

## Review Article

# Enhancing Food Security through Agroforestry for Sustainability – A Review

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## ABSTRACT

Adequate and property access to income and resources such as adequate access to food, potable water, health facilities, and education to fulfill basic desires is livelihood. Sustaining livelihood is most serious challenge round-faced by policy and decision-makers in current state of affairs. During this context land-use choices that sustain livelihood security and lessen susceptibility to environment and environmental modification are necessary. The accord is that we tend to currently want an agriculture that may “multi-functionally” increase food production whereas at the same time, as dedicated to policy objectives, improving environmental and social issues. Together with global climate change, soil depletion, and market unpredictability, farming must become even more resilient to numerous insecurities, all of which reduce property and may worsen hunger. Agroforestry will play a serious role in bringing the required level of diversification together with sustainability. Agroforestry has the probable to supply food security and facilitate to poverty reduction together with its contribution to atmosphere security viz. conservation, carbon sequestration are extremely necessary. Traditional agriculture and its management, such as agro-forestry methods, will certainly provide choices to increase livelihoods by coincidentally generating food, fodder and fuel in the same way as mitigating the effect of global climate change. Currently, governments and organizations have an opportunity to re-balance agricultural policy and expenditure towards such multi-goal approaches. In doing so, the requisite improvements to multiple international obligations can be accomplished around the interlinked themes of food security, climate change, conservation of diversity and social well-being.

### Keywords

Agroforestry,  
Livelihood, Food  
security,  
Sustainable  
development

## Introduction

According to the World Food Programme (WFP), that says the amount of individuals facing crisis hunger is anticipated to virtually double this year to 265 million. Already,

quite 820 million individuals don't get enough food to eat, and another a hundred thirty five million individuals face acute hunger or starvation. Increase that, the economic destabilization caused by COVID-19, and another a hundred thirty million

people are in danger of hunger by the top of 2020, says WFP. The quickness with that a health crisis transforms in an exceedingly hunger crisis shows however fragile is our food systems to shocks of any nature. Over 800 million individuals were undernourished in 2019 – a majority living in low-income countries.

With the pandemic, vulnerable households' ability to shop for basic food can decline, similarly as their risk to earn a daily income. several countries full of food insecurity – as an example within the Horn of Africa, West Africa, Latin America and parts of Asia – have key agricultural seasons beginning around world Food production is vulnerable by preventive measures taken against Covid-19 consequently reduced farmers ability to access inputs, labour or credits. A discontinuous food production chain might reduce confidence within the reliable flow of basic food commodities that might rock the markets and near food costs.

Thus, there's an at hand risk that the pandemic can have devastating consequences for individuals living in low-income countries, with long-run repercussions on people's diets and livelihoods. Forests, plants and agroforestry give important contributions to Food Security and Nutrition (FSN). All of those contributions are even additional necessary in times of crisis. They contribute to livelihoods and to the diversification of production and sources of financial gain therefore additionally increasing the resilience of households.

They supply ecosystem services -water regulation, soil fertility and conservation, pollination, temperature regulation- that support farming systems and contribute to their adaptation to climate change. They're a necessary element of property and resilient food systems, contributively to the four

dimensions of nutrition retreat and food each for the forest-dependent communities and globally. Agroforestry – a distributed land management system within which trees or shrubs are grown up around or among crops or grassland – will pay to diet safety and additional nutrient diets by contributing to improved diverseness and nutrition, higher yields, and additional various livelihoods for farmers.

This combination of agriculture and forestry will build a spread of healthy foods obtainable, whereas at a similar time causative to additional property food production systems that also are additional resilient to environmental shocks and will upsurge the flexibility of vulnerable teams in times of crisis. When done properly, the inclusion of trees in agriculture will guarantee continuing access of nutrient foods for the foremost vulnerable populations, similarly as sustained functions of native food markets, price chains and systems.

Whereas hoping on one crop tends to guide to food insecurity and singular financial gain bursts, a diversity of crops will give an additional nutrient-rich diet, shut the hunger gap between harvests of staple crops, and make opportunities to earn an additional stable financial gain. During this crisis, it's important to support vulnerable smallholder farmers and food staff similarly because the entire food supply particularly for vulnerable urban areas. A number of these ways include; putting in place vegetable kitchen gardens and growing a spread of fast growing indigenous vegetables which don't need a lot of preparations and external inputs like cowpeas, amaranths, jute, cassava leaves.

Crops like *Moringa oleifera* mature within 6 months and therefore the leaves are extremely nutrient. Growing Short term trees that give food like pigeon peas is also

differently which will facilitate cushion in times of crisis; fodder trees that feed stock for nutrition like bush also will guarantee healthy stock and thus the supply of milk for youngsters and fresh mothers; leguminous plant *Sesbania sesban* and *Calliandra* trees area also fast maturing (less than one year) crops for provision of fuel wood and fodder.

The farmers but additionally would like future plans tree institution plans as they grow the short term trees for immediate edges to address the crisis. Farmers will invest in apiculture and tree nursery management for income-generating. As this pandemic has been started since begin of 2020, the most concern is food for sustenance and property for future. During this context, agroforestry play a significant role for manufacturing food, fodder and fuel to satisfy the necessity of the individuals within the world.

