on these opportunities, NTFPs can play a much larger role in KP's development.

NTFPs and Climate Resilience

Climate change is a major challenge for mountain communities. Floods, GLOF, droughts, and changing weather patterns threaten their livelihoods. NTFPs help communities become more resilient by:

1. Providing diverse sources of income so people are less vulnerable.
2. Supporting soil fertility and water conservation.
3. Encouraging biodiversity and reducing deforestation.
4. In simple terms, NTFPs help both people and nature adapt to a changing climate

Case Study: Chitral (Chilghoza Enterprise)

Kalash Valley Birir is one of the Kalash valleys having Chilghoza forests and source of livelihood for local people, Mr. Shams Ur Rabbi, 42 years, a pine nut collector who once sold Chilghoza cones to middlemen for just Rs. 1,500 per 4kg bag. Even after all his hard work in the forest, his income remained meager, and the unsustainable harvesting practices were also unscientific.

Everything began to change when the NTFP Directorate with the Community-Based Enterprise (CBE) model in the valley. Introducing Shams ur Rabbi and other community members received training in sustainable harvesting, processing, and marketing. They were also provided with Chilghoza harvesting toolkits and access to a modern processing and packaging unit.

With these new skills and facilities, Shams ur Rabbi started processing the nuts himself, packing them under the NTFP-CBE brand, and selling through the NTFP Outlet. The results were life changing. Instead of Rs. 1,500 per 4 kg bag, he now earns around Rs. 10,000–11,000 per kg selling 250 grams of premium Chilghoza for Rs. 2,000. In the 2024 harvest season alone, he earned over Rs. 1.3 million.

"*Before the CBE, I used to sell Chilghoza cones for a small amount and never*

imagined how valuable they really were. Now, with proper training and facilities, I process and sell my own product — earning a good income while protecting our forests. This project has changed not just my livelihood, but the future of our community." Mr. Sham ur Rabbi, Chilghoza Collector and Trader, Kalash Valley Birir"

For him, this is more than income _ it's empowerment. Sustainable harvesting has improved forest health, women are now involved in sorting and packaging, and the community sees the true value of their natural resources (Figure 1).

Mr. Sham ur Rabbi's story is a powerful example of how local NTFP-based enterprise, when guided by knowledge and community spirit, can transform lives and forest landscapes alike.

Figure 1. Picking drying and packing and marketing of Chilghoza

Way Forward

Looking ahead, a regional and collaborative approach under the framework of SAARC can play a vital role in promoting Non-Timber Forest Products and agroforestry across South Asia. The following key actions are recommended:

Strengthen Regional Cooperation on NTFPs and Agroforestry

SAARC member countries share similar ecosystems, cultural practices, and forest-based livelihoods. Establishing a SAARC NTFP and Agroforestry Network can foster cooperation in policy harmonization, knowledge exchange, and regional trade facilitation. Joint initiatives may include cross-border research, training programs, and standardization of quality and

certification systems for NTFP products such as medicinal plants, nuts, resins, and essential oils.

1. Train and Empower Rural Communities

Capacity building of rural and forest-dependent communities is crucial for sustainable resource management. Through SAARC collaboration, training modules and exchange visits can be organized for collectors, farmers, and community enterprises. These should focus on sustainable harvesting, value addition, packaging, quality improvement, and entrepreneurship skills, ensuring that local people—especially women and youth—are directly involved and benefit economically.

2. Support Research, Innovation, and Technology Transfer

Research institutions across the SAARC region should collaborate on identifying high-value NTFPs, developing climate-resilient agroforestry models, and improving post-harvest and processing techniques. Regional research grants and innovation hubs could be established under SAARC to promote eco-friendly technologies, product diversification, and bio-trade development.

3. Develop Enabling Policies and Fair Market Mechanisms

Governments of SAARC member countries need to frame policies that recognize NTFPs as economic commodities and promote community-based enterprises. Regional guidelines for certification, product traceability, and fair-trade practices can be developed to ensure equitable benefits for collectors and farmers. The establishment of a SAARC NTFP Market Platform would also enhance visibility and regional marketing opportunities for local products.

