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Sustainable farming in Uttarakhand hills: Problems and improvements.

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Abstract: Sustainability says use the resources or do things in a manner so that future generations can enjoy the same lifestyle or resource use that we enjoy today. Sustainable farming means the production of plants, food, and animal products by using farming techniques that are beneficial for ecosystem health and at the same time promote economic profitability. This article systematically describes different types of sustainable farming practices, the practices in use in Uttarakhand hills, what are draw backs in the present system and what can be done to make it future ready. There are number of sustainable farming practices but agroforestry is the only one which is not only most suitable but also have been in practice in these hills from time immoral. However, the present agroforestry system in small holdings of Uttarakhand Hills is mainly fodder based low input subsistence production system for self- consumption with subsidiary benefits like: fuel-wood, fruits and small timber. Components of the agroforestry system vary along altitudinal gradient. The experiments conducted by our team (generally under laboratory conditions) reveal that it is safe to cultivate some agricultural crops including legumes in proximity of certain trees (e.g. Zanthoxylum armatum, *Ougeinia oojenensis* and *Celtis australis*.In spite of the fact that farmers have been growing a number of perennials especially trees around their farmland, there is lack of systematic approach. For sustainable farming a systemic design is to be propagated as per the land capability class and climatic condition of the area. There is need to experiment on new models comprising of new tree species as well as new crop species. Tree farming on the higher scale is not possible for certain old/outdated rules and regulations. Diversification in existing system-combining medicinal, aromatic herb, and spices in agroforestry is highly desirable option. There is lack of institutional setup in this area. The best option is to establish Krishi Vijyan Kendra (KVK also known as Farm Science Centre) in every district. These Krishi Vijyan Kendra can be hubs/integrated centres for all activities related to agriculture, forestry and horticulture. Ministry of Environment, Forests, and Climate Change, Govt. of India have issued a draft policy statement to bring agroforestry under 'Green credit' system. It will help farmers getting some monetary benefit through agroforestry trees cultivation. In addition, if unnecessary restrictions on tree farming are removed, these hills can become a hub for tree farming. This will not only increase tree cover in these hills but will also contribute to soil and water conservation and climate change mitigation. The green credits thus earned will ultimately benefit local communities.

Keywords: Sustainability • Economic Profitability • Uttarakhand Hills • Tree farming • Green credit

Introduction

Meaning of Sustainability:

According to Oxford Dictionary, Sustainability is defined as "the ability to be maintained at a certain rate or level." In terms of the environment, it's defined as "avoidance of the depletion of natural resources in order to maintain an ecological balance." In layman terms, sustainability is about using the resources or doing the things in a manner at present so that future generations can enjoy the same lifestyle or resource use that we enjoy today.

Over use of resources and subsequently degradation of environment /ecology has become an area of concern all over the world during the last few decades. The result has been search for innovation and alternative methods to save our ecology/environment. One such initiative is sustainable farming. It simply means the production of plants, food, and animal products using farming techniques that are beneficial for ecosystem health and at the same time promote economic profitability. Sustainable farming encourages farmers to experiment and employ recycling methods, in

addition to the conventional methods of farming. The use of crop waste or animal manure is a very good example of recycling in sustainable farming. The two ingredients are transformed into fertilizer that enrich soil. Sustainable farming is not only economical, but it also aims to conserve natural resources. Sustainable farming also helps reduce the need for chemical fertilizers and pesticides which are great sources of water and soil pollution. The aim is to make the process more organic and cleaner.

Benefits of Sustainable Farming

Sustainable farming has a range of benefits which are enlisted below:

- It promotes biodiversity at local level.
- It conserves water.
- It helps reduce agricultural waste.
- It enhances soil health and fertility
- It helps mitigate climate change impacts as trees and shrubs capture and store carbon in their wood and in the soil for a long period.
- It promotes energy efficiency through green energy systems (solar and hydro).
- No activities are carried out which produce greenhouse gases thus it helps decrease greenhouse gas emissions.
- Microclimatic habitats are created which are beneficial for survival and breeding of beneficial insect species and pollinators.
- It promotes coexistence with animals and wildlife.
- It creates additional economic opportunities for farming communities.
- It enhances social and economic equity.

Methodology Adopted:

This is a review paper and personal observations and cited references are the basis of entire presentation.