This review deals with however agroforestry fulfill the necessity of individuals additionally to keep up balance of the setting for property. This major challenge to world food security is that they ought to about double food production over consequent few decades, particularly thanks to rapidly growing demand from the developing world (Food and Agriculture Organization of the international organization (FAO), Godfray *et al.*, 2010; The Royal Society, 2009). To realize yield will increase, the employment of chemical inputs, genetic improvement, and mechanization has currently become typical, because of their success within the past (with the vital exception of Africa; Pretty and Bharucha, 2014).

However, typical agriculture has conjointly been a principal explanation for varied social and environmental issues as well as temperature change, loss of biodiversity and ecosystem integrity, land degradation, water insecurity, and disruption of social systems

(Godfray *et al.*, 2010; Maxwell, Fuller, Brooks, and Watson, 2016; Pretty and Bharucha, 2014). Consequently, there's currently in depth accord that we want to move away from the present, narrow focus on yield, and toward a lot of "multifunctional" agriculture that conjointly respects (and ideally enhances) broader social group and environmental goals, below the rubric property intensification (Godfray and Garnett, 2014).

Indeed, the continued deprivation of loams and environments intimidate the property of food production itself, as will world environmental modification (Amundson *et al.*, 2015; Foley *et al.*, 2011; Potts *et al.*, 2010; Tscharrntke *et al.*, 2011). Here, we tend to first counsel that the justifiable expansion objectives Griggs *et al.*, 2013; United Nation General Assembly, 2015) offer a broad and coherent framework for multifunctional agriculture, as this international agreement already combines food security (SDG2) with environmental, climate and sustainable objectives, underlining the need for a multi-targeted approach. We tend to then describe however an extremely multifunctional different already exists in agroforestry. We tend to shortly explore however typical agriculture tends to dominate as compared to alternatives like agroforestry, with multiple negative consequences. Finally, we tend to define issues in making a lot of acceptable balance of approaches.

One issue with a multigoal approach is that each agricultural possibility can have an effect on every individual goal otherwise (and each actor can provide completely different weight to the action of every goal). However, food is prime to human life, and then we tend to assume that multigoal agriculture should 1st be ready to increase yield sufficiently to satisfy the SDG of food security. Once that criterion is glad, the

choices that advance alternative SDGs most powerfully (or compromise them least severely) would receive priority.

Additionally, every agricultural approach can have an effect on the SDGs otherwise for completely different social groups and different geographies. Meanwhile food security and therefore the SDGs generally are significantly relevant to the developing world (United Nations General Assembly, 2015), we tend to focus our discussion on the small-scale agriculturalists UN agency represent over ninetieth of developing-world farmers (Graeub *et al.*, 2016; International Fund for Agricultural Development/United Nations Environment Programme (IFAD/UNEP), 2013) and conjointly the bulk of these living in economic condition (World Bank, 2015). Among that physical and human geographic, one in every of the foremost multifunctional types of agriculture is agroforestry: the combined production of trees and agricultural species on constant piece of land (Sahoo and Wani, 2019). Though it's usually been studied for its ecological advantages and peasant-farmer associations (Horlings and Marsden, 2011), scientific proof currently displays that the espousal of agroforestry will increase yields by an element of 2 (average 96% during a multistudy analysis; Pretty and Bharucha, 2014), betting on crop sort, native conditions, and level of experience (Waldron, Justicia, and Smith, 2015). These yield will increase are shown to replicate multiple system services provided by the trees, as well as increased soil nutrient standing (e.g., through chemical element fixation), condensed produce strain (e.g., finished abridged heat and precipitation extremes), reduced attrition (binding of soil by roots), and directive of water system (hydraulic uplift of problem by tree roots; Waldron *et al.*, 2015). What is more, the yield enhancements will be SDG (secure) consequently of agroforestry sustains soil

fertility and might smooth refurbish sullied properties (Leakey, 2014; Nair, 1993). Nevertheless, food security itself doesn't simply rely upon harvest (FAO, 2008; World Bank, 2015).

An extra essential element is resilience to climate change and to shocks (sudden, massive variations in weather, harvests, market costs, and input costs), which might cause major hunger crises (Chappell *et al.*, 2013; Orr and Mwale, 2016). Agroforestry will increase crop resilience to many probably temperature change effects, like drought or higher temperatures, subsequently it enhances water infiltration and storage whereas reducing evaporation and temperature extremes (Charles, Munishi, and Nzunda, 2013).

It conjointly will increase livelihood resilience resultantly the supply of free ecosystem services by the trees reduces dependence on unpredictable, distant commodity markets; once harvests are poor, the trees conjointly offer different sources of each income and food, as an example, fruit, fodder, or fuel (Thorlakson and Neufeldt, 2012).

Additionally to progressing food security, agroforestry may too augment several communal scopes of the SDGs. It offers a conduit obtainable of economic condition (a major driver of hunger itself; World Bank, 2015) properly the combination of accumulated yield, low cost, and extra tree-based farm product will considerably increase net farm (Miller, Munoz-Mora, and Christiaensen, 2017).

