Status of an indigenous agro-forestry system in changing climate: A case study of the middle Himalayan region of Tehri Garhwal, India

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ABSTRACT: The agro-forestry system is one of the best known indigenous practices for livelihood. In view of instant decline in the rainfed hill agro-forestry system the present study was undertaken in the hilly villages of Uttarakhand state of India with the major objective to assess the status and effects of various factors on this centuries old indigenous agro-forestry system. The survey documented a total of 26 herbaceous food crop species and 21 woody species that were raised by farmers in the selected villages of Uttarakhand. A total of 37 plant species available in the agro-forestry system and used for curing various ailments by traditional healers were also documented during the survey. The major cereals produced by farmers were *Oryza sativa* L., *Echinochloa frumentoacea* Link., *Eleusine coracana* (L.) Gaertner and *Triticum aestivum* L. The indigenous system of cropping was locally called as Baranaja that revolved around the production of > 12 varieties of crops. Besides food, the species grown in the agro-forestry system were used for multiple purposes. Water scarcity, migration of youth in search of employment and changing socio-economic and climatic conditions were some of the major reasons for declining agro-forestry system and abandoning the agricultural land.

Keywords: Agro-forestry; indigenous practices; climate change; conservation and management; Tehri Garhwal

The majority of indigenous hill agricultural systems in the Garhwal Himalayan region of India is operated in the rainfed areas and therefore the onset of monsoon is the crucial determinant for the hill farmers. Historically, the abundant rains during summer and rainy seasons helped farmers of the middle Himalaya to expand their agricultural practices and grow a variety of cereals and pulses (Shiva, Vanaja 1993; Singh, Jardhari 2001). The surrounding natural resources and sufficient agricultural production had simultaneously shaped the cultural milieu and living style of the local people, which revolved around the settled agriculture and animal husbandry (Gautam, Singh 2005). However, over a period of time, changing climatic conditions, especially weakening of summer monsoon and shift in the groundwater level triggered changes in the indigenous agricultural practices. The groundwater level is estimated to be going down at a rate of 4 cm per year in northwestern India that includes the Garhwal Himalayan region (Kaur et al. 2009). The farmers of this region started diversifying the cropping system, and in order to reduce the degree of risk and vagaries of climate, many crop species were sown together. This practice was traditionally called as 'Baranaja' cropping system, which leads to a symbiosis relationship between different plants and contributes to increased productivity of crops (Kothari 1994; Shiva 1996).

In this indigenously evolved cropping system of Baranaja, more than 12 varieties of crops were cultivated together. Further, depending on the different biophysical and environmental set up, some tree species were also domesticated on the agricultural land, which simultaneously developed the indigenous agro-forestry system in the middle Himalayan region. Besides, to cope with the monsoon failure and change in climate, the local people designed the indigenous agro-forestry system in such a way so that the livelihood requirement may be maintained even in the lean periods. Nonetheless, in extreme situations, people started migrating from one place to other for sustaining the burden of survival. Traditionally, the hill farmers have maintained close linkages and balances between agriculture, forestry and animal husbandry, and based on these linkages the land use patterns are determined in the Garhwal hills (Maikhuri et al. 2009). Some 20 years ago, about 76% of the human population was reliant for livelihood on 21% of land suitable for agriculture in the Garhwal hills (Dadhwal et al. 1989). However, several factors including the continuous shortage of water over the years have severely impacted the traditional cropping systems. The historical evidences suggest that availability of water has always become a main reason for all the major ancient human civilization to grow and flourish, at the same time, climate-induced human migration is evident across the globe including the western and central Europe, Germany, North American West Coast, Alaska and Central Andes (Gupta et al. 2006).

Realizing the gravity of ongoing decline in the centuries old rainfed hill agro-forestry system due to several reasons including climate change and scarcity of water, it is imperative to study this once highly sustained indigenous agro-forestry system. It is a well known fact that without understanding the various land use practices adopted by farmers of the rainfed land, it is difficult to achieve the food security and various livelihood concerns of the local people (Kothari 1994; Kala 2007a,b; Kala et al. 2008; Kaur et al. 2009; Maikhuri et al. 2009). Therefore, the present study aims to understand and assess the status of the indigenous agro-forestry system in the middle Himalayan region of Tehri Garhwal of Uttarakhand. Attempts were also made to study and analyze the various factors, including climate change responsible for decline in the indigenous hill agro-forestry systems.