Observations and Discussion

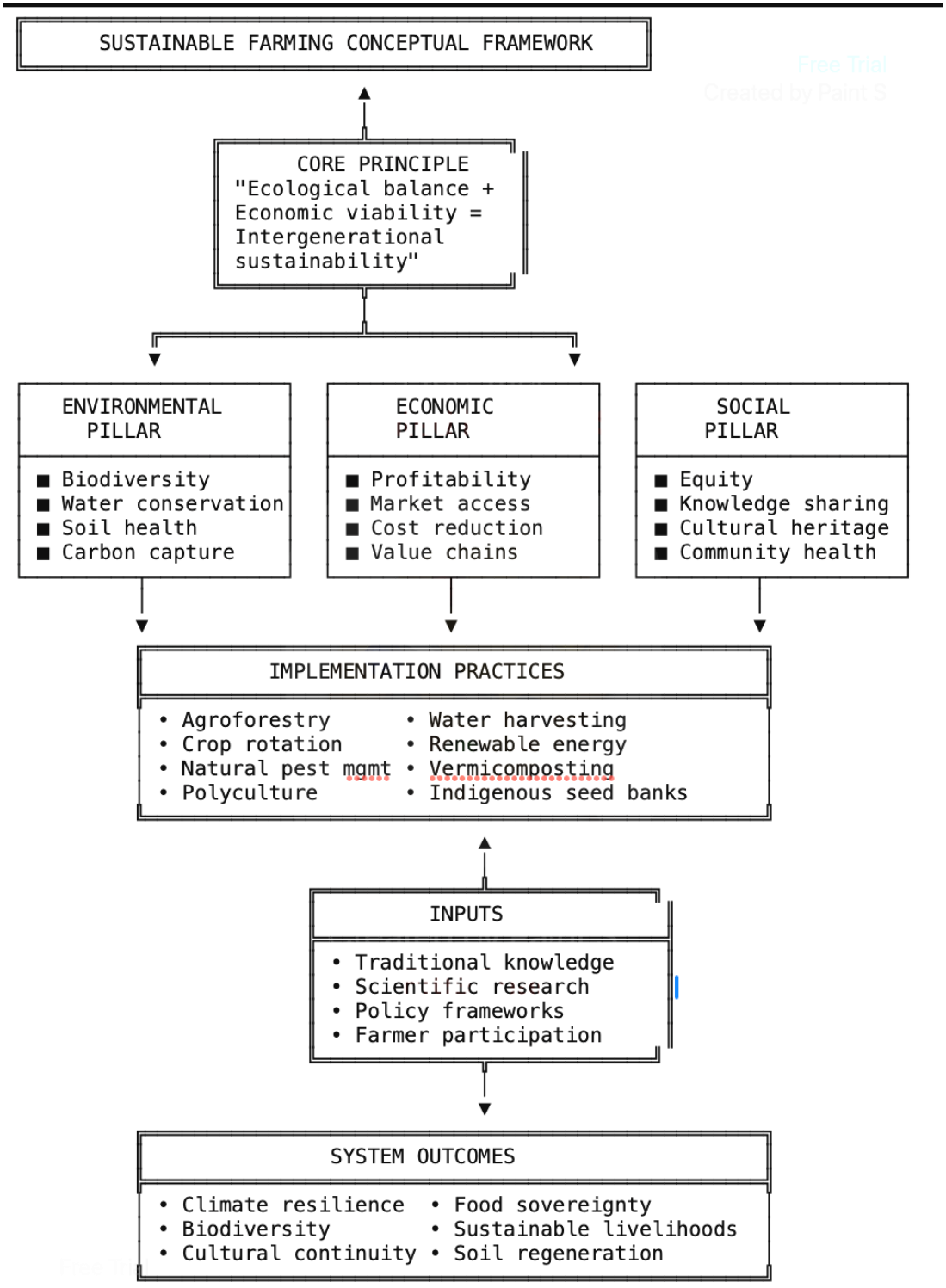
Sustainable Farming Practices: Sustainable farming can be achieved through different practices depending on various factors like farm size, geographical location, soil conditions, slope, terrain and economic condition of farming community etc. Following are the major sustainable farming practices.

Crop Rotation

Crop rotation is an important aspect of sustainable farming and has many benefits. Each crop has specific nutrients requirement and if same crop is grown repeatedly, it will deplete specific soil nutrients. Crop rotation is the practice of growing different crops each season, with the new crops being used to replenish the nutrients the previous crops have used. Crop rotation also plays a role in pest and disease control. Since certain pests are attracted to certain plants, changing the crop(s) each season prevents pest populations from growing too fast or getting out of control. Similarly crop rotation also prevent the occurrence of diseases in crops.

Natural Pest Management

It is also known as integrated pest management which means avoiding artificial and chemical pesticides. Natural pest and disease management allows natural predators to control pest populations. Birds, lizards and insects all play a role in keeping pests at bay. It's also important to note that not all insects are harmful to a farm.



Permaculture

In this practice the perennial crops such as fruit trees, nut trees, shrubs, and annual crop species are grown together in a designed manner/system that is similar to a natural ecosystem (wild) where different species grow in four functional strata. It is a food production system to reduce waste of resources and create increased production efficiency. This system is one of the methods to reduce waste, reduce inputs and maximize growing efficiency and crop yields. This practice is similar to what is known as 'home garden' in agroforestry.

Controlling Soil Erosion

Healthy soil is key to a good crop yield. Age-old techniques like tilling the land, plowing etc. still work and pay. Organic manuring, use of cover crops etc. also help improve soil quality. Growing trees and shrubs along bunds or in rows and in many other design in farmland reduce chances of soil erosion as tree and shrub canopies and stem receive the down pouring rain drops before they hit the soil. Instead of running rainwater moves slowing thus helping water percolation. Trees and shrub also help soil from scorching heat thus maintain soil temperature as well soil water.

Use of Renewable Energy Sources

One of the practices of sustainable farming is to use renewable resources where ever possible - wind and solar are two best examples. Solar panels can be used to power electric fences as well as run small tube wells and light houses and farm lands. Wind turbines can be used to capture energy to be used for drying, lighting etc. Running rivers and rivulets can also provide a source of hydroelectric power (small scale). While solar and wind energy for agriculture is cost effective without much technical knowhow, however, hydroelectric power generation is bound by govt. rule and regulations as well as need technical manpower to build and install.