Additionally, farmer movements within the developing world have expressed a scarcity of equity and dignity within the manner their livelihoods will be negatively laid low with distant supply-chain actors, then have wanted

larger local management of nutriment creation (e.g., “food sovereignty”; Chappell *et al.*, 2013). In agroforestry, this sense of management, equity, and integrity in the workplace will be strengthened by decreased dependency on external chemical inputs and greater resilience to encourage fluctuations (Chappell *et al.*, 2013).

In addition, on-farm trees produce extensive fuel wood, reducing the need to cut down natural forests and jointly saving smallholder relationships (especially women) from walking long distances (sometimes > 20 km) in search of fuel, thus improving the well-being of women and freeing them from teaching and tending to children, offering farm labor, or producing addition to improvements (Kiptot, Franzel, and Degrande, 2014; Sharma *et al.*, 2016). The on farm supply of fuel-wood conjointly represents a crucial, hunger-related variety of energy security for rural communities, being low cost, promptly accessible, and basic to extracting decent calories from food.

### **Scenario study of relevant issues accountable for rural living calamity**

There is an earnest requirement for a sensible situation investigation of the different elements, which add to or are connected with the country jobs emergency, for its administration by asset reclamation cum-protection.

The scenario analysis of some important factors is recorded herein below.

### **Land degradation vis-à-vis livelihood scenario**

Land resources are subject to extreme qualitative and quantitative degradation, largely due to flawed land use practices, which are the main propeller of livelihoods. Rural agrarian livelihoods depend heavily on

natural resources, but a vicious circle of over-exploitation and land degradation has set in, which negatively impacts livelihoods. The severe degradation of land, with 57% of the total land area degraded on account of environmental and manmade reasons, such as soil erosion due to water runoff and loss of vegetative cover, over-use of chemicals in agriculture, and more intensive cultivation, is a key concern (IDFC, 2013).

Country agrarian vocations rely vigorously upon common assets, yet an endless loop of over-abuse and land debasement has set in, which contrarily impacts jobs. The serious debasement of land, with 57% of the complete land region corrupted because of ecological and artificial reasons, for example, soil disintegration because of water overflow and loss of vegetative cover, over-utilization of synthetic compounds in farming, and more concentrated development, is a key concern (IDFC, 2013).

The information (The World Bank, 2016) of most recent fifteen years: 2001 - 2015 uncovers simply 0.2% expansion in agricultural place where there is the nation, which is very inadequate to help the populace blast of the nation except if in any case the waste and neglected terrains are put to some beneficial reason. Land degradation is an anthropogenic induced process and poses biggest threat to livelihood security of the rural communities across the country. The fast decline in per capita land area, due to inheritances during successive generations, besides unrestrained land acquisitions/diversions for various non-agrarian purposes of the fast growing urbanization, forms a remarkable bottle neck for farming returns. All of these factors combined with increased rate of land degradation contribute towards to livelihood crisis, which can only be resolved by optimization of land productivity through multiple land use.

### **Farming vis-à-vis livelihood consequence**

Agriculture, a significant base for the provincial occupations of India, is under genuine dangers. For quite a long time, food instability, neediness and climatic difficulty have commended each other hampering vocations of the provincial poor, destabilizing supportable improvement of this nation. For sure, in the course of the most recent forty years rural creation has gone under expanding hazard because of the unfriendly atmosphere changes, land and soil corruption.

Over 70% of the provincial family units rely upon farming as their chief methods for occupation (Government of India, 2015). Little holder agribusiness faces numerous difficulties including low efficiency, high reliance on downpour took care of farming, instability of the conventional land residency framework and ecological debasement because of unreasonable agrarian practices in rustic India (Kumar *et al.*, 1999). As such little holder horticulture stays at low efficiency prompting high rate of destitution, low financial conditions and occupation stress among rustic little holder ranchers (Banyal *et al.*, 2011).

Huge decreases in flexibility may imply that the biological systems, on which jobs are based, separate, causing trouble (Government of India, 2006). Supportability of provincial vocations and flexibility of characteristic assets are two crucial directions of economical advancement of a nation. Raising interest and supply holes of rural produce advances deforestation and exhaustion of backwoods for food, creating an inconvenient neediness assets corruption endless loop.

Because of all that, rural creation has rarely coordinated the necessities of the individuals adding a lot to the country vocation emergency, which must be settled by

substitution of customary cultivating practices of occasional and mono-trimming frameworks with multitier incorporated numerous editing tree-crop plantations under agroforestry, for quick streamlining of cultivating yield per unit zone of land.

### **Forest vis-à-vis livelihood scenario**

Critical livelihood – forest linkage of a huge forest dependent population has been identified as one of the factors affecting forest degradation in India (Forest Survey of India, 2011). As per a few evaluations, India has generally been described as a low woods cover - low deforestation nation presented to huge direct-human prompted deforestation and corruption in recent many years (Ravindranath *et al.*, 2012). Quicker financial advancement of timberland inhabitants (generally living underneath the destitution line and confronting starvation) relies upon ranger service improvement.

