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Innovative Agroforestry Interventions for Alternative Economically Viable Livelihood Development to Support Climate Resilient Mountain Agriculture

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ABSTRACT

Agroforestry holds the key in providing alternative economically viable livelihood development and to support mountainous farmers to adapt to climate change. Innovative agroforestry interventions integrating animal production, horticulture etc into cropping systems exist that can help farmers improve yields and provide resilience for supporting livelihoods particularly among marginal communities. But, the lack of knowledge, technical know-how and other information among the farmers are major barriers in adoption of agroforestry. Millions of the farmers of mountainous regions already wrestling with water scarcity, which would be more severe in climate change scenario. The Himalayan regions are have been considered to be highly sensitive to climate change. Indeed, Innovative agroforestry interventions have the potential to conserve natural resources, improve productivity and provide resilience to climate change. The present paper highlights the need for developing innovative agroforestry interventions to promote various alternate livelihood options through diversification, adoption of high yielding varieties and development of innovative products from forest resources. Of these, spice based agroforetry, silvi-medicinal systems, Van silk cultivation, bamboo and ringal cultivation and development and use of farm resources based products like bamboo based composite structures, Seabuckthorn herbal tea, Ghingaroo juice (*Crataegus crenulata*) and incense products etc holds a promising potential to be explored as better options for future scenario.

***Keywords*:** Climate-smart Agriculture; Animal Production; Horticulture; Agroforestry

1. Introduction

Modern agriculture cover a range of risks related to production, prices and markets, financial, institutional and social aspects that often are directly or indirectly associated with weather impacts. In contrast, the buffers provided by trees and forests during periods of food insecurity may be adversely affected by climate change impacts and environmental degradation. In response so-called 'climate-smart agriculture' solutions are intended to increase "resilience" to climatic impacts, improve livelihoods and food security, as well as addressing adaptation and mitigation objectives. Agroforestry is recognized as an important component in climate-smart agriculture (defined as agriculture that brings humankind closer to safe operating spaces across spatial and temporal scales for food systems, in the context of climate change (Neufeldt *et al*. 2013) for both its adaptation and mitigation roles (Thorlakson and Neufeldt 2012). One important feature is that trees and agroforestry systems provide a wide range of products and services that can substitute for each other and, in the right circumstances, can be produced synergistically. Similarly, livestock-keeping diversifies rural communities' production options and is often adapted to relatively marginal environments, which can promote climate-resilience (MacOpiyo *et al*. 2008, Thornton and Herrero 2008).

Hills cover major part of Uttarakhand State of India that cover approximately 90 per cent of the geographical area. The total forest area under various classes of the forest is 37999.53 km^2, which is 71% of the total geographical area (Uttarakhand forest statistics, 2013-14). A majority of the area of the state is under forests and wastelands thus leaving behind only a small amount of land (about 12 %) for cultivation. Further anomolies like shift in monsoon patterns, landslides, cloud bursts and drying up of natural springs, crop depredation by wild animals *etc.* have resulted into the practice of hill agriculture as uneconomical one which is prelevant in most of the mountain regions of the state. Further mountain communities are likely to face drastic changes in their food and farming systems due to extreme and unusual weather patterns. Many may suffer from reduced water availability and increased pests linked to decreasing rainfall and increasing temperatures. In such a scenario deliberate use of suitable tree species in the agricultural landscape i.e agroforestry systems viz., agrisilvicultural, agrisilvipastoral, hortsilvicultural, hortisilvipastoral, energy plantations and multiple use vegetative cover, vegetative checkdams and stream bank plantations make the mountain agriculture resilient to the climate. Likewise, van Noordwijk *et al*. (2011) stated that trees in the agriculture landscape, in various forms and under various types of management, play a critical role in reducing vulnerability to uncertain and changing climates. Trees can buffer macro-climate, microclimates, modulate water flows, store carbon and provide food for the people. Key questions are what types of innovative agroforestry interventions are needed for ensuring alternative economically viable livelihood development to support climate resilient mountain agriculture.

The present paper highlights the existing and innovative agroforestry interventions to develop various alternate livelihood options through diversification, adoption of high yielding varieties and development of forest resource based innovative products to support climate resilient mountain agriculture.