Biodynamic Farming

Biodynamic farming is the practice wherein livestock, plants and crops are raised together, managing the farm as one unit where the needs of each species supports the other. Biodynamic farms promote soil health and resilience, since they are similar to the way plants and animals coexist in natural ecosystem. Biodynamics emphasizes the importance of reducing the use of external inputs (such as use of chemical fertilizers and pesticides) by generating the necessary inputs for soil health and fertility for food production onsite. It involves the practices such as composting, application of animal manure from farmed animals, cover cropping or rotating complementary crops. In biodynamic farming, the high biodiversity of plants, animals and beneficial insects help replenish soil fertility and enhance plant growth to create a resilient ecosystem that support each other's health. Agroforestry also encompasses all these.

Polyculture

Polyculture or multiple cropping or mixed cropping involves growing multiple crops at the same time and in the same unit. The selected species usually complement each other, and by growing multiple species farmers can better utilize available resources. Diverse products can be produced in one plot while fully utilizing available resources. High species diversity makes the system more resilient to weather fluctuations, provides a balanced dietary products and applies natural mechanisms for preservation of soil fertility, insect-pest and disease control. In broader sense this practice is part of agroforestry.

Agroforestry

Agroforestry has been referred to as one of the most powerful methods to mitigate climate change impacts. It is a traditional agricultural system in which certain new innovations have been added during last few decades. The practice involves planting trees and shrubs amongst crops, to create a favorable microclimate that maintains favorable temperature and soil humidity, while protecting crops from wind or heavy rain. Trees play many important roles: they stabilize soils, minimize nutrient runoff and improve soil structure. Trees also provide fodder, timber, fuelwood, fruits, seeds etc. They also help in integrated pest management because trees are home to bats, birds, insects etc. who work as natural pest eliminators. Trees capture more carbon-dioxide and hold it for longer time. Trees can be cut and wood/logs sold at times when money is needed like disasters, droughts.

Mulching and Groundcovers

It's possible to dramatically reduce the growth of weeds and conserve soil by using mulch

and ground covers around plants. This form of natural weed suppressant can, in some cases, eliminate the need for herbicides. Organic mulch material like, wood chips, straw or grass clippings also improve nutrient retention in soils and encourages the activity of soil microorganisms that help create healthy aerated soil structure. This reduces the need for tillage as soils are less compacted.

Food Forest

Food forests (also known as forest gardens or home gardens-again a part of agroforestry) are based on natural forest ecosystems and designed permaculture systems that consist of a multilayered edible forest. These food forests are composed almost entirely of perennial food plants, including a canopy of tall and dwarf fruit and nut trees, a fruit shrub layer, layers of perennial herbs, mushrooms and vegetables at the ground level, climbing plants, and underground root vegetables. Food forest systems are very productive because of both the diversity of plants and individuals plant take advantage of each other's existing niche within the system. It is based on the assumption that some plants need full sunlight, while others can survive in twilight and still others in sun flecks.

Managing Grazing

A periodic shift or planned rotation of the grazing lands for cattle is. Moving/ shifting livestock offers them a variety of grazing pastures. This way they receive various nutrients, which are good for them. The excreta of these animals serve as a natural fertilizer for the land. Change of location also prevents soil erosion as the same patch of land is not trampled upon constantly and hardening of soil is avoided.

Better Water Management

In water management the selection of the right crops is essential. The local crops are best as they are more adaptable to the weather conditions of the region. Crops that do not demand too much water are the best for dry areas. Unplanned irrigation systems lead to other issues like depletion of water resources, dry land and soil degradation. In water management another aspect is rain water harvesting systems to store rainwater and use them in drought prevailing conditions. A number of innovative methods have come on the subject. In towns and cities municipal wastewater can be used for irrigation after recycling. This needs developing separate pipe lines for waste water transport. Water is becoming scare and there is need to improve infrastructures to save water and use it judicially.

Growing Older Varieties

We have lost almost 90 percent of the crop, fruit and vegetable seed varieties over the last 100 years. These have provided the most nutritious and flavored food to generations of our ancestors. The industrialization of the global food system has resulted into a system where only a few varieties of our food plants are grown commercially. This has also changed the food habits of human beings. The farmers need to grow older varieties of crops to preserve the biodiversity of seeds and save the seeds that will nourish our children before the world lose them also and many other remaining varieties of our food plants forever.

Reduced Transportation Costs

The sales of the produces in the local market saves transportation and packaging problems and cost. It also eliminates the need for storage space. Therefore, when stuff is grown and sold in local markets, it makes a community self-sufficient, economically sound, saves energy and doesn't harm the environment in any way.

Urban Agriculture

The practice of urban agriculture or home agriculture has gained immense in recent years, with advances in farming practices making home agriculture more feasible than ever before. Since most of the world population is predicted to live in cities in the future, there is tremendous scope for urban agriculture to make a significant positive impact on how we produce our food around

the world. At least this can fulfill house hold needs.