Consequently, India's timberlands bridle a huge potential for business based exercises for the woods subordinate networks, in this manner overcoming any issues between poor people and woodland based market. With a particularly gigantic populace relying upon woodland for means occupation, the techniques for controlling backwoods corruption should be centered around decreasing the reliance by making elective vocation open doors for the timberland subordinate networks, giving elective advancements to diminish the hole popular and supply of timberland items by reception of reasonable reaping practices.

The provincial populace of India, having lion's share of minor and little ranchers, establishing around 70% of the all-out populace, are in propensity for supplementing the agrarian deficiencies from the backwoods assets, prompting subjective and quantitative

disintegrations in timberland. The timberland debasement and decreasing ranch efficiency, get enflamed by unreasonable reliance of the taking off populace, which prompts rage of occupations emergency. The new "Durban Declaration" (WFC, 2015) during the XIV World Forestry Congress, has underlined the significance of woodlands as major hotspot for food security and improved jobs and further added that the backwoods of things to come will expand the flexibility of networks by giving food, wood energy, safe house, grub and fiber; creating pay and work to permit networks and social orders to flourish; holding biodiversity; and supporting practical farming and human prosperity by settling soils and atmosphere and managing water streams. The reports (FAO, 2002) represent that one out of four of the world's poor depends straightforwardly or in a roundabout way on timberlands for their occupations.

Forest is significant common capital, which consolidates with different resources for support vocations, particularly among poor people (Sahoo and Wani, 2020). Individuals like to produce a lot of their vocations from woodlands since it is a suitable alternative; anyway for some, timberland reliance is frequently a last occupation resort (Byron and Arnold, 1999). Under such a circumstance restoration of the woods assets, by agroforestry, turns into the need of the period.

### **Agroforestry vis-à-vis livelihoods linkage scenario**

Agroforestry is a reasonable alternative for assuring business security by its different usufructs and administrations. This superb land use innovation offers an elective answer for address swamp profitability for asset obliged little holder farmers (Puri and Nair, 2004). Agroforestry innovations have widely been investigated and acquainted with small farmers in India for more than thirty years

(Bijalwan *et al.*, 2011). Agroforestry keeps on supporting occupation improvement through creation of food, grain, fuel wood and lumber and synchronous moderation of the unfriendly effect of environmental change (Islam and Quli, 2016).

Notwithstanding exploration and augmentation endeavors during most recent couple of many years numerous little holder ranchers have still not embraced agroforestry innovations because of numerous quandaries (Dagar, 2012). Notwithstanding grand commitment, the appropriation level of agroforestry frameworks by little ranchers is as yet insufficient (Islam and Quli, 2016). Nonetheless, except if ranchers generally embrace these advances as a component of their cultivating framework, the possible advantages of agroforestry on occupations and the climate won't be acknowledged (Ali and Chaturvedi, 2008).

### **Agroforestry for resolving rural livelihood crisis**

At a stage when the ecological censorship has acclaimed global unanimity, the rationale of deliberation on sustainable land-use through agroforestry, becomes very pertinent (Quli and Singh, 2011). A necessity for modification in farming for improving economy and sustainability has been emphasized (Government of India, 2001). Diversification of agriculture by other land use systems like forestry, animal husbandry, horticulture and fisheries etc., also has been envisaged, to make it more lucrative and ecologically sustainable (Swaminathan, 2001).

The National Agriculture Policy 2000 emphasizes the need for agricultural diversification by encouraging the integrated and holistic growth of watershed rainfed areas and by increasing the production of

biomass through agro-forestry and farm forestry with community participation. Recessions in national forestry and agricultural sectors have necessitated “multifunctional approach to agricultural farming practices” based on integration of interventions like forestry and animal husbandry into conventional agriculture.

Indian Economy has been exposed to challenges due to soaring population, widening demand-supply gap of livelihood essentials i.e. food, fodder, fuel, fruit and variety of NTFPs consequent to natural resource degradation and adverse climate change. Agroforestry having synergistic integration of several production systems has accorded its’ proactive adoption around the world, except India, where the pace of adoption are yet to achieve satisfactory level, due to various factors like predominance of small land holdings, inertia of farmers, complications in harvesting and marketing of timber trees, improper marketing facilities etc. The agroforestry has slowly been gaining ground in India and as per data (Forest Survey of India, 2013) an area of 111,554 Km<sup>2</sup> (3.39% of the total geographical area of the country) of the country, is now under agroforests, which have initiated bio-remediation of the socio-economic and eco-climatic crisis, for reverting rural livelihood sustainability.

According to the 2019 report, the total forest cover of the country is 712,249 square kilometers (21.67 percent of India’s total geographical area) slightly up from 708,273 sq. km (21.54 percent) in 2017. The tree cover of the country is 95,027 sq. km (2.89 percent of the total area) over somewhat up from 93,815 sq. km. (2.85 percent) in 2017. With a proven credential to boost livelihoods by augmenting agricultural risks, agroforestry enriches the soil by fixing nitrogen by leguminous trees, improves drainage,

expedites soil enrichment by steady and efficient nutrient cycling, optimizes land productivity to enhance farming returns.