2. Adoption of existing agroforestry systems in different mountainous zones

Diversification is another important component to reduce the risk of crop failure, in terms of the plants themselves, the landscape they are farmed in and mixed production systems. Traditional farming landscapes involving local crop varieties are often resistant to droughts and pests provide living gene banks where crops can continue to evolve and shift across ecological niches to adapt to climate change. Climate-smart agriculture promotes a set of practices and business models that can help reduce emissions and build resilience. It aims to address both food insecurity and climate change by improving resistance to climate impacts, reducing greenhouse emissions. Pan-tropically, agroforestry (www.worldagroforestry.org), livestock-keeping (www.ilri.org/) and the interactions between these practices are crucial for the livelihoods of rural communities (Garrity 2004, McDermott et al. 2010). Agroforestry has its own role to play in all these zones. There are structural as well as functional changes in the agroforestry systems in different zones (**Table 1**).

Zone	Agroforestry system	Agricultural crop	Tree Species
Shivalik (Sub temperate mid hills 750-1500m)	Agrisilviculture Agri-hortisilviculture Silvipastoral	Rice, Wheat, Maize, Mustard, Pea, Barley, Mandua, Jhingora, Pearl millet, Urd, Mung, French bean, Cabbage etc.	**Forestry Sp:** Bhimal, Toona, Sehtoot, Kachnar, Khirak, Chura, Chir etc. **Horticulture Sp**: Pear, Plum, Apricot etc. **Grasse Sp:** *Apluda mutica, Chrysopogonsp., Heteropogon, Agrostis, Thameda anathera, Arundinella nepalensis, Digetaria decumbense, Panicum coloratum, Chloris gayana, Bracharia decumbens, Pennisetum clandastymum, Setaria, sphacelata, Pennisetum orentalis, Pennisatum flaccidium etc.*
Lesser Himalayas (Temperate high hills 1500-2500m)	Agrisilviculture Hortiagriculture Hortisilviculture Silvipastoral	Wheat, Maize, Barley, Mandua, Jhingora, Pearl millet, Pea ,	**Forestry Sp:** Pangar, salix, Banj, Kharsu, Moru, Buransh, Poplar, Thuner, Raga, Deodar, Kafal etc. **Horticulture Sp:** Apple, Walnut, Pear, Apricot, Almond etc.

		French bean, Cabbage, Ramdana, Potato, Buckwheat etc.	**Grasse Sp:** *Aragrostis spp, Bromis intermis, Festuca arundinacea, Dactylus glomerata, Festuca, Kobretia, Cymbopogon distans, Chrysopogon royleanus, Dandhonia cachemyriana, Digetaria decumbense, Festuca arundinacea, F.pretensis Kobretia, Panicim repens, Setaria anceps, Chrysopogon serrulatus, Lolium multiflorum, Pancium cladystymum, Chloris gayana, Poa annua, Lolium vigidum, Arundinalla nepalensis, Phleum pretense, Poa annua etc.*
Higher Himalayas (Dry Temperate zone above 2500m)	Agrisilviculture Hortisilviculture Silvipastoral	Wheat, Barley, Potato, Buckwheat etc.	**Forestry Sp:** Hippophae, Betula, Salix etc. **Horticulture Sp:** Apple, apricot, Almond, etc. **Grasse sp:** *Danthnia cachemyriana, Koeleria cristata, Calamagrotis emodensis, Festuca lucida, Brachypodium sylvaticum, Trisetum spicatum, Andropogon tristis, Phleum alpinum, Agrostis munroana, Deschampsia caespitose Hilictotrichon virescens and Deyeuxia pulchella.*

Table 1. Needs to revive existing Agroforestry systems found in different agro climatic zones of Uttarakhand

2.1 Shiwalik region (750-1500 m)

Agroforestry systems in this sub tropical zone are traditional and are less developed. In this zone, agrisilviculture, agrihorticulture, silvipastoral and agrisilvipastoral systems are generally found. The agriculture crops are grown as per the season, rotation and needs of the farmers. Fodder trees are grown on field bunds and homesteads generally for meeting the farmers own requirement without any geometric arrangement. Bhimal (*Grevia optiva*), khirak (*Celtis australis*), Kachnar (*Bauhinia variegate*) and kimar (*Morus serrat*a) are most important tree species of this zone. These species are generally harvested for the fodder and fuelwood after 5-7 years of planting. Among these trees, *Grewia optiva* provides excellent fodder in winters when no other green fodder is available. While Kimar and Khirak are lopped in summer to rainy season. There is no regular management of all the above trees species. However, with efficient management practices like pollarding, yield of fodder and fuelwood can be certainly increased. In addition to above trees, shisham (*Dalbergia Sissoo*), khair (*Acacia catechu*), dhak (*Butea monosperma*), siris (*Albizia lebbek*), simal (*Bombax ceiba*), bamboo (*Dendrocalamus strictus*), subabul (*Leucaena leucocephala*), tuni (*Toona ciliata*), bakain (*Melia azedarach*), harar/behra (*Terminalia spp*.), Timla (*Ficus roxburghii*), Mangiri (*Ficus palmata*) etc. are also retained by the farmers (Bhatt & Rawat, 1993; Singh and Gautam, 2004).