4. Promote Experience Sharing and South-South Learning

South Asia has a wealth of traditional knowledge and practical experience in NTFP management and agroforestry. SAARC should facilitate study tours, joint conferences, and knowledge-sharing forums among member countries. Learning from successful models—such as community forestry in Nepal, agroforestry innovations in India, and NTFP enterprises in Pakistan—can help replicate best practices across borders.

5. Foster Public-Private-Community Partnerships

Encouraging partnerships among governments, NGOs, research institutions, and private investors can accelerate the NTFPs value chain. Regional business forums and trade fairs under the SAARC umbrella could link producers with buyers, attract investment, and promote regional branding for forest-based products.

6. Promote Climate Resilience and Biodiversity Conservation

Integrating agroforestry and NTFPs management into regional climate and biodiversity strategies will support ecosystem restoration and carbon sequestration efforts. SAARC can mobilize funding from global climate mechanisms to scale up these initiatives, contributing both to livelihood enhancement and regional environmental stability.

Proceeding

Regional Experts Meeting on Role of Agroforestry in Improvement of Rural Livelihood and Build Climate Resilient Communities in the Region

Date: 23-25 September 2025
Mode: Virtual
Organized by SAARC Agriculture Centre (SAC), Dhaka, Bangladesh

SAARC Agriculture Center (SAC) organized a 3-day regional expert meeting in virtual mode on the "Role of Agroforestry in Improvement of Rural Livelihood and Build Climate Resilient Communities in the Region" The program has been approved by 15th Governing Board meeting and endorsed by 59th Programming Committee meeting of the SAARC Agriculture Centre, Dhaka, Bangladesh.

Background

South Asia is home to more than 40% of world's poor and one in every five people is undernourished (UN, 2018 report). South Asia has 14% share of global arable land, and it is annually shrinking at an alarming rate due to salinization, desertification, floods, erosion and infrastructure development. Indeed, the ongoing degradation of soils and ecosystems in our region threatens the sustainability of food production. As such, we have daunting tasks to produce enough food to feed 1.7 billion populations, which is 24.75% of global population and the growth rate of our population is higher than global average. Conventional agriculture is the mainstream approach to producing enough food, but has come under increasing threat, due to the worsening climatic and environmental conditions, land and soil degradation, enhanced by a huge population pressure on limited resources. Diversification of agricultural practices is important to achieve food security and improve rural livelihoods and at a same time builds climate resilience. Agroforestry is one of the sustainable agricultural systems practiced in South Asia since time immemorial and its traditional and indigenous knowledge play an important role as extension and training in rural communities. Agroforestry, as a science and practice, has the potential to contribute to the improvement of rural livelihood, due to the capacity of its various forms to offer multiple alternatives and opportunities to smallholders to enhance farm production and income, while protecting the agriculture environment (FAO, 2004). It is also one of the most multifunctional forms of agriculture, where trees and

agricultural species grow on the same piece of land (Garrity et al., 2015) and increase resilience of crops and farm livelihoods, especially among the most vulnerable food producers. It enables smallholder farmers to cater to their subsistence need of food, fuel wood, fodder, fibre, medicine and timber; to create employment opportunities and provide substantial cash incomes which could be used in food, if in case the crop failed. It helps restore degraded land, wasteland and fallow land, improve soil fertility, address problems of nutrition, energy and environment.

Rationale

There are number of studies carried out in the SAARC region on improvement of rural livelihoods through agroforestry practices and its benefits in multifunctional forms. The study conducted by Singh et al., (2018) found that agroforestry practiced by the farmers of Jharkhand generated significant cash income which in turn contributed to the improvement of their livelihoods, beside improving soil fertility and reaping other environmental benefits. A case study of Dhading district in Nepal concluded that agroforestry system has contributed to biodiversity conservation and production of diverse products to maintain the sustainable livelihood of farming households. Similarly, Hanif et al., (2018) carried out study in Northern Bangladesh found that farmers livelihoods improved enormously by practicing agroforestry as they have more access to food, fodder and fuel wood which is reflected by greater access to livelihood capitals. Therefore, it is of utmost importance to assess the role of agroforestry in the improvement of rural livelihoods at regional level and identify barriers of scaling-up and enhancement of agroforestry practices effectively in our region. South Asia is one of the most vulnerable regions in the world to climate change in view of the huge population, large number of poor facing food insecurity, inappropriate soil and management practices on marginal lands leading to increasing rates of land degradation and the impacts of climate change on agriculture (Hossain et al., 2016).