Minimization of economic risks by high income generation and in cropping enterprises is one of the most prominent benefits of agroforestry. It provides long term investment opportunity, diversified land use, commercial tree cropping and best option for absentee landlords besides generating diversified on-farm employment, wood and Non-Wood Forest Produce (NWFP) and raw-material supply to forest based industries. Agroforestry supports large number of forest based industries besides offering lucrative direct returns and employment generation.

### **Agroforestry systems for revival of sustainable livelihoods**

Properly designed agroforestry systems generate enormous potential to revolutionize the productivity of bio-production systems, on sustainable basis, in terms of qualitative as well as quantitative enhancements in production of food grains, fruits, fodder, industrial raw materials, fish, egg, chickens, red meat, milk, silk, lac and various other animal products, as well as variety of NWFPs for resurgence of sustainable livelihoods with very effective and far reaching indispensable ecosystem ameliorative impact. Based upon the global analysis of agriculture and water status, adoption of multi-sectoral integrated land-use with long lasting solutions has been recommended (Bossio *et al.*, 2007) obviously suggesting use of agroforestry under Farming systems. This paper mainly targets rehabilitation of the total 67.81 million ha, of wastelands, which amounts to 20.62% of the total geographical area of the country, across the country. However, the temporary/ occasional fallows and conventional farm land with low/ inadequate farming intensity are also recommended to be covered by

agroforestry under this proposed plan.

### **Women's Involvement in Agroforestry**

Some women were found to be engaged as sole farmers in agroforestry (19.1 percent), thereby improving their social and economic status in agroforestry. 33% of female agroforestry farmers have been found to be widowed, so they become active in agroforestry in order to feed themselves and their families.

About 67% of wedded females had older and slight spouses, so they assumed control over the cultivating errands. Both male and female relatives assume a basic part in agroforestry by cooperating in tree improvement and spread. Ladies share the duty with men for tree and yield assurance, water system, weeding and collecting of yearly harvests. Ladies are likewise answerable for the post-gather stockpiling and handling of food items, for example for custom made food from organic products, vegetables and grain crops for both family unit utilization and for the market.

### **Livelihood Security by agroforestry**

#### **Food security**

Asia is the "landmass of the current century", as indicated by some; yet, a few examiners have demonstrated that numerous Asian nations will be unable to take care of their extended populaces in the 21st century. From one viewpoint, there is less land per individual in Asia today than in different pieces of the world and on the other, gainful land is dynamically being uprooted by urbanization. Truly, food creation in the general Asian setting expanded at a similar rate as that of human populace FAO. Nonetheless, populace development has outsmarted the food creation patterns in the previous decade, inferring the need to enlarge

food creation.

As indicated by FAO, there are around 800 million individuals in the creating scene who experience the ill effects of yearning. What's more, the majority of this (60%) is in Asia with South Asia representing about 36%. To exacerbate the situation, increments in oat yields are easing back down in all areas of the world due to the supposed "innovation weariness", and Asia is no special case. Woody lasting based creation frameworks, for example, agroforestry, can possibly meet the food security of individuals (Sahoo and Wani, 2019).

Farmers rely more upon yearly yields, the little and peripheral ranchers in the jungles have for some time been rehearsing agroforestry to meet their food, grain and fuel prerequisites. Aside from guaranteeing food creation, such frameworks likewise would upgrade financial re-visitations of the cultivators. The higher money livelihoods give more noteworthy "purchasing influence" regarding food, particularly when agriculture isn't drilled, or when the yields fall flat. Additionally, expanded creation is a type of danger shirking, which is of extraordinary importance with regards to the current horticultural emergencies that numerous nations in South and Southeast Asia are encountering. Agroforestry to give substitute kinds of revenue and work to the rustic poor additionally has been highlighted. The different items (organic products, vegetables, flavors and so forth), which are accessible all year in frameworks, for example, home nurseries not just add to food security during the "lean" seasons yet in addition guarantee food variety.

They are also sources of mineral nutrients for improving household nutritional security especially for "at-risk populations" (e.g., women and children). In trial contemplates, target families altogether expanded all year

creation and utilization of nutrient rich leafy foods contrasted with a benchmark group without gardens. This, thus, lightened inadequacies of iodine, nutrient A, and iron and made offspring of nursery proprietors less inclined to xerophthalmia. As meager or no synthetic information sources are utilized, the produce from agroforestry is additionally expected to be of prevalent quality.

Over the period when input use in agribusiness was advanced in Asian farming, agroforestry being less information escalated was disregarded as a method for food creation. The advancement network, specifically, was not interested by such blended gardens in with dispersed or potentially limit planted trees. The woody lasting based combinations were additionally thought to be less profitable and hard to oversee; all things considered, the "replicable models" of info concentrated creation rehearses got Agroforestry. Therefore, smallholder mixed tree-gardens in Asia reflects a major unexploited potential for productivity and profitability enhancement. Beside that households food security condition in Jessore district of Bangladesh highly improved by practicing Agroforestry.