MATERIAL AND METHODS

Study area

The present study was carried out in the Hisriyakhal group of villages of Tehri Garhwal district in the Uttarakhand state of India. The Uttarakhand state lies in the northern region of India and spans over an area of 53,485 km^2. Of the total 8,479,562 human population of the state, 78% lives in rural areas. The agriculture land in the hills of Uttarakhand is scattered and fragmented. The per capita land holding of Uttarakhand farmers is 0.2 ha, and about 36% of rural families live below the poverty line. Agriculture contributes around 37% to state gross domestic production (Maikhuri et. al. 2009). The district Tehri Garhwal lies in the hilly areas of the state and agriculture is the major occupation of its inhabitants. This district consists of 182 villages with 61,569 ha area under cultivation, of which irrigated land is only 7.4% (Srivastava 2007). Uttarakhand is famous for its biodiversity, culture, tradition and mythology. The large altitudinal differences from the Himalayan foothills to the high altitude snow laden peaks and subsequent variations in the climatic and topographical conditions have established and maintained the vegetation and wildlife of the study area.

Survey methods

Field surveys were undertaken in four villages of the Hisriyakhal block, namely Chaka, Soudu, Nausilya and Ghuna located in the Tehri Garhwal district of Uttarakhand state in India. Semi-structured questionnaire survey was conducted in the villages and the head person of the each family was interviewed for collection of information on the indigenous system of agro-forestry, which included the pattern and production of agriculture and other crops. In the absence of headperson, the elder member of the family was interviewed. Information was also gathered on the effects of changing climate in terms of declining water availability on the indigenous agro-forestry systems. The indigenous uses of agriculture and forestry species were also recorded. The agricultural land was also surveyed for the availability of agro-forestry species, their composition and structure. Group discussion was also conducted with farmers for understanding the problems and prospects with the agro-forestry system in the study area along with the perceptions of local people on the climate change and indigenous agro-forestry. The information was also acquired through field inspections, field observations, participation in the social life of local farmers and their cultural events. The availability status of woody species (tree and shrub) in the agriculture field was studied by counting the number of tree individuals in one ha quadrat. A total of 3 such quadrats were laid down and the woody species with their individuals were enumerated in each quadrat.

RESULTS AND DISCUSSION

Indigenous agro-forestry structure, composition, and uses

A total of 26 herbaceous food crop species and 21 woody species raised by farmers in the selected villages of Uttarakhand were documented during the present investigations. There were two prominent cropping seasons – *ravi* (April–September) and *kharif* (October–March) in the study areas. In *ravi* season, about 12 varieties of crops were cultivated, which was called Baranaja (local term for 12 varieties of crops). Of these 12 crop species, 5 were cereals, such as *Oryza sativa* L. (Dhan), *Amaranthus cruentus* L. (Chaulai), *Echinochloa frumentoacea* Link. (Jhangora), *Eleusine coracana* (L.) Gaertner (Maduwa), and *Zea mays* L. (Mungri) and 6 were pulses. *Echinochloa frumentoacea* was produced in the highest quantity (7,500 per year), followed by *Eleusine coracana* and *Oryza sativa*. Of the pulses, *Macrotyloma uniflorum* (Lam.) Verdc.