Climate variations in South Asia will be varied and heterogeneous, with some regions experiencing more intense precipitation and increased flood risks, while others encounter sparser rainfall and prolonged droughts. Climate change will likely have significant livelihood impacts on the smallholder farmers in our region and further exacerbate food insecurity and poverty. Agroforestry can help build climate resilient communities because it absorbs some of the climate change impacts and develop resilience to floods and drought, contributing to a more robust livelihood system. It is considered as one of the most effective means to mitigate and adapt climate change impacts. The enhancement of agroforestry program in our region was recommended by ‘A Policy Paper on Common Challenges and Priorities in SAARC Region”

(2017), 'Multi-sectoral Program Development Consultation Meeting (2018) and SAARC Agriculture Ministers' Meeting in Thimphu (June 2018). Moreover, this agroforestry program is inline with the 'Regional Context' of 'Agroforestry: The Way Forward' developed as outcome of the Regional Consultation Meeting in 2015, New Delhi, India. Therefore, SAC has taken the initiative to arrange the Regional Experts Meeting on the Role of Agroforestry in Improvement of Rural Livelihood and build Climate Resilient Communities in the face of climate change in SAARC Region. The information and ideas generated through this regional expert meeting will be used to develop a regional project on enhancement of agroforestry in the region, which is directed by the Thimphu Statement on Agriculture and Rural Development (June 2019). Objectives: Assessing the role of agroforestry practices in improvement of rural livelihood in the region; evaluating the contribution of agroforestry for building climate resilient communities; and identifying barriers to scale-up agroforestry practices in the region.

Execution

The three-day regional expert meeting was held virtually from 23-25 September 2025. Focal points of SAARC member countries namely Bangladesh, Bhutan, Nepal, Pakistan and Sri Lanka presented their country status report on agroforestry and its role in improving rural livelihoods and climate resilience. Researchers, practitioners, and academia from different international organizations, INGOs, universities shared their insights in the context of meeting objectives. International organizations such as Asia Pacific Network (APN) of Agroforestry, Switzerland, RECOFTC-Nepal, Alliance for Agri-Food/Forest Action-Nepal, WWP-Pakistan, Gazipure University-Bangladesh, Bangladesh Agriculture University, Central Research Institute for Dryland Agriculture, Hyderabad, India, Shaheed Benazir Bhutto university, Dir, Khyber Pakhtunkhwa, Director NTFP, Khyber Pakhtunkhwa, Pakistan and University of Peradeniya, Sri Lanka participated in the virtual meeting and share their thoughts about the status of agroforestry in the region and strategies and approached to scale up in respective countries.

Inaugural Session

The meeting was moderated by Dr. AHM Taslima, STO, SAC started the meeting by welcoming participants to a three-day regional expert meeting on agroforestry's role in improving rural livelihoods and building climate-resilient communities in the SAARC region. Program coordinator, and Senior Program Specialist (NRM) Dr. Raza Ullah Khan welcomes the participants of virtual meeting, by highlighting the importance of agroforestry in South Asia, Dr Khan underlined the climate change and other socio-economic challenges face by the region, and stress upon transition to agroforestry system in South Asia. Dr. SK Dhyani, Senior Fellow CIFOR-ICRAF, was the

keynote speaker of the event. Dr. Dhyani highlighted the role of agroforestry in addressing climate change impacts and promoting sustainable development in South Asia. Agroforestry, which integrates trees with crops and livestock, offers solutions for food security, water conservation, and carbon storage and need for policy mainstreaming, institutional mechanisms for planting material production, and public-private partnerships to scale up agroforestry Dr. Dhyani added. He further added that South Asia will experience a 50% increase in food demand by 2050, since South Asia cannot afford to convert cropland into forests, hence agroforestry can be instrumental by creating a conducive conditions for sustainable agriculture.