Fruit trees viz., apricot (*Prunus armeniaca*), plum (*Prunus saliciana*) and peach (*Prunus pessica*) are also grown by medium scale farmers in this zone. About 250 trees/ha are generally planted. These trees commence the production after five years of plantation. Intercropping of beans and peas are taken for two to three years. However, low chilling varieties of peach can be intercropped upto six years.

In this zone many new silvipastoral systems have been developed after years of research. These technologies are well suitable and highly profitable. Some of the important recommended combinations are: *Leucaena leucocephala + Chrysopogon fulvus / Eulaliopsis binata, Dalbergia Sissoo + Bhabar grass, Albizia lebbeck* + Bhabar grass or other grasses, *Grevia optiva* + fodder grass in steep slopes etc (Narain et.al 1998).

2.2 Lesser Himalayas (1500 to 3000 m)

The major practice in the lesser Himalaya is line planting on the terrace risers. It is reported that intercropping a young apple orchard with grasses and legumes under rained conditions for one year can give yields of green grass varying from 24,000 to 31,000 kg/ha and those of legumes varying from 24,000 to 26,700 kg/ha and millet and peas as the best crop comibnations with apple.

In agrisilviculture system, forest trees viz. *Quercus* spp (banj, moru and kharsu), *Aesculus indica* (Pangar), *Robinia, Alnus*, are retained by the farmers for meeting the basic needs of fuelwood, fodder and small timber. Generally, the trees are not planted in any systematic manner and no attention is given to spacing to get full density per unit area. These primitive practices are of not economic importance. However, using appropriate technologies, agroforestry can contribute to sustained production of crops and livestock, on these lands.

In this zone, silvipastoral systems are more commonly found where lopping of trees and grazing of grasses by nomadic graziers is a common practice. People have the right to graze their animals and collect the fodder, fuelwood and timber for their needs. The forests and civil soyam land in this zone suffer from high grazing pressure. Sattered trees are generally found on these lands. However, fodder tree species are now being taken under Joint forest management programmes and Van Panchayat forests for improvement of these lands.

2.3 Higher Himalayas (>300m)

This dry temperate zone is mainly dominated by the grasses viz., *Danthnia cachemyriana, Koeleria cristata, Calamagrostis emodensis, Festuca lucida, Branchypodium sylvaticim, Trisetum spicatum, Andropogon tristis, Phleum alpinum, Agrostis munroana, Deschampsia aespitose, Helictotrichon virescens* and *Deyeusia pulchella.* In addition shrubs and trees like *Hippophae salicifolia, H tibetiana* (chharma/chuk), wild apricot, *Betula utilis* are also found. The tree species are heavily lopped for fodder and fuelwood. So the Silvipastoral system and Silvi-horticultural systems are needed to be strengthened for harnessing the real potential of Agroforestry systems.

3. Innovative agroforestry interventions to generate livelihood and enterprise through use of local materials

3.1 Bamboo based agri-silvicultural system for N-W Himalaya region and bamboo as construction material

Suitability of land and climate, large holding size, huge market for bamboo wood, fast returns than other tree species, regular income after four years, and easy cultivation favors large scale cultivation of bamboo from the land where other crops fail to perform. High yielding genotypes of bamboo species viz., *Bambusa balcooa*, *B. tulda*, *B nutan*, *D. asper* and *Dendrocalamus hamiltoni* in low and mid hills under block plantation of 5m x 5m and on boundary at the spacing of 5m or 3m were introduced. Intercrops like wheat, soybean, rapeseed, bean, mustard are grown successfully for first two years.

Recently the Government in a landmark initiative has promulgated the Indian Forest (Amendment) Ordinance 2017 to exempt bamboo grown over non forest areas from the definition of tree, thereby dispensing with the requirement of felling or transit permit for its economic use. Hence the need and development of bamboo based agroforestry systems hold a high potential in different parts of the mountainous areas.

In modern times, engineered bamboo is used to make prefabricated bamboo houses with the help of bamboo based panels, veneers and laminated boards. The technology can be adopted for construction of low cost houses with cost ranging from Rs. 300 to 500 per square feet depending upon design and nature of interior finish. Advances in structural engineering and development of bamboo composites have opened new vistas for durable, light weight and aesthetics construction materials.