The concept of localize food production system requires that we grow food much closer to home, including in cities. Therefore, today, many innovative and sustainable growing techniques are already in the practice in cities, including backyard farms and gardens, community gardens, rooftop farms, growing crops in urban greenhouses, indoor hydroponic farms etc. If it is done at large scale it will also reduce transportation cost/ energy use and reduce greenhouse gas emission.

Hydroponics and Aquaponics

These two innovative techniques that have changed the way crops are grown by removing the need for soil. Instead it advocates growing plants with roots in water and providing nutrients directly to the plant through the water in which the roots are grown in. In hydroponics, root systems are placed directly in a specialized mineral solution, or sometimes they are grown in gravel. The nutrients need of the plants is fulfilled through the water given (in which nutrients are dissolved) to the plant. Aquaponics combines raising aquatic animals and the growing of hydroponic crops in a integrated system. In this system/method, the water from the animal is used to nourish the plants. Since the water contains nutrients from the animal waste, it can be used to feed the plants. It is then recycled back into the system to be used once again by the fish. But the system/method needs infrastructure which is not possible on the part of marginal farmers. Moreover, this system/method is possible only for high value crops.

Out of 16 above mentioned sustainable farming practices, agroforestry is the only one which is not only most suitable but also have been in practice in these hills from time immoral.

Agroforestry in Uttarakhand Hills

The farming system in Uttarakhand hills consists of growing food crops along with trees. This system is traditional/ age old and still practiced in these hills as mechanized farming is not possible here. This traditional agroforestry system encompasses all elements described herein includes old varieties are grown, those crops are grown which need less water, multiple cropping is prevalent, animal dung plus crop residue/ leafy animal beddings are composted for manure to fertilize crops, crop rotation is common, water from springs, perennial small rivers is channeled to irrigate crops etc. The present agroforestry system in small holdings of Uttarakhand Hills is mainly fodder based low input subsistence production system for self- consumption with subsidiary benefits like: fuel-wood, fruits and small timber.

Main Features:

Average farm size is 0.20 ha/household (Swarup 1993)

Diverse needs are fulfilled by one system with escape routes during natural calamities.

* It plays important role in sustainable resource conservation and food security.
* It is diversified and intensified farming systems through integration of indigenous trees and crops.
* The system is sustainable for the farmers, stabile of resources as generally only local resources are used, with minimum of risk.
* Cereals, millets, pulses and oilseeds are intercropped with fodder and fuel wood yielding trees. In some places, horticultural tree crops are intercropped with seasonal vegetable.
* Lopped tree foliage is fed to animals as fodder and pruned wood is used for fuel, while in inter bund or inter row space annual crops are sown. Trees are generally grown either at the edge of field or along bunds
* Animal dung along with animal bedding leafy material is composted. Manure so obtained is used as fertilizer- a delicately woven organic agriculture system.

* Agroforestry full fills 13% and 2% of total firewood and fodder requirement of the people.

Components of the agroforestry system vary along altitudinal gradient (Sachan et al. 2007).

Lower Altitude (300m -1000m)

Ten multipurpose tree species (MPTs) are grown in this altitudinal range. Following are the main features of the system:

*There are on average142 trees per hectare of land in agrisilvi (agriculture + trees) system

**Grewia optiva* has the maximum density (35.0/ha), followed by *Ougeinia oojeinensis* (24.0/ ha).

*Wheat and barley are cultivated as winter cereal crops.

*Paddy, barnyard millet, finger millet, soya bean and black gram are cultivated as summer crops.

*In some places there is tradition of cultivating wheat as sole crop or intercropped with mustard and pea.

*Barley is cultivated either as sole crop or in association with lentil.

*Finger millet is intercropped with cowpea, horse gram, soya bean and amaranth and at some places it is cultivated as sole crop.

Middle Altitude (1000m – 2000m)

10 multipurpose tree species (MPTs) are grown in this altitudinal range. The main characteristics of the system are outlined below:

*Average tree density in farm lands is 136 trees/ha.

*Maximum tree density is present for *Celtis australis* (32.0/ha)

*Wheat and barley are cultivated as winter cereal crops,

*Paddy, barnyard millet and finger millet are cultivated as summer crops.

*Wheat is cultivated either as sole crop or intercropped with mustard and pea.

*Barley is grown either as a sole crop or mixed crop with lentil.

*Finger millet is intercropped with cowpea, horse gram, soya bean and amaranth and at some places it is cultivated as a sole crop.

Higher Altitude (above 2000m)

*6 multipurpose tree species (MPTs) are grown in this altitudinal range.

*Average tree density is 102 trees per hectare.

**Quercus leucotrichophora* has maximum tree density (37.0/ha),

*Barley and wheat are cultivated as winter cereal crops;

*Paddy, barnyard millet, finger millet and foxtail millet are cultivated as summer crops.

*Wheat is cultivated mixed with lentil and mustard.

*During summer, finger millet is cultivated with amaranth.

*Growing beans as sole crop or in combination with cereals is major activity at many places.

*Growing potato as sole crop is also characteristic feature in many areas.

Uses of Trees

Trees are major source of fodder, fuel, timber, fruits, seeds, vegetable, and animal bedding material especially during winter. Trees are available for sale if needed. Trees are also used as support for climbing vegetables. Moreover, *O. oojenensis*, (locally known as sadan) is a leguminous nitrogen fixing tree species, has a promising future in the improvement of agroforestry systems in the area. *O.oojensis* and *Boehmeria rugulosa* are excellent for wood curving and in very near past both species were used to make utensils especially for making/storing curd and ghee.