Special Guest Mr. Tanvir Ahmad Torophder, Director (ARD &SDF), SAARC Secretariat, Nepal emphasized the potential of agroforestry to address climate change and improve rural economies, called for the supportive policies and regional cooperation to let agroforestry play its significant role. Chief Guest Dr. Md. Mahmudur Rahman, Additional Secretary (PPC), Ministry of Agriculture, Bangladesh highlighted successful agroforestry initiatives in South Asia, cited success stories and agroforestry models from Bangladesh. Dr. Mahmudur Rehman stressed upon the need for further development and implementation of agroforestry practices to tackle regional challenges of climate change and rural development.

Technical Session

The first technical session of day-1 was chaired by Dr. M. Saifullah, Member Director (A&F), BARC. The session is titled Stocktaking on Agroforestry Role in Improving Rural Livelihood and Climate Change Resilience.

The technical session starts with country presentation from Bangladesh by Dr. Kazi Noor-E-Alam Jewel, PSO, BARC. Dr. Jewel gave an overview of Bangladesh's land use, forest coverage, and agroforestry practices and highlighted the country's challenges, including deforestation and loss of agricultural land, and introduced various agroforestry models developed by institutions like BARC and BAU. Ms. Ganga Maya Rizal from Bhutan presented on their country's agroforestry practices, noting that 70% of Bhutan is covered by forest and discussing the challenges and opportunities faced in implementing agroforestry systems. Both presentations emphasized the importance of integrating trees with crops and livestock to enhance food security, biodiversity, and climate resilience. Mr. Surya Prasad Baral presented on Nepal's agroforestry systems, highlighting the country's diverse landscapes and the integration of trees with agricultural crops. They discussed various agroforestry models, case studies, and the challenges and prospects of implementing agroforestry practices.

Dr. Roland Frutig from Asia Pacific Agroforestry network talked about ways out of deficit Agriculture Toward Resilient Food Systems, and discussed the

foundation and development of agroforestry initiatives, focusing on capacity building and plant material supply in India and Africa. He highlighted the complexity of agroforestry systems, particularly with subsistence farmers, and emphasized the importance of water, carbon, and nutrient cycles in agriculture. Dr. Frutig also addressed the challenges of water scarcity and the potential of agroforestry to regenerate degraded lands, particularly in arid zones. He concluded by emphasizing the economic benefits of agroforestry, including the multiplication of grasses for income generation, and the adaptability of agroforestry systems to various climate zones.

Participants discussed challenges in agroforestry, including seed availability and quality, with Dr. Frutig noting the need for partnerships to address these issues. The conversation ended with plans for further discussions and collaborations over the next two days.

Agroforestry Initiatives in Pakistan

Presenter: Dr. Umar Farooq

Key Points:

- Pakistan faces serious land management challenges, including arid climatic conditions, deforestation, and climate change-induced disasters such as recent floods that displaced millions.
- Agroforestry initiatives include the Billion Tree Tsunami Project (2014), which successfully restored forest cover, created rural employment, and provided climate resilience benefits.
- Challenges: weak market links, limited extension services, and inadequate policies.
- Proposed solutions: formulation of supportive policies, provision of financial incentives, and increased research investment.
- WWF Pakistan's initiative: plantation of 1.4 million acacia and 2,055 fruit plants with a 63.6% survival rate, engaging 20,000 farming families and rural women in nursery development and beekeeping.

Agroforestry Practices in Sri Lanka

Presenters: Ms. CH Piyasiri, Ms. PD KD Jayarathna

Key Points:

- Sri Lanka's diverse agroclimatic zones support a variety of agroforestry systems, contributing to greening efforts and combating climate change.
- Benefits: biodiversity conservation, ecosystem services, and livelihood support.
- Challenges: deforestation, biodiversity loss, and lack of farmer incentives.

