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Resilence in agricultural productivity through agroforestry: Possible contribution to food security in Nepal

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Abstract
Deforestation, growing scarcity of tree products, environmental degradation, climate change, have created serious problems for rural land use in many developing countries like Nepal. Nepal continues to face exacerbating poverty, decreasing agricultural productivity and food insecurity. Increasing population, accelerating deforestation, poor soil and water management, and increasing poverty and land degradation directly obstructed the food security and human health of millions of Nepalese people. Agroforestry systems viz., agri-silviculture, agri-horticulture, silvi-pastoral, agri-silvi-pastoral and other systems like aqua forestry, apiculture with tree species may increase food production and has been increasingly enlisted in the campaign to meet these threats to the rural economy. It possesses the potential to contribute to the food security due to the capacity of its various forms to offer multiple opportunities to farmers to enhance farm production and income.

To achieve global food security, we need to approximately double food production over the coming decades. We need a multi-functioning agricultural system which can simultaneously enhance social and environmental goals. Agroforestry is emerging as the promising option to sustain agricultural productivity and livelihoods of farmers. With food shortages and increased threats of climate change, interest in agroforestry is gathering for its potential to address various on-farm adaptation needs, and fulfill many roles in Agriculture, Forestry and other land use (AFOLU) related mitigation pathways. In Nepal, 70 to 80 percent of the population are rural dwellers relying on forest lands and subsistence agriculture for their livelihoods. Various agroforestry techniques are finding enormous application in the hilly region of Nepal and are lifting many out of poverty and mitigating declining agricultural productivity and natural resources. Agroforestry as a sustainable practice helps to achieve both mitigation and adaptation objectives while remaining relevant to the livelihoods of the poor smallholder farmers.

Nepalese people along with government now have the opportunity to rebalance agricultural policy and investment toward Agroforestry approach. In doing so, they could achieve important improvements on multiple international commitments around the interlinked themes of food security, climate change, biodiversity conservation, and social well-being through diverse food production, natural resource conservation, improving nutrition, health and increasing economic income of rural poor people. Thus, Agro-forestry as the sustainable agro-ecological approach can be successfully introduced to enhance an adaptive agricultural approach that can increase food security and livelihood options as well as addresses the climate change threats.

Keywords: Agroforestry, foodsecurity, climate change, livelihood

Introduction
Agroforestry is defined as a collective name for land use systems and technologies where woody perennials are deliberately used on samel and management units as agricultural crops and /oranimals insome form of spatial arrangement ortemporal sequence (Leakey, 2010; Lundgren and Raintree, 1982).Agroforestry – the integration of trees and shrubs with crops and livestock systems – has strong potential in addressing problems of food insecurity in developing countries like Nepal. Done well, it allows producers to make the best use of their land, can boost field crop yields, diversify income, and increase resilience to climate change. About 870 million people were chronically undernourished in 2010, the majority living in developing countries and depend on agriculture for their livelihoods. In order to meet the global demand for food which is expected to increase by 60% by 2050, agricultural production must increase by 70–100% and most of this will have to come from smallholder fields. In context of Nepal it is the 17th poorest country in the world; 41% of the population are under-nourished and 30 of its 75 districts are food insecure. Also, 66% of the population live off a combination of agriculture and forest products. Nepal has three main geographical regions – high mountains, Middle Hills and the low-lying plains (Terai). The Middle Hills are home to 44.2% of Nepal's population, 66% of whom derive their livelihood largely from a combination

of agriculture and forest products. The forests and agricultural lands are closely linked systems providing food, fodder, fuel wood, grazing, timber and non-timber forest products. Agroforestry has been shown to provide a number of benefits to farmers. For instance, it can enhance soil fertility in many situations and improve farm household resilience through provision of additional products for sale or home consumption.

Many smallholder farmers in hilly region of Nepal practice agroforestry. The population density per square kilometer of cultivablel and for the country is 620, for the hills it is 1100. In the hills, 96% of the population are small farmers with less than 1.0 ha per household, the average is 0.3ha, and 4% of the hill people are landless (FAO/SIDA, 1978).Agriculture provides livelihoods for 68 percent of Nepal's population, accounting for 34 percent of the GDP (ILO 2017). However, agriculture is adversely affecting the food production due to reduced productivity resulted by severe land degradation, climate change, etc. Most of the countries like Nepal focuses on reforestation and forest protection initiatives to mitigate climate change and these efforts are conflicting with the requirement of expanding the agricultural production to feed the growing population (Mbow *et al*, 2014).

This paper investigates the potential of using agroforestry in food security combined with current land use and land use problems, agro-forestry systems being practiced, opportunities for climate change mitigations to promote sustainable agricultural and forest products by increasing biodiversity and environmental resilience by critically review ingrecent scientific findings.