Benefits of Trees in Agroforestry

*Trees are assets whose value increases over time

*It produces higher income per unit area than sole crop cultivation

*The system is resilient to climate change and less labor intensive

*It provides quality fodder and enrich soil fertility through leaf fall, root decomposition

and nutrient retrieval by roots and nitrogen fixation by nitrogen fixing trees/shrubs.

*The system also provides marketable products-seeds, fruits, timber, medicine etc.

*Trees in the system reduce scorching heat which helps maintain soil surface temperature ad soil moisture. It also helps ground water recharge through stem flow and slow run off.

*Trees in agroforestry store biomass through higher carbon sequestration thus providing climate mitigation services.

- Trees can be sold/ lend/mortgaged for obtaining loan during stress period.

Allelopathy

The combination of trees with crops is subject to many direct/indirect interactions between trees and crops. These interactions impact production/productivity of crops. Among these interactions the most important is allelopathy. The term allelopathy denotes the ability of one plant to stimulate or inhibit growth and development of neighboring plants. In the present agroforestry system there are certain species which are alleopathic to certain crops. The interaction between trees and crops have the following components:

*The growing plants (including trees) and decomposing plant material, release numerous biochemical compounds (allelochemicals) that alter the seed germination, seedling growth, physiological processes and rhizophere and nitrogen fixing organisms.

*Allelopathic tree crops can reduce growth, development and yield of other crops growing simultaneously or subsequently in fields (Nazir et al. 2007; Thapliyal et al. 2007).

*However, allelopathy is considered safe and effective measure for biological control of weeds.

*On the bases of their utility and allelopathic interactions the importance of these trees in agroforestry in Uttaraakhand hills decreases in the order *Ougeinia oojenensis* > *Celtis australis* > *Boehmeria. rugulosa* > *Ficus auriculata* > *Kydia calycina* > *Holoptelea integrifolia* > *Moringa Oleifera* >*Adina cordifolia* > *Grewia oppositifoliai* > *Quercus leucotrichophora* > *Bauhinia variegata* > *Ficus cunia*. (Bhatt and Todaria, 1990; Kaletha et al. 1996; Bhatt et al. 1997; Dhanai et al. 2008).

The experiments conducted by our team (generally under laboratory conditions) reveal that:

It is safe to cultivate some agricultural crops including legumes in proximity of certain trees (e.g. Zanthoxylum armatum, *Ougeinia oojenensis* and *Celtis australis* (Bhatt et al. 1993, Basotra et al. 2005, Negi et al. 2007, Singh et al. 2007)

*Among summer crops *Echinochoa frumentaceae* – is most resistance and *Eleusine coracana* - moderately resistance to allelopathy.

*Among winter crops *Triticum aestivum*, *Hordeum vulgare, Brassica compestris* can be cultivated along with *Ougeinia oojenensis*

**Brassica compestris* is more resistance to allelopathic effects.

Therefore, for sustainable farming careful consideration is to given to tree-crop combination as not every crop can be grown under/near every other tree. The results and observations of our studies for a oeriod of more than 10 years reveal that farmers need to plan what he/she intends to grow on his farm land and accordingly tree species and crops are to be selected so that there is least alleopathic impacts on crops.

Sustainability Indicators of present Agroforestry

*It is self -sufficient to marginal farmers-food, fuelwood, fodder, fruits, etc. requirements are fulfilled to some extent by one composite unit

*It has in built insect-pests and disease management system

*The present system is capable of diversified products production

*It is capable of ecological balance-maintenance of plant and soil microorganism diversity.

Gaps in Present System

*It is traditional with low diversity especially in terms of tree components

*It is slowly losing traditional agro biodiversity which is replaced by some modern crops like soya beans, although in terms of market, soyabean is giving good return to farmers.

*There is no tradition of value addition to produce, although not much is produced for sale. But whatever is produced, if value addition is carried out, can fetch good prices in market.

*Few new products from traditional crops have been attempted but scaling have not been done although, new markets have opened in recent years.

*Low/ negligible market linkages are available, if available, farmers get low prices for their products.

*There is low productivity of tree crops as well as food crops.

*Declining soil productivity is the major concern. One major reason for it the soil erosion due to sloping agriculture.

*No genetic improvements both in traditional agriculture crops and tree crops have been attempted.

*Very few experimentations have been carried out to introduce old crop varieties/new crops/new tree species in the system.

Problems

Agroforestry and its improvement:

Proper design of the system

In spite of the fat that farmers have been growing a number of perennials especially trees around their farmland, there is lack of systematic approach. The entire length of the bunds/terrace risers is not planted systematically. Hardly 1/3 area is planted. The number of trees (including fruit trees) per farm holding is approximately 30. There is no specific admixture between the trees and crops. The trees including fruit trees are grown for domestic use and rarely the products are sold in market (Negi et al. 2000). For sustainable farming a systemic design is to be propagated as per the land capability class and climatic condition of the area.

Introduction of New Indigenous Tree Species

In fact, this traditional agroforestry system is subsistence based and not much is available for sale. Because of declining productivity people are not interested in farming anymore and who so ever is still engaged in farming is doing so under compulsion. Thus there is need to experiment on new models comprising of new tree species as well as new crop species. The following abundantly available, useful and indigenous species need consideration and experimentation.