Table 1. Status of annual crop production in selected villages of Tehri Garhwal

	Crops		Production/family/year (kg)	Total production village wise (kg)				Total
	Latin name	local name		Chaka	Soudu	Nausilya	Ghuna	
Cropping season *kharif* (March–September or summer rainy season)								
Main crops	*Amaranthus cruentus* L.	Chaulai	2.00	20	60	10	14.0	104
	Oryza sativa L.	Satti	50.00	500	1,500	250.0	350.0	2,600
	Echinochloa frumentacea Link.	Jhangora	150.00	1,500	4,500	750.0	1,050.0	7,800
	Eleusine coracana (L.) Gaertner	Maduwa	100.00	1,000	3,000	500.0	700.0	5,200
	Macrotyloma uniflorum (Lam.) Verdc.	Gahath	15.00	150	450	75.0	105.0	780
	Vigna mungo (L.) Hepper	Urd	4.00	40	120	20.0	28.0	208
	Phaseolus vulgaris L.	Chhemi/rajma	5.00	50	150	25.0	35.0	260
	Cajanus cajan (L.) Millsp.	Tor	5.00	50	150	25.0	35.0	260
	Sesamum orientale L.	Til	2.00	20	60	10.0	14.0	104
	Vigna unguiculata (L.) Walp.	Sonta	0.50	5	15	2.5	3.5	26
	Raphanus sativus L.	Mula	5.00	50	150	25.0	35.0	260
	Zea mays L.	Mungri	2.50	25	75	12.5	17.5	130
Vegetables	*Cucurbita maxima* Duch. ex Lam.	Kadu	50.00	500	1,500	250.0	350.0	2,600
	Lagenaria siceraria Standl.	Launki	25.00	250	750	125.0	150.0	1,275
	Tricosanthes anguina L.	Chachenda	5.00	50	150	25.0	35.0	260
	Momordica charantia L.	Karela	10.00	100	300	50.0	70.0	520
	Brassica rugosa (Roxb.) Bailey	Rai	5.00	50	150	25.0	35.0	260
	Spinacea oleracea L.	Palak	5.00	50	150	25.0	35.0	260
	Colocasia himalayensis	Pindalu	10.00	100	300	50.0	70.0	520
	Momordica dioica Roxb. ex Willd.	Kankora	5.00	50	150	25.0	35.0	260
Cropping season *ravi* (October–March or winter season)								
	Triticum aestivum L.	Gehun	35.00	350	1,050	175.0	245.0	1,820
	Hordium vulgare L.	Jau	10.00	100	300	50.0	70.0	520
	Lens esculenta Moench.	Masur	6.00	60	180	30.0	42.0	312
	Pisum sativum L.	Matar	0.50	5	15	2.5	3.5	26
	Solanum tuberosum L.	Alu	10.00	100	300	50.0	70.0	520
	Brassica campestris L.	Sarson	5.00	50	150	25.0	35.0	260

(Gahath) produced the highest yield, followed by *Phaseolus vulgaris* L. (Chhemi) and *Cajanus cajan* (L.) Millsp. (Tor). Apart from this, 8 varieties of vegetables were also cultivated by farmers during April to September: of these *Cucurbita maxima* Duch. ex Lam. (Kadu) was produced in the highest quantity, followed by *Lagenaria siceraria* Standl. (Launki). In the *kharif* season, a total of 6 crops were cultivated by the farmers, of these 3 were cereals and 3 were pulses and vegetables. *Triticum aestivum* L. (Gehun) was the major cereal, and farmers produced about 1,850 per year, with average production of 35 per family (Table 1).

The major woody species grown by the farmers in their agro-forestry system were *Celtris australis* L. (Khadik), *Melia azedarach* L. (Daikan), *Grevia optiva* Dumm. ex Burret. (Bhimal), *Pinus roxburghii* Sarg. (Kulai) and *Toona serrata* (Royle) M. Roemer (Tun). The forestry species served for multiple indigenous uses including fodder, fuelwood, fibres, timber, medicine and food. Some of the species were also used for religious purposes. The seeds of *Pinus roxburghii* (chir pine) were also gathered to eat. Besides, two species were used as bio-fencing (Table 2). The fodder trees such as *Melia azedarach, Celtris australis* and *Grevia optiva* were planted on the agricultural land as well as within the village premises. During the scarcity of fodder in the summer season these fodder tree species were lopped to feed cattle, especially milking animals. The fodder trees are planted at the bunds of the land. Among all the tree species, *Grevia optiva* was the most important multipurpose species that once planted on the terrace bunds regenerated naturally. The seedlings were then protected by farmers. Apart from fuelwood, fibre, fodder and medicine, the bark and stem of *Grevia optiva* were used to make baskets.