Current land use

The total arable land in Nepal is about 2.35 millionhectares. The average land holding is 0.96 ha. There are two cropping systems: one based on riceproduction on irrigated flat land, and the other basedon the production of maize and millet on rainfedl and. Livestock rearing is an integral component off arming practice in Nepal. It is the second major economicactivity in rural areas accounting for 20-30% of the total annual farm income.

Together with agriculture, forestry plays a centralrole in the economic and social life of the rural people. The total forested area is about 5.51 millionhectares (Master Plan for the Forestry Sector 1998).Forests provide about 42% of the feed for livestock(WECS 1995b). As livestock plays a central role, mainly in the hill farming system, most farmers canbe described as agro-silvo-pastoralists. The traditional style of farming in Nepal is 'terrace farming'; where receding flat surfaces are cut into a sloped plain. While labor intensive, this practice also threatens to cause soil erosion, water pollution, and a depletion of the plant and animal species, seriously jeopardizing the ecological balance of hilly landscapes.

Land use problems

About 1/4th of the (Mountain an Hills combined) and 1/3rd of the area of Terai is suitable for agriculture and forest covers. Much of the hill and mountain areas are very fragile and vulnerable to landslides. Terai lands are regularlythreatened by flooding and sedimentation (Karkee, 2004).Traditionally, the people of Nepal are heavilydependent on forests for the supply of fuel wood, fodder and timber. Most of the accessible forest is degraded, largely as a result ofland-use practices that are not compatible with thesoils, vegetation, topography, and environment of the country. One of the major problems of Nepal in terms of landuse development is the veryheterogeneity of the agro-ecological zones.

Enhancing Agricultural performance

In the view of the subsistence-type upland farmer, staple foods for home consumption rather than wood are the most important products of agroforestry farms. These foods consist of cereals (e.g., rice, corn), root crops (e.g., taro, cassava, sweet potato), and pulses (e.g., beans) and are mostly annual rather than perennial food crops. Legume-tree-based agroforestry normally yields greater sustained outputs per hectare per year compared with agroforestry with ordinary trees. The primary reason for this yield difference is the nitrogen fertilizer contributed by legume trees. Use of legumes as fertilizer trees have provided about 50-200 kg N ha-1 N inputs to the associated crops with a yield increase of 2-3 times and the planting of those species can be a tradeoff between natural diversification and nutrient inputindependent management (Garitty, 2004;Tscharntke *et al*, 2011).As long as the legume trees do not overcrowd and over shade the food crops, and as long as the trees are appropriately matched with site conditions to enable them to fix sufficient amounts of nitrogen to satisfy the requirements of the food crops, legume-tree-based agroforestry on upland subsistence farms will be more productive. Leaf litter from crop and shade tree combination increase the stability of the decomposing microbes and other microbial communities acting as critical links in Nitrogen and Phosphorus cycles.

Current Agroforestry System being Practiced in Nepal

The aim of developing agroforestry within Nepal is to meet the present and future requirements of food crops, fuel wood, fodder, small timber and environmental protection. In order to design land-use system as an Agroforestry system, it should always have the first component: the woody perennial. In most Agroforestry systems, the second component (the herbaceous species) is also involved, such as apiculture and aquaculture (pisciculture) with trees. The third set of components (animals) is present in some Agroforestry systems.

Agri-silviculture: - This system is common in all agro-ecological zones of Nepal, where agriculture crops are grown in terrace flat and trees are grown in terrace bunds, borders and slopes. Agriculture crops and trees are grown together in the same lands at the same time. *Acacia Nilotica* is raised on the bunds of rice fields and has high tolerance to water logging. It grows rapidly getting benefits from irrigation and fertilizer given to rice crop.

Agri-Horti system: - This system is common in home gardens of mid-hills, Terai and Inner Terai of Nepal, where fodder trees such as *Artocarpuslacucha* (Badahar), *Bauhinia longifolia* (Tanki), *Leucaenaleucocephala* (Ipil Ipil) etc and timber and fire wood species such as *Dalbergiasissoo* (Sissoo), *Eucalyptusspp*, *Melia azedarach* (Baikaino), etc are grown around fruit orchard that act as shelter belt, and agriculture crops such as ginger, turmeric, yam, and vegetables are grown under fruit trees.

Agri-Silvipasture: - This system is common in all agro-ecological zones of Nepal, where land is marginal for crop production. Under this system farmers in dryland grow field crops and forest trees together up to a particular stage but in a later stage, the gravsses are raised in place of field crops in the vacant space between the forest trees. Thus, there resource –

poor farmers are assured if wood, agricultural products and grasses.