### **Poverty reduction**

Agroforestry provide a greater contribution of the total income of farmers per year. This contribution is obtained from agricultural crops, forestry (timber) and livestock. Agricultural crops such as cocoa, coffee, cloves, rice and fruits derive most of their income due to crop harvest to include plants that do not require a long time and has economic value so that farmers get a continuous income to meet daily needed. Timber species are widely grown in agroforestry is chrysolite, bayur, teak, sengon, medang and hibiscus. Timber grown mostly for long-term savings, if households

need large amounts of cash then the wood is cut down. Timber prices vary widely depending on the type, age, size, and quality of the wood. Commercialize livestock farmers as savings for the future. Many households keep cattle that are regularly sold or redeemed for cash and food as part of their normal activities yearly. Cows and goats are the animals that most commonly cultivated by farmers. Cost of production in agroforestry management covers the cost of fertilizer, pesticide, labour, and seed. Land management is not carried out intensively. By following agroforestry as suggested above farmers get additional income that would help to expenditure and ultimately involved to poverty reduction. People having more physical assets reveal that he/she enjoys more social status than others. They observed during their study farmers which are performing agroforestry having more no. of physical assets as compare to non agroforestry practitioner (Table 1).

The concept of Trees outside Forests (ToF) arisen in the mid-90s FAO as a comprehensive methodology which envelops incorporated tree based cultivating framework in farmlands and pasturelands to advance reasonable rural creation and woodland asset preservation. In fact, in limited scope agrarian creation frameworks, TOF the executives appears to hold a high guarantee as a scaffold between food creation and natural assurance, because of its ability to reestablish the biological systems and improve soil ripeness. Farmers invite tree editing since they are monetarily beneficial since they give considerable money wages which could be reused into food in the event of harvest disappointment.

Thus agroforestry as a strategy to uplift the economic conditions of the farmers while rehabilitating the degraded uplands has made inroads in the productivity site. Although the

future returns from the harvesting of mature trees in the farm forests are expected to further improve the farmers' income and well-being.

### **Environmental security**

#### **Enhancing soil fertility**

The primary objective of soil conservation is to improve or maintain soil fertility. To accomplish this, control of disintegration, upkeep of natural issue and actual properties, natural issue expansion, support of supplement is fundamental. In this manner agroforestry framework comprise supportable land use and assists with improving soils in the quantity of ways. Upkeep and improvement of soil richness essential for worldwide food security and natural supportability, environmentally solid agroforestry frameworks, for example, intercropping and blended arable-animals frameworks can build the manageability of rural creation while diminishing nearby and off-site outcomes and lead to feasible farming.

Alternate land-use systems such as agroforestry, agro-horticultural, agro-pastoral and agro-silvipasture are more effective for soil organic matter restoration. Samra and Charan and Ram Newajet *al.*, were also observed that soil organic carbon status increased by 5 to 6 times higher in agroforestry system than growing of either sole tree or sole crop.

#### **Biodiversity conservation**

Over exploitation of natural resources is a major challenge for sustainable production and livelihood security. Deforestation is that major cause which affected the biodiversity of an ecosystem. Agroforestry with components like trees, agricultural crops,

grasses, livestock etc. provides all kinds of life support. However, agroforestry may not entirely reduce the deforestation but in many cases it acts as an effective buffer to deforestation. Trees in agroforestry system act as a refuse to biodiversity after catastrophic events such as fire. The traditional society of coastal belts and tropics of the country practicing home gardens and sacred groves helps in biodiversity conservation.

#### **Carbon sequestration**

Tree components in agroforestry systems can be significant sink of atmospheric carbon (C) due to their fast growth and high productivity. By remembering trees for rural creation frameworks, agroforestry can, seemingly, increment the measure of C put away in terrains dedicated to agribusiness, while as yet taking into account the developing of food crops. In agroforestry framework, tree parts are overseen, regularly seriously by pruning of limiting rivalry and augment complementarity. The pruned materials are generally non-clock items. Such materials are frequently gotten back to soil. Moreover, the measure of biomass and consequently C that is collected and traded from the framework is moderately low according to the profitability of the tree. Therefore, unlike in tree plantations and other mono culture systems, agroforestry seems to have unique advantage in terms of C sequestration. In India, evidence is now emerging that agroforestry systems are promising land use system to increase and conserve aboveground and soil C stocks to mitigate climate changes (Table 2). The average potential of agroforestry has been estimated to be 25 t C ha<sup>-1</sup> over 96 m ha. In this way the total potential of agroforestry in India to store C is about 2400 mt, but the C storage capacity varied from region to region and also depends upon the growth and nature

of tree species involved in the system.

### **Livelihood security comparison of traditional agroforestry system and commercial agroforestry system**

In the traditional agroforestry systems since the trees are naturally growing especially in traditional agroforestry region and are just allowed to be thriving by the farmers, the costs associated with management of the trees are negligible except that of indirect costs associated with the shade and competition due to moisture and nutrient needs. Therefore, only the benefits from trees on account of harvest and sale of tree produce were accounted, while commercial agroforestry system is characterized by trees in close association with crops either on farm bunds/ boundaries or within the fields. Socio-economic diagnosis of traditional as well as commercial agroforestry practices followed by farmers in western Uttar Pradesh carried out by Dwivedi *et al.*, and they found that tree species like *Azadirachta indica*, *Acacia nilotica*, *Dalbergia sissoo* and *Eucalyptus spp.* were dominant species in traditional system whereas, *Populus deltoides* and *Eucalyptus spp.* were the main species of commercial agroforestry. Fuel wood (50.6 %) was major driving force for agroforestry adoption followed by additional income (24.4 %) and shade (17.5 %) in traditional agroforestry region indicated in table While, additional income (71.3 %) was the major factor in commercial agroforestry region. Although traditional agroforestry seems less promising as compared to commercial agroforestry, but it is also relevant to the farmers (Table 3).