**Alnus nepelensis* is an indigenous nitrogen fixing, non- leguminous, fast growing species found abundantly in nature and can be introduced in agroforestry. Presently it is not used at all but covers vast forest area in middle altitudinal range (1500 – 2000 m). Wood of this species needs to be investigated for its widespread use.

**Populus ciliata* is another fast growing indigenous hill species commonly known as pahri pipal as its leaves are similar to pipal (*Ficus religiosa*) . It can similarly be introduced in Agroforestry for wood production. Wood of this species is suitable for plywood and match industries. As against to *Alnus nepelensis* it does not cover vast forest area but grows naturally in mid altitudinal range of 1500-2000m.

**Ulmus wallichiana* a naturally growing hill species leaves of which presently used as fodder occasionally. It is another species which can be introduced in agroforestry. It is also found growing in mid altitudinal range of 1200-2000m. But it has very big canopy which makes it unsuitable for agroforestry, however, regular pruning of canopy can solve the problem.

*Other species for domestication can be searched based on products-fruit, fodder small

timber/ seeds (marketable products), quick growth for early return, and sparse canopy.
*New crops especially medicinal herbs have not been introduced at scale needed for market linkages although this has great potential here. Middle altitudinal and high altitudinal ranges are highly suitable for medicinal plant based agroforestry.
*Horticulture based agroforestry has big scope here. Perennial fruit crops + seasonal vegetables have great scope as the region is insufficient in both fruits and vegetable which generally come from plains except at few places. At few places it has been attempted successfully and people are doing it profitably.
*Spices based agroforestry i.e. spices + trees (as shade tree -*Alnus* + black cardamom) as practiced in Sikkim has high potential here because *Alnus napelensis* is local well adapted tree species. Some other spices in combination with trees or sole crop can also be tried. This trial should be carried out by the existing scientific /academic institutions located in the region.
Any new agroforestry/agriculture system must contain tree component as it essential for moisture and nutrient retention in the soil as well as soil erosion control. For land having more than 15% slope there exists an agroforestry model known as Sloping Agriculture Land Technology (SALT) most suitable for sloping land, mountains, hills (Tacio 1993).

Tree farming:

Tree farming on the higher scale is not possible for certain old/outdated rules and regulations. As per U.P. Protection of Trees in Rural and Hill areas Act 1976 (which is still applicable to Uttarakhand even after separation from U.P.) permission is required for felling of trees even on peoples own land. Felling of some species like juglans (*Juglans regia*), Mango (*Mangifera indica*), Banj (*Quercus* spp.), deodar (*Cedrus deodara*) and sal (*Shorea robusta*) is completely banned through a notification of dated Jan 26, 1982. Moreover, there is restriction on the movement of forest produce except for transit within village. All these have discouraged people from planting trees on their own lands. In June 2025 Ministry of Environment, Forest and Climate Change (MoEFCC), Govt. of India, has circulated a draft regarding tree cultivation and falling in agroforestry. But is too complicated and cumbersome especially for marginal farmers and farmers living in far flung area (mountains and hills). Further, if someone creates a forest in his own land, the land is considered forest land under Supreme Court orders and nobody is allowed to do anything on forest land as per various forest rules and regulations.
Hence, for sustainable development including sustainable farming forestry activities should be considered as livelihood option for mountain/hill people. I therefore, strongly advocate for modernization/ liberalization and market orientation in the production and marketing of trees and their products. There is need for hill/mountain specific agroforestry/forest policy.

Livestock rearing:

Livestock rearing is an integral part of traditional farming in these mountains. Farmers keep both cattle and ruminants and mean number per household is around 5.5. Most of these are local breads, poor in milk yield. Most of time all these livestock are free ranging and travel 8-10 km per day. Thus much of their energy is used in free ranging and farmers even do not get the dung which is essential part of composting and manure for agriculture production. Animal feed is chronic problem in the region. Thus there is need to upgrade the present livestock (by breeding or introduction of certain good breeds adaptable to hill/mountain climatic conditions). Further, the region has no tradition of growing animal feed. Therefore, introduction of short rotation animal feed is also needed.

Agriculture in Agroforestry

Conserving agriculture diversity-

30-40 crops including minor crops and pluses are available in these hills and some of the crop produce are in great demand- Ragi (*Eleusine coracana*), Horse gram Local name- Gahat (*Microtyloma uniflorum*), Tor Dal (*Cajanus cajan*), Amaranth (*Amaranthus virdis*), kidney beans (*Phaseolus vulgaris*), Red Rice (*Oryza longistaminata*), Barnyard millet (Local name Jhongra (*Echinochloa frumentacea*), Jakha (*Cleom viscosa*) etc. Interestingly most of these crops are drought resistance. Mass production of these is need of the hour to fill the market demand. However, improving quality and quantity of traditional agricultural crops by genetic techniques is also needed as per area production is very low. Some of the dry areas in these hills are suitable for millet production.

New product formulations

From traditional crops new product formulation can be taken up with the help of private companies and food research institutions, example biscuit and baby food formulated from traditional crop *Eleusine coracana*. The market for millets and their products is increasing due to their dietary values and fetch good prices in market.