Agri-horti-Silvivulture: - This system is common in-home gardens of mid-hills, Terai and Inner Terai of Nepal, where fruit trees are grown along with crops and multipurpose tree species (MPTs).

Silvo-Fishery: - In this system, trees and fruit trees are being planted along the embankment of the fish pond. This system is popular in Terai and inner-Terai of Nepal, where trees and fish included in the same system. Some farmers also included duck and pigs in aqua-silviculture systems.

Sericulture: -Growing of mulberry trees for silk production is also common in practice where mulberry leaves are used to feed the silk worm at larva stage for the production of silk. The cocoon of the silk worm is harvested for reeling the silk.

Achieving Food and Nutritional Security

Reaching food and nutritional security requires a range of interconnected approaches fromincreasing the crop yield and soil fertility, bio fortification of staple foods to cultivating widerange of plants which provide edible fruits, vegetables, nuts and diversify the diets of the people(Jamnadaas *et al*, 2013).The diverse products (fruits, vegetables, spices etc.),which are available year-round in systems such ashome gardens not only contribute to food security duringthe "lean" seasons but also ensure food diversity(Kumar and Nair, 2004).The smallholder mixed tree slopes, uplands and degraded lands in Nepal thus represent a substantial unexploited potential for enhancing productivity and profitability. agroforestry systems with multiple crops willhelp to avoid risks of food insecurities as they provide not only variety of tree commodities butalso local food trees, vegetables and even ediblefungi and mostly profits gained are superior thanmonoculture systems (Kumar, 2006; Pushpa kumara *et al*, 2012). Fuel wood and charcoal also plays asignificant role in the food and nutritional securityas they produce energy and generate high income inspite of introduction of modern energy sources. In Nepal Agroforestry practitioners spent less on fuelwood, rely less onnatural fuelwood sources, and they require less time for fuelwood collection.

Climate Change Mitigation and Adaptation

Agroforestry plays a significant role in two key dimensions of climate change; mitigation of greenhouse gas emissions and adoption to changingenviron mental conditions (Garrity, 2004; Morgan etal, 2010; Schoene berger, 2005).Cultivated lands have the potential to contribute significantly to climate change mitigation by improved cropping practices and greater numbers of trees on farms. The agroforestry practices are based on a variety of management approaches and have potential positive implications for climate change mitigation. It is known that agroforestry systems have 3–4 times more biomass than traditional treeless cropping systems. Combining adaptation with mitigation has been recognized as a necessity in developing countries like Nepal, particularly in the AFOLU (agriculture, forestry and other land use) sector. Agroforestry in general may increase farm profitability through improvement and diversification of output per unit area of tree/crop/livestock, through protection against damaging effects of wind or water flow, and through new products added to the financial diversity and flexibility of the farming enterprise.

Opportunities, Challenges and Overcoming Challenges

There is a growing evidence that in some circumstances, agroforestry is more profitable than forestry lone, and may have a number of social advantages for the farmer and from the nation's view point. The principle of agroforestry could also be applied wellin the development Non-Timber Forest Products. It has been estimated that about 61 percent of the total forest areas could come under communityforestry. There is ample scope for putting into practice different types of agroforestry systems in the seareas. Moreover, agroforestry can be practiced gainfullyin leasehold forest areas. The potential for developing different types of agroforestry system inprivate areas is enormous, if market opportunities arealso developed.

The main challenges affecting agroforestry adaptation are lack of technical skills, lack of quality seed, lack of manpower, and market inaccessibility. Also, agroforestry takes relatively longer periodto realize benefits than other conventional agricultural systems, farmer involvement should bestimulated by the assuring land security and tree tenure. Land should be recognized as a commonbenefit while applying community inclusivestewardship principles. Furthermore, the small holder farmers play anundeniable role in the agriculture sector. Failure to extend advance agricultural methods hinders the smallholder farmers in developing countries in achievingoptimal benefits in agroforestry. Apart from theinnovative limitations, small holder farmers sufferstructural limitations due to the limited investmentopportunities available compared to otherconventional agricultural practices such asmonocultures of cash crops.

Conclusions

Agroforestry is a provider of crucial benefits in food and nutritional security. The potential ofthese woody perennial-based production systems ineasing food insecurity and averting environmentaldegradation in the developing world is of utmost importance. Hence, Nepal should focus on the use of agroforestry as a tool to achieve food security and should be increased and refined due to its amplepositive social and environmental benefits. Thus, Agro-forestry as the sustainable agro-ecological approach can be successfully introduced to enhance an adaptive agricultural approach that can increase food security and livelihood options as well as addresses the climate change threats.

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