### **Recommendations for promoting agroforestry**

Keeping in view the magnificent potentials of agroforestry in restoration of eco-climatic and socio-economic regimes of rural areas, which

uphold the rural livelihoods, following recommendations (Government of India, 2001) are to be taken care of:

Commercial agroforestry should be practiced in areas where irrigation is available. Suitable species include *Acacia nilotica*, *Bamboo species*, *Casuarina equisetifolia*, *Eucalyptus species*, *Populus deltoides* and *Prosopis cineraria* for different agro-climatic and edaphic conditions;

High-tech modern nurseries should be established on catchment area basis;

Agroforestry should be tried in rain fed areas by adopting various agroforestry models that would provide additional income as well as complementing agriculture;

Elite clones (higher yielding and disease resistant) of important agroforestry species should be developed for different edaphic and climatic conditions. Corporate/ Private sector should also be encouraged to take up R and D activities and promote new agroforestry products;

Agroforestry product research, new product development, new designs and quality standards should be evolved for downstream processing;

Market information system should be developed to inform farmers about the major buyers, market trends, etc;

All restrictions on felling of trees, logging, transport and marketing of forest produce should be removed;

Establishment of agroforestry boards and marketing federations should be encouraged to improve the bargaining power of farmers in domestic and export market.

**Table.1** Physical asset of the respondents

Physical asset	Agroforestry Practitioners (Percentage)	Non agroforestry Practitioners (Percentage)
Television (No.)	55	38
Radio (No.)	8	14
Mobile Phone (No.)	100	95
Bicycle (No.)	74	66
Motorcycle (No.)	24	10
Power-tiller (No.)	12	5
Spray-machine (No.)	26	32
Shallow-machine (No.)	21	15
Paddy threshing machine (No.)	33	20

**Table.2** Total C storage under agro-forestry systems in different regions of the country

Region	Agroforestry system and components	Total C storage (t C / ha)
Semi-arid region	Silvi-pastoral system (age 5 years)	9.5-17.0
	<i>Acacia nilotica</i> + natural pasture	19.7
	<i>A. nilotica</i> + established pasture	12.4
	<i>Dalbergiasissoo</i> + natural pasture	17.2
	<i>D. sissoo</i> + established pasture	16.2
	<i>Hardwickiabinata</i> + natural pasture	
	<i>H. binata</i> + established pasture	17.0
North- western India	Silvipastoral system (age 6 years)	6.8-18.5
	<i>Acacia/ Dalbergia/ Prosopis</i> + <i>Desmostacya</i>	1.5-12.3
	<i>Acacia/ Dalbergia/ Prosopis</i> + <i>Sporobolus</i>	
Central India	Block plantation (age 6 years) <i>Emelinaarborea</i>	24.1-31.1
Arid region (Rajasthan)	Agri- silvicultural system ( age 8 years)	12.7 -13.0
	<i>Emblicoefficinalis</i> + <i>Vigna radiate</i>	8.6 - 8.8
	<i>Hardwickiabinata</i> + <i>Vigna radiate</i>	
	<i>Colophospermummopane</i> + <i>VignaRadiata</i>	4.7 - 5.3
North-western Himalays	Silvi-pastoral system	2.17
	Agri- horti- pastoral	1.15
	Horti -pastoral	1.08

**Table.3** Determinants of traditional Vs commercial agroforestry system

Traditional agroforestry system		Commercial agroforestry system	
Major reason	Percentage (%)	Major reason	Percentage (%)
Additional income	71.3	Fuel wood	50.6
Source of money in emergency	17.5	Additional income	24.4
Source of fuel wood	2.5	Shade	17.5
Source of employment	4.4	Timber	3.8
Others	4.4	Others	3.8

### **Financing forests’ contribution to climate change mitigation and adaptation**

Sources of finance have emerged to support forest-related mitigation efforts, together with the Clean Development Mechanism (CDM) below the city Protocol and voluntary carbon markets, and, additional recently, the REDD+ (Reducing Emission from Deforestation and forest Degradation in Developing Countries) Partnership, the Forest Carbon Partnership Facility (FCPF) and also the Forest Investment Program (FIP) of the Strategic Climate Fund. REDD+ activities also are actively supported by bilateral and organization funding. Numerous funds managed by the global setting Facility (e.g. the variation Fund), also as different support – through tripartite, bilateral and NGO channels, offer money help for global climate change adaptation of forests, biological science and forest-dependent individuals.

The necessity for funding for adaptation measures is growing, as recognized within the Copenhagen Accord, which places equal weight on mitigation and adaptation.