Some of the crops such as *Cleome viscosa* L. (Jakkhya) were not cultivated and although growing as weeds on the agricultural land it was interestingly an important cash crop. Generally, it was weeded out from the agricultural crops, and only a few individuals were left to grow with the crops. A single individual of jakkhya might have produced 50–100 g seeds

Table 2. Status of tree species in the agro-forestry system of selected villages of Tehri Garhwal

	Latin name	Local name	No. of individuals·ha^{-1}	Major ethno-botanical uses
Trees	*Grevia optiva* Dumm. ex Burret.	Bhimal	34	fodder, fibre, fuel
	Pyrus pashia Buch.-Ham.	Melu	42	fruit – edible
	Prunus persica (L.) Batsch	Aru	11	fruit – edible
	Celtris australis L.	Khadik	23	fodder
	Sapium insigne Royle	Khinna	2	
	Pinus roxburghii Sarg.	Chir	1	timber, fuelwood
	Bombax ceiba L.	Semal	2	flower – vegetable
	Toona serrata (Royle) M. Roemer	Tun	1	timber
	Prunus cerasoides D. Don	Paiyan	5	religious
	Mangifera indica L.	Aam	1	fruit – edible
	Punica granatum L.	Anar	1	fruit – edible; fruit cover – medicine for cough & cold
	Melia azedarach L.	Daikan	2	fodder; timber
	Ficus semicordata Buch.-Ham. ex Smith	Khainu	2	fruit – edible
	Ficus auriculata Lour.	Timla	1	fruit – edible
Shrub	*Berberis asiatica* Roxb. ex DC.	Kingod	26	root – medicine; fruit – edible
	Rhus parviflora Roxb.	Shaunlu	10	stem – toothpaste; fruit – edible
	Rubus ellipticus Smith	Hisar	22	fruit – edible
	Ficus palmata Forsk.	Bedu	16	fruit – edible
	Carissa opeca Stapf.	Karonda	20	fruit – edible
	Vitex negundo L.	Shiwali	3	bio-fencing, medicinal
	Euphorbia royleana Bioss.	Sullu	4	bio-fencing

depending on the soil, water and farm yard manure conditions. The major use of Jakkhya was to flavour different dishes made up of pulses and vegetables. Jakkhya was sold at the rate of Rs. 12/– per kg. Because of trade and changing climatic conditions it has been reduced over the years. The other reason of low production of Jakkhya was the continuous reduction of manure in the field.

Many of these species growing in the agro-forestry system were used by local people and in most cases by some specialized traditional herbal healers for curing various types of diseases prevalent in the study villages. The present survey documented 37 plant species growing in the agro-forestry system and used by traditional healers for curing multiple diseases. Of these medicinal plants, 11 were tree species, 7 shrubs and 19 were herbaceous species (Table 3). Different plant parts of these species, such as bark, root, leaf, stem, flower and seed were used for medicine preparation. In general, the traditional agro-forestry system in the study villages was raised and nurtured in such a way that the basic requirement of living for food, shelter and medicine might have been achieved.

Traditional ecological knowledge and management of agro-forestry

Only few species of trees were planted on the agricultural land by the farmers. By growing only a few species of trees the farmers reduced the risk of crop competition with trees. It is a known fact that once the tree is established, its underground parts go deeper in the soil than the agricultural crops, which also helps in diminishing competition for nutrients and soil moisture. The increase in competition between trees and agricultural crops may reduce the crops yield. There are reports on minimum number and maximum yield strategy adopted by farmers elsewhere in the world to diversify land use in agroforestry systems (Zeide 2008). The farmers of the study villages kept on lopping and thinning trees in the agro-forestry system, which maintained the space and provided a critical factor for the survival of crops, the sun light. A study conducted elsewhere has pointed out that the wood quality gets improved by pruning or cutting of branches. Besides, it also helps to grow trees taller (Zeide 2008).

Each village ecosystem in the study area was mainly revolved around the practices associated with agriculture, forestry and animal husbandry. The villagers had developed interrelationships and linkages between these practices in such a way that the existing resources may be optimally utilized for maintaining the continuity of the system. In the period between harvesting one crop and sowing another crop, the domestic animals were freed on the land used for agriculture. This helped to supply manure and maintained the fertility of land. The entire agro-forestry system was purely organic and cattle dung was used to increase the fertility of land. Each family in the study villages had about 0.8 ha of land under the agro-forestry system. Accordingly, all 52 families of the 4 study villages had about 42 ha of land under agroforesty that was treated annually by about 400 quintals of cow dung as farm yard manure. A part of the cattle dung was also used as fuel by sun drying. The agriculture land was surrounded by scattered chir pine (*Pinus roxburghii* Sarg.) trees and the understory in these thin forests was grazed and browsed by domestic animals. Due to the altitudinal gradients, the cattle dung in these pine forests with other organic matter drained down in the agricultural field and subsequently increased the fertility of the land.