Institutional setup

The Uttarakhand hills lack farmers/farming centric policies and approaches. The following steps are needed to make the present system sustainable.

Diversification in existing system-combining medicinal, aromatic herb, and spices in agroforestry is highly desirable option. If successful it can fetch good money in big national and international market. It shall also improve soil health.

There is lack of institutional setup in this area. Every district needs to have a extension center which can provide training for value addition, skill development, market and agriculture/ horticulture/forestry related information to farmers.

District agriculture and horticulture office may also help provide market linkages and buy back system involving pharma and food companies.

The best option is to establish Krishi Vijyan Kendra (KVK also known as Farm Science Centre) in every district. These Krishi Vijyan Kendra should be hubs/integrated centers for all activities (training, innovation, dissemination of information, supply of seed and seedlings etc.) related to agriculture, Forestry and Horticulture).

Seed/ Seedling Supply

Presently the region lacks quality seed or planting material of almost all species including trees. The productivity is dependent equally on quality seed and planting material without of which all efforts will come to naught. The following steps if implemented properly can overcome this deficiency:

By establishing a network for regional tree/spices/medicinal/aromatic plant domestication – presently no such program exists.

Planting materials production and supply (medicinal plants, spices, aromatic plants, vegetable and trees) have to be taken seriously by govt. as well as by private players. Presently there is lack of local source(s) from where farmers can obtain these planting materials.

Quality seed/planting material production itself is a big business/enterprise which can be taken up by young unemployed education persons (agriculture, horticulture, and forestry graduates) with the active back up by govt./banks/NGO

Presently whatever is supplied to farmers is purchased outside the state and nobody knows their quality. A locally well adapted planting material is must for higher survival, quick growth, and yield.

Improving Soil Fertility

Soil in hills/mountains is nutrient deficient and needs consistent enrichment/replenishment for meaningful production. The following steps can help improve soil fertility:

Soil enrichment by adding organic matter regularly. Presently whatever organic manure is added to soil is inadequate.

Introduction/planting of leguminous fodder grass/shrubs/small leguminous trees on bunds/margins of agriculture farms. Repeated pruned material of these trees/shrubs/grasses can be added to agriculture fields. This measure will twin objectives- nutrient replenishment and prevention of soil erosion.

Developing better and time saving technology of composting. Even today agricultural field are fertilized with organically composting manure. The domestic animals are fed with grasses and tree leave fodder. Some of tree leaves are also used as animal bedding especially during winter. All this along with animal urine and dung is used for composting and ultimately used to fertilize agriculture fields. Thus agriculture in these hills is truly organic. The composting method takes six months. A new method/ technology is needed to reduce this period.

Introduction of vermicomposting. Vermicomposting has emerged as additional option for organic fertilization. However, this needs some technical knowledge and training. This is also one of the business option for young educated ones.

Rain water harvesting has become essential as most of the natural springs, small rivers have dried up and there are summer water crises even for drinking at some places. In many places, the old ponds, and small lakes have also dried up. All these can be rejuvenated either through rain water harvesting by channelizing run off water towards these structures or by biological means (by planting grasses, shrubs or trees) or by mechanical means (by constructing small check dams to slow down running rainy water). New ponds and small lakes can also be created to store rain water wherever it is possible and feasible.

Consolidation of land ownership:

Farm land in hills and mountain has three inherent characteristics: one- small landholding (on average it is in the range of 0.20ha) which is in the form of small terraces, secondly, landholding is scattered over a long distance of 1-2 km (somewhere more than this), nutrient deficient. Scattered land holding in these hills need consolidation so that farmers can concentrate their efforts at one place. It has been tried in few places but need policy and administrative intervention at once if agriculture is to survive in these hills. It is very complicated issue because some people have only drylands, while others have only irrigated lands while still others have both drylands and irrigated lands. Govt. needs not one formula but site specific too many formulas to satisfy the aspirations/demand of people.

Land capability in Uttarakhand:

Hills and mountains have location specific problems depending upon slope and soil. Geologically it is divided into different sub divisions each with unique characteristics. Further Uttarakhand has diverse agro-climatic zones leading to varied agriculture practices. Agriculture throughout mountains' and hills is neither feasible nor practicable. The system of division of land per altitude and slope into different categories is needed. Certain areas will be suitable for mono-cropping agriculture; others shall be suitable for horticulture, still others will be suitable for agroforestry, or horticulture and finally lands unsuitable for all these activities should be used only for tree planting or forestry related activities.