### **Overcoming challenges**

Beneficial effects are not universal and certain practices may predominate negative or neutral effects and the performance of agroforestry systems depends on relative influence of tree species selection and management, soil characteristics, topography, rainfall, agricultural practices, priority for food security, economic and social development options, etc. (Kumar, 2006; Mbow *et al.*, 2014 b). Firstly, to achieve desired social and environmental benefits designing the right agroforestry system by selecting the most suitable plants and management practices is a must. Selection of species must carefully done in response to local priorities and biophysical conditions (Mbow *et al.*, 2014 a). Even though, the shade trees are competitors for water use, some studies have shown that by understanding the different root attributes of intercropped trees such as contrasting spatial rooting pattern, root morphology and mycorrhizal status it is possible to achieve optimal use of complementary resources such as water (Tscharntke *et al.*, 2011). For an example, use of a combination of deep rooted

and shallow rooted species in agroforestry systems can improve the efficient use of soil water and nutrients. Not only the appropriate crops and trees, favourable sites, suitable management practices, it is also important to integrate those practices into local livelihood systems and communities as they act as initiators of the transformative change in land use. As agroforestry takes relatively longer period to realize benefits than other conventional agricultural systems, farmer involvement should be stimulated by the assuring land security and tree tenure. Land should be recognized as a common benefit while applying community inclusive stewardship principles. Continuous low returns may negatively affect the capability of farmers to improve their optimal management systems (Ofori *et al.*, 2014). Hence, improving micro-credit at local level, appropriate and adequate financing at grass-root level and promotion of agroforestry as a potential and profitable investment is also crucial.

To meet the desired address social and economic barriers, uphold social conditions such as gender synergies, development of more coordinated, structured and fair market systems with collective bargaining for both inputs and outputs of agroforestry, better transport infrastructure, involvement of lesser intermediaries in the supply chain, better investment in characterization of tree foods, provision of incentives from payment for eco system services and certification schemes should be adopted (Tscharntke *et al.*, 2011). In addition, management of the demand side aspects such as change in diet specially in the growing urban population percentage, should also considered seriously (Mbow *et al.*, 2014 b). Another major challenge is to scale up successful tree domestication approaches (Ofori *et al.*, 2014). Improving the knowledge beneficial traits of the existing indigenous plants used in agroforestry and development

of new cultivars from those indigenous species, availability and ample access to high quality planting material and the safe trans-boundary transport of superior cultivars developed in different parts of the world are also important. Furthermore, the small holder farmers play an undeniable role in the agriculture sector. In South Asia about 80% agricultural lands are less than 0.6 ha in extent (Kumar, 2006).

Failure to extend advance agricultural methods hinders the small holder farmers in developing countries in achieving optimal benefits in agroforestry. Apart from the innovative limitations, small holder farmers suffer structural limitations due to the limited investment opportunities available compared to other conventional agricultural practices such as monocultures of cash crops. In general, profitability can be increased through improving and diversification of output per unit area of tree/crop/livestock and by addition of new products to enhance the financial diversity and flexibility.

Subsequently, consideration of academic network ought to identify with techniques and devices proper to acquire most extreme advantages from agroforestry in different human and environmental settings. Additionally, logical information ought to be meant leaders and the strategy designers and implementers should desert the moderate isolation of climate, farming and other related areas as discrete spaces and grasp the need of a comprehensive way to deal with deal with all the viewpoints under one framework.

Since most ecological and economic studies are conducted separately the information is difficult to be linked and it is challenging to estimate real time financial benefits, extent and trends of agroforestry, as government inventories do not include those (Morgan *et al.*, 2010). Even Food and Agricultural

Organisation's Global Forest Assessment do not recognize agroforestry as a land use as it is categorized as agriculture or as a forest. However, available information hints the percentage of agroforestry is increasing many parts of the world (Mbow *et al.*, 2014 a). The growing appreciation in developed countries will enhance understanding and support for its expansion in the developing countries ensuring the needed investments (Garrity, 2004). Agroforestry have potential to contribute to the maintenance of biodiversity in natural systems due to the reduction in overreliance of rural communities on natural forest resources, as they are able to maintain their production systems through improved agroforestry systems. Commercial agroforestry important for assured income as compared to traditional, but both forms of agroforestry have specific roles to play in the livelihoods.

We currently have the chance to pull together both strategy and account, so they better mirror a proper equilibrium of farming arrangements in a multigoal structure. For less-standard strategies like agroforestry, such a rebalancing would bring enormous new venture, research, and institutional enhancements, driving yields upwards.

The necessities of poor people should be straightforwardly tended to with their investment to guarantee supportability on which consistent development depends. Improving vocations will require that new methodologies are received and monetary responsibility made sure about.

By assessing and capitalizing on this potential, we could significantly enhance global goals on food security, social well-being, and environmental integrity, as we have committed to under the SDGs. Agroforestry allows the growth of multiple crops simultaneously and provides several

livelihood benefits to farming households. Commercial opportunities exist for farm communities to transform their traditional agroforestry systems towards market orientation.

To achieve this transformation, smallholder farmers must develop intensive deliberate management systems designed to yield quality products from priority species that meet market specifications. Most farmers are ill-prepared for this challenge because their traditional extensive management approach produces small quantities of many products primarily for household consumption with limited market sales.

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