One of the important aspects of the traditional agro-forestry system was to produce fodder for livestock. After thrashing crops to grains, the residue or hey was used for feeding cattle during the lean period. The dry crop residue and grasses were piled and stored around homestead trees for the use by cattle during the lean period. This storage of dry grasses and crop residue was locally called 'Parkhunda'. In the case of fodder adequacy to cattle, some of the crop residue was scattered on the agricultural land for improving the fertility of soil. The farmers were also very particular for seeds used to raise next year's crops. To protect such seeds from fungus infection and pests, the farmers used to treat them with cow urine, ash, and *Azadirachta indica* (A. Juss) Callus (locally called as Neem) leaf and stored it in a separate box made up of wood or bamboo. After separating grains the stems of wheat plants were used to prepare carpets and baskets. Such baskets made of wheat stems were also used to store grains.

Changing climate and effects on agro-forestry system

Water scarcity was a common problem of all the villages in the study area. The water quantity has either decreased several times or the water sources have completely dried up in the area over the years. It was hard to get even drinking water. Due to scarcity of water people were forced to drink dirty polluted water stored for several days, which was very unhygienic. During summer, the villagers were

Table 3. Various crops and other plant species used by specialized traditional herbal healers for curing diseases in the study villages

Latin name	Family	Local name	Plant used	Medicinal uses	Life form
Pyrus pashia Buch.-Ham.	Rosaceae	Melu	fr	digestive disorder	shrub
Prunus persica (L.) Batsch	Rosaceae	Aru	lf, bk	cold and cough, suppressed urination	tree
Grevia optiva Dumm. ex Burret.	Tiliaceae	Bhimal	lf, fr, st	bone fracture, child birth, fever	tree
Lagenaria siceraria Standl.	Cucurbitaceae	Lauki	fr, lf	jaundice, cracks	herb
Bombax ceiba L.	Bombacaceae	Semel	rt, bk	blood dysentery, asthma, dysentery, fever	tree
Celtis australis L.	Ulmaceae	Khadik	bk	leprosy	tree
Cleome viscosa L.	Cleomaceae	Jakkya	sd, lf	rheumatic arthritis, wounds	herb
Colocasia esculenta (L.) Schott	Araceae	Pindalu	tuber	indigestion	herb
Cucurbita maxima Duch. ex Lam.	Cucurbitaceae	Kaddu	sd, fr	intestinal worms	herb
Curcuma domestica Valeton	Zingiberaceae	Haldi	rh	skin and digestive disorder, blood purification	herb
Euphorbia royleana Boissier	Euphorbiaceae	Sullu	latex	antiseptic	shrub
Hordeum vulgare L.	Poaceae	Jau	sd	pimples, urinary complaints	herb
Lens esculenta Moench.	Fabaceae	Masur	sd	skin diseases	herb
Mangifera indica L.	Anacardiaceae	Aam	sd, bk	diarrhoea, haemorrhage, scabies, tonic	tree
Carissa opeca Stapf.	Apocynaceae	Karonda	lf, rt, bk	fever, purgative	shrub
Cajanus cajan (L.) Millsp.	Fabaceae	Tor	sd, lf, fl	skin burn, mouth sores	herb
Brassica compestris L.	Brassicaceae	Sarson	wp	migraine, cough, leprosy	herb
Brassica rugosa (Roxb.) Bailey	Brassicaceae	Pahari rai	sd	body-ache, skin diseases, cold	herb
Berberis aristata DC.	Berberidaceae	Kingode	rt, bk	fever, eye complaints	shrub
Amaranthus spinosus L.	Amaranthaceae	Chaulai	wp	blood purification, cold, cough, snake bite	herb
Ficus auriculata Lour.	Moraceae	Timla	fr	digestive disorder	tree
Ficus palmata Forsk.	Moraceae	Bedu	fr	digestive disorder	tree
Ficus semicordata Buch.-Ham. ex Smith	Moraceae	Khaina	fr	digestive disorder	tree
Melia azedarach L.	Meliaceae	Daikan	fr, lf	antiseptic, abortifacient