In hills and mountains, sustainability depends on soil and water conservation. It is therefore, desirable to first identify and classify the land according to its capacity. The land capability classification is a systematic arrangement of different kinds of land according to their ability to produce on permanent basis. Land capability classification map is normally prepared by interpreting a standard soil survey map based on the specification suggested by

All Indian Soil and Land Use Survey Organization (Soil Survey Manual

Land capability classification is a crucial tool for sustainable land management in Uttarakhand mountains, helping to identify the potential of land for different uses and preventing misuse, especially in a region with high ecological value. Land capability classification is based on its physical characteristics. It considers factors like slope, soil type, drainage and climate. The general land capability classes for mountain and hills is given in Table 1 (Anon 1979b):

Table 1:The general land capability classes for mountain and hills

Capability class	Description	Suggested land use and management
Class I	1-2% slope with deep soil	Cultivation of agricultural crops
Class II	2-10% slope with deep soil	Cultivation of agricultural crops with graded bunds. Horticultural orchards
Class III	10-15% slope with deep soil	Cultivation of agricultural crops with broad based terraces or bench terraces. Horticultural orchards.
Class IV	15-33% slope with deep soil	Cultivation of agricultural crops with graded vertical trenches or drains for drainage
Class V-VII	0-33% slope with shallow	No cultivation of agricultural crops soil, rocks, denuded hillocks Cultivation of tree crops, pastures with severe erosion with poor of perennial vegetation drainage
Class VIII	Precipitous slopes, badly eroded	Forest, wildlife with complete hillocks protection

The factual position with regards to different land capability classes in Uttarakhand hills is as below (Kumar et al. 2021):

Class I-II 0.77%- generally available in plain areas.

Class III- IV 1.05%

Class V 21.63%

Class VII-VIII 11.24

Based on different studies (Negi et al 2009, Kumar et al 2021) around 21-22% land area is suitable for plantation crops, aromatic and medicinal herbs and around 11-12% area is suitable for agroforestry and pastures. The recent studies say that large area (nearly 57-58%) is not suitable for agriculture out of which 19-20% area is permanently unsuitable for agriculture. Thus only about 2-3% area is highly suitable for agriculture which is valleys along different rivers.

Scope in Agroforestry

Ministry of Environment, Forests, and Climate Change, Govt. of India should be persuaded to bring agroforestry under 'Green credit' system. It will help farmers getting some monetary benefit through agroforestry trees cultivation. If unnecessary restrictions on tree farming are removed, these hills will become a hub for tree farming as a very high private lands are vacant due to absentee land owners/ migrations which can be put to tree farming. This will not only increase tree cover in these hills but will also contribute to soil and water conservation and climate change mitigation. The green credits thus earned will ultimately benefit local communities.

The aspiration of people/communities become higher as society reaches at higher developmental stages. People aspire to have more money to have comfortable life with secured resources to provide better education and living to their next generation. The old agricultural system in hills is basically a subsistence farming hardly anything available for sale. The problem in these hills is manifold like the hills themselves. I have dealt with the problems in this write up and have made efforts to put forward suggestion how to solve

them. All these have been summarized in Fig 1.

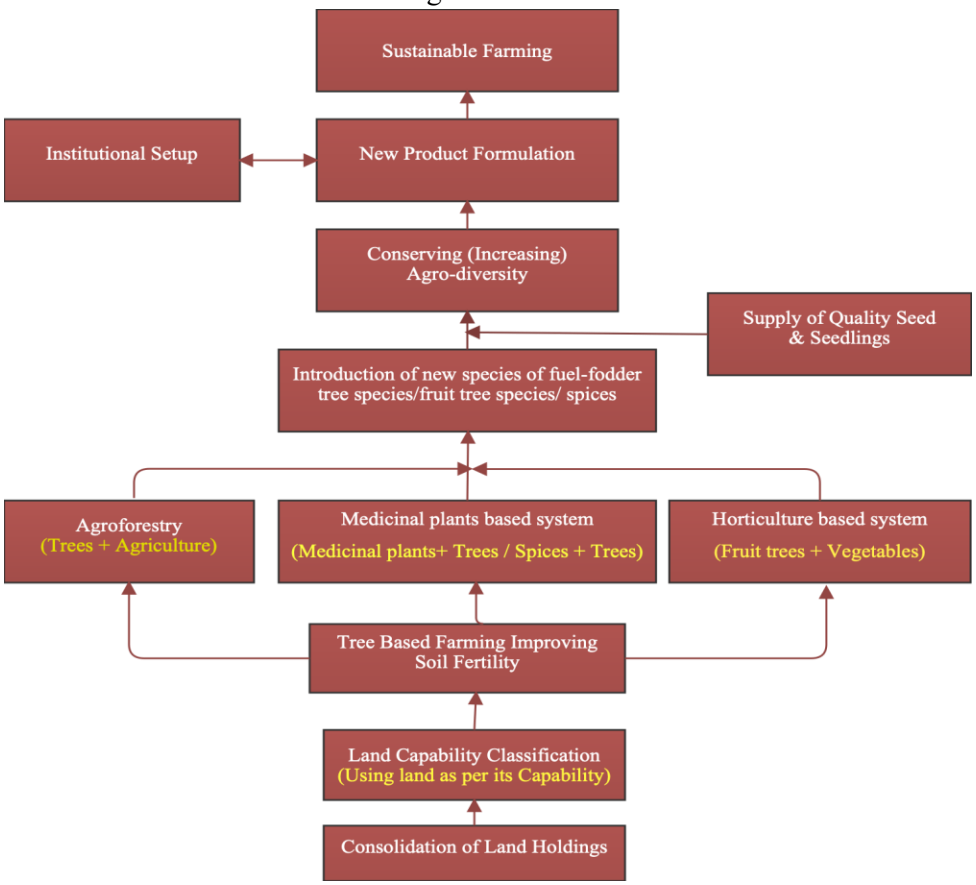


Fig.1: A consolidated statement about the steps needed to have sustainable farming in Uttarakhand Hills.

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