3.2 Silvi-medicinal system or intervention of medicinal plants: an opportunity for alternative livelihood development

Lemon grass (*Cymbopogon flexuous*), Sweet basil (*Ocimum basilicum*), Akarkara (*Spilanthes acmella*), Kaunch (*Mucuna pruriens*), Ashwagandha (*Withania somnifera*), Kantkari (*Solanum khasianum*) and Kalmegh (*Andrographis paniculata*) were selected having reviewed their natural habitats and growth conditions. The trial was conducted for two consecutive years and to everyone's surpise, out of seven medicinal plants, four medicinal plants namely Akarkara, Kaunch, Kantkari and Kalmegh were found to be economically viable due to better yield and healthy financial returns. *Spilanthes acmella, Mucuna pruriens* and *Solanum khasianum* produced maximum yield when grown on northern aspect with net returns of Rs. 34,639, 15,567 and 2879, respectively, per hectare in a growing season of four to six months depending on the species (Sanwal etal, 2011, 2013, 2015,2017). Similarly many remunerative silvi-mediinal systems need to be developed for alternate livelihood generation of mountainous areas.

3.3 Spice based agro-forestry systems for livelihood development in mountainous areas prone to crop depredation by wild animals

Rhesus like a wide range of food, including roots, shoots, leaves, fruits even grasses. Conflicts often occur when non-human primates and other wild animals raid crops and compel local farmers to give up the farming. Hence monkeys and other wild herbivores are considered pests in the areas of massive agriculture, horticulture and other plantations since they damage the crops and orchards. Hence there is a need to develop tree and crop based systems which are not liked by the monkeys and other herbivores but are economically viable. For this purpose after a series of surveys a trial was conducted to plant screened trees and crop species not liked by monkeys and other wild herbivores in the medicinal and aromatic tree conservation and development centre of Sharda range of Haldwani forest division. Spices based agroforestry system was considered as one of the best systems for ensuring livelihood security in man-monkey conflict areas of the region.

Curry patta, Tejpatta, Lemon grass, Wild Tulsi, and other traditional spices like Chilly, Ginger etc based agroforesty systems hold a promising potential in areas sensitive to crop depredation by wild animals besides ensuring the economic profitability.

Recently GI (Geographical indicator) certificate to Tejpatta (*Cinnamomum tamala*) is set to benefit over 10,000 farmerse involved in its production in the state of uttarakhand as dry leaves of the tree, which sell for Rs 60 to 65 per kg., are expected to now fetch more money.

3.4 Seabuckthorn in high altitude areas like Mana, Niti, Bhyundar and high altitude areas in Uttarakashi etc (Hippophae rhamnoides and H. Salicifolia)

Seabuckthorn is specific to certain high altitude areas and as such there is a scope to improve the quality of the areas already under seabuckthorn in specific sites under Seabuckthorn. Keeping in view, the proven high potential of seabuckthorn in environmental conservation, health protection and economic augmenting of Himalayan States, seabuckthorn cultivation (selected watersheds esp in vulnerable areas around river banks and hill slopes), community mobilization for plantation of seabuckthorn and commercialisation of seabuckthorn products hold a good potential to boost alternative livelihood development of the local people. For instance Seabuckthorn herbal tea and Juice (Leh berry) have high medicinal value.

3.5 'Van Silk Cultivation' for people living in and around the forest areas

Tusser cultivation with active participation of local communities could be one such area which can benefit for them. Vanya Silk cultivation can be allowed on *Terminalia arjuna* (Arjun), *Terminalia tomentosa* (Asan), *Shorea robusta* (Sal), *Syzygium cumini* (Jamun), *Quercus leucotricophora* (Ban oak), *Q. serrata, Q. himalayanan* etc (MoEF No. 2-1/2003-FC (Pt III) dated 07.06.2004).

3.6 Innovation, new technology and product options

Ghingaroo juice (*Crataegus crenulata*) and incense products and many other herbal products etc holds a promising potential to be explored for future scenario. Advancement in technology and innovation can encourage more number of manufacturing units. Also there would be need for market establishment with product testing for quality being a necessity which will ultimately lead to market acceptability.

4. Conclusion

Communities in the Mountainous areas need to be empowered and their livelihoods need to be improved so that they can take responsibility for the preservation of natural resources and fulfill their role as mountain stewards. Innovative agroforestry models may facilitate easy adoption that may result in the sustainability of mountainous agriculture over the years. It is imperative to support and promote the synchronisation of modern technologies with traditional and indigenous knowledge for sustainable rural development resulting in the efficient use of existing resources and diversification of activities leading to rural enterprises to support climate resilient mountain agriculture.

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