Recommendations: establishment of a national agroforestry policy, enhanced financial incentives, and promotion of farmer–researcher partnerships.

- Practical challenge in dry zones: farmers hesitant to plant trees due to root intrusion concerns. Suggested solution: careful selection of suitable tree species and models such as alley cropping.

Agroforestry and Agroecology in Nepal

Presenters: Sudha Khadka, Country Director, RECOFTC, Nepal and Sujata Tamang, Alliance for Agri-Food/Forest Action

Key Points:

- RECOFTC promotes context-specific agroforestry systems through capacity building, partnerships, and municipal-level collaboration.
- Forest Action Nepal focuses on community-led research and innovation, promoting transitions from agroforestry to agroecology to address soil degradation and climate change.
- Emphasis placed on participatory approaches, locally tailored systems, and farmer empowerment for sustainable adoption.

Discussion:

- Participants highlighted the need for stronger knowledge exchange across South Asia.

Suggested initiatives

- Sharing successful practices via documentaries and demonstration site visits (Dr. Gamini).
- Using digital platforms and virtual site tours (Dr. Raza).
- Exploring global linkages such as Africa–South Asia knowledge exchanges and outreach through YouTube platforms like “Agroforestry Power Ladies” (Dr. Roland).
- Bhutan raised the need for fodder tree germplasm (legumes for dairy livestock). SAC offered to discuss possibilities for material exchange within SAARC member states.

Agroforestry for Climate Change Adaptation – South Asian Perspective

Presenter: Dr. Abiar Rahman, Gazipur Agricultural University, Bangladesh

Key Points:

- Agroforestry is a critical strategy for enhancing climate resilience, food security, and rural livelihood improvement in South Asia.

- Successful models: homestead gardens, multi-story agroforestry systems, and community-based agroforestry practices.

Emphasis on:

- Policy support for wider adoption
- Market development to encourage farmer participation
- Research collaborations among universities and institutions to strengthen agroforestry education and policy.

Concluding Remarks

The meeting reaffirmed agroforestry's significance in addressing climate change, improving livelihoods, and enhancing ecological sustainability in South Asia. While challenges such as weak policy frameworks, market gaps, and farmer hesitancy remain, the discussions highlighted clear pathways forward:

- Development of national and regional agroforestry policies
- Enhanced financial and technical support for farmers
- Investment in research, education, and demonstration sites
- Promotion of regional knowledge sharing and germplasm exchange

The participants emphasized that with coordinated action and stronger regional collaboration, agroforestry can play a transformative role in building climate-resilient rural communities in South Asia.

SAARC Agriculture Centre

Regional Experts

Role of Agroforestry in Improvement of Rural Livelihood and Build Climate Resilient Communities in the Region

Date: 23-25 September 2025
Mode: Virtual
Organized by SAARC Agriculture Centre (SAC)

Program Schedule
Meeting Time: 23-25 September 2025 (10:30 am to 14:00 pm BST)
Moderator: Dr. AHM Taslima, STO, SAC

Day 01 (23 September 2025)

Time	Particular	Speaker
Inaugural Session		
10:30 - 10:40	Welcome & Opening Remarks	**Dr. Raza Ullah Khan**, SPS (NRM), SAC
10:40 - 10:50	Introduction	**All Participants**
10:50 - 11:00	Objectives and overview of program	**Dr. Raza Ullah Khan**, SPS (NRM), SAC
11:00-11:20	Agroforestry as a Strategy for Addressing Climate Change Impacts, Promoting Inclusive and Fostering Sustainable Development in the Region - **Keynote Speaker**	**Dr. Dhyani Shiv,** Fellow CIFOR-ICRAF
11:20-11:25	Remarks by the Special Guest	**Mr. Tanvir Ahmad Torophder** Director (ARD&SDF), SAARC Secretariat, Nepal
11:25 -11:35	Remarks by the Chief Guest	**Dr. Md. Mahmudur Rahman,** Additional Secretary (PPC), Ministry of Agriculture, Bangladesh **Member,** GB-SAC from Bangladesh
11:35-11:45	**Break (10 minutes)**	
Technical Session-I		
Stocktaking on Agroforestry Role in Improving Rural Livelihood and Climate		

Change Resilience
Chair: Professor Dr. Md. Abdur Rahim, Head of the Department of Agricultural Science at Daffodil International University (DIU)
Rapporteurs: SPO (NRM)

11:45-12:10	Presentation from Bangladesh	**Dr. Md. Saifur Rahman, Dr. Kazi Noor-E Alam Jewel** Focal Persons, Bangladesh
12:10-12:35	Presentation from Bhutan	**Ms. Kesang Tshomo, Ms. Ganga Maya Rizal** Focal Persons, Bhutan
12:35-01:00	Presentation from Nepal	**Mr. Surya Prasad Baral, Mr. Jibraj Paudel** Focal Persons, Nepal
01:00- 01:10	**Discussion, Q &A**	
1:10 - 1:35	Agroforestry - Ways Out of Deficit Agriculture Toward Resilient Food Systems	**Dr. Roland Frutig** Agroforestry Promotion Network
1:35 – 2:00	**Discussion, Q & A**	

Day 02 (24 September 2025)

Technical Session-II

Time	Particular	Speaker
Stocktaking on Agroforestry Role in Improving Rural Livelihood and Climate Change Resilience **Chair: Dr. Md. Saifullah, Member Director (A&F), BARC** **Rapporteurs: SPO (NRM)**		
10:30-10:55	Country paper presentation of Pakistan	**Dr. M. Umer Farooq, Dr. Khalid Rafique** Focal Persons, Pakistan
10:55-11:20	Country paper presentation of Sri Lanka	**Ms. CH Piyasiri, Ms. PD KD Jayarathna** Focal Persons, Sri Lanka
11:20-11:45	Agroforestry for Resilient Ecosystems and Communities: Lessons from RECOFTC'S Community-Centerd Approach.	**Sudha Khadka** Country Director, RECOFTC, Nepal
11:45 - 12:10	Greening Communities and Combating Climate Change with Agroforestry- Sri Lankan Experience	**Prof. D.K.N.G Pushpakumara** Uni. Peradeniya, Sri Lanka
12:10 - 12:35	Fostering Agroecological Practice through Community led Research and Innovation	**Dr. Sujata Tamang** Alliance for Agri-Food/Forest Action
12:35 – 01:00	**Discussion, Q & A**	
01:00-01:25	Cultivating Biodiversity:	**Muhammad Irfan,** Manager, Food

	Sustainable Agroforestry for Cotton Farmers	and Agriculture Program | WWF-Pakistan
01:25 - 01:30	**Break**	
01:30 - 01:55	Agroforestry for Climate Resilience and Socio-Economic Sustainability in South Asia	**Prof. Dr. Abiar Rehman**, Gazipur Agricultural University, Bangladesh and Country Director ICRAF-CIFOR
01:55 - 02:10	**Discussion, Q & A**	
Day 03 (25 September 2025)		
Technical Session-III		
Time	**Particular**	**Speaker**
Chair: Mr. Farid Uddin Ahmed, Ex -Member Director, BARC **Rapporteurs: STO and SPO (NRM)**		
10:30-10:55	Agroforestry for improving Rural Livelihood and Climate Change Resilience: Experiences in rainfed areas of India	**Dr. VK Singh**, Director, Central Research Institute for Dryland Agriculture, Hyderabad, India
10:55-11:20	Socio-Economic Importance and Climate Change Mitigation Potential of Agroforestry in the HKH Ranges of Pakistan	**Dr. Adnan Ahmad,** BBU University of Upper Dir, Pakistan
11:20 - 11:45	Agroforestry and Ecosystem Service: A Way to Mitigate Climate Change Impacts	**Dr. Kazi Kamrul Islam**, BAU, Bangladesh
11:45-11:50	**Break**	
11:50-12:15	From Forest to Market: Scaling up NTFP Enterprises for Sustainable Livelihoods and Climate Resilience in Khyber Pakhtunkhwa with **video clip**	**Rashid Hussain,** Director NTFPs, Khyber Pakhtunkhwa, Pakistan
12:15-2:00	**Brainstorming Session** **Chair: Dr. Md. Baktear Hossain, Member Director (NRM), BARC** **Rapporteurs: STO and SPO (NRM)**	

Zoom Banner

Social Media Circulation

LinkedIn and Facebook

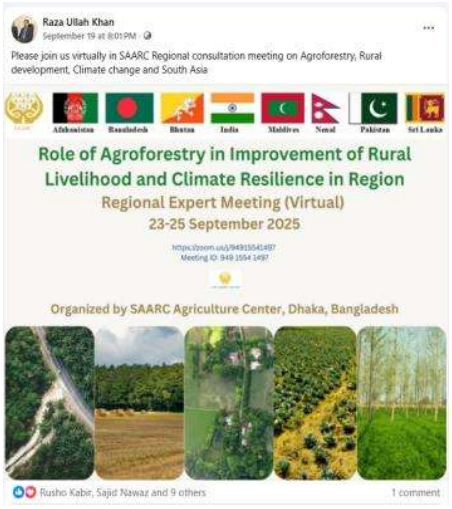

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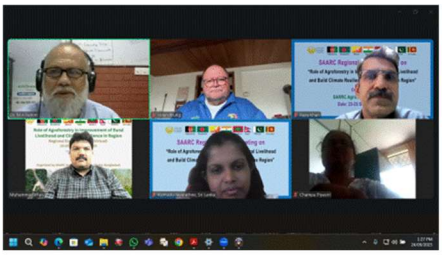
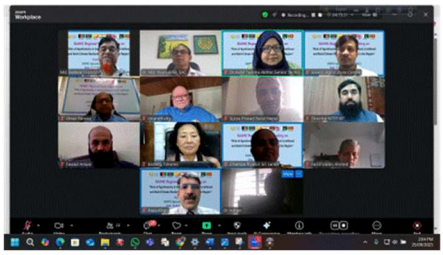
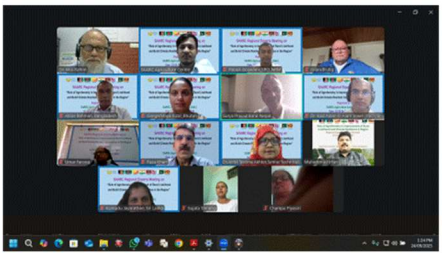
Photo Gallery


Glimpses of online Regional Expert meeting on Role of Agroforestry in Improvement of Rural livelihood and Climate Resilient Communities in South Asia

A few slides from Guest Speaker's presentation

Ways out of Deficit Agriculture
Roland Frutig, agroforestry consultant, Switzerland
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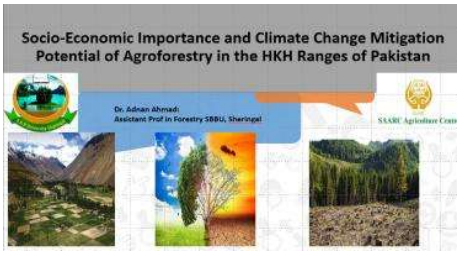
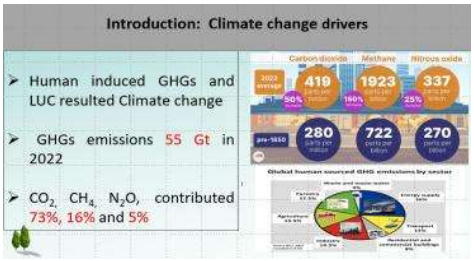
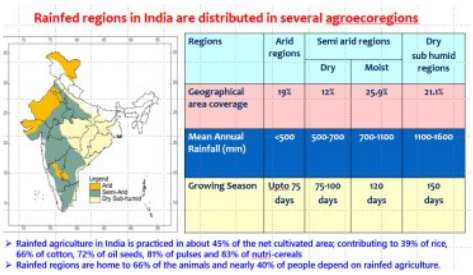
/roland.frutig@bluewin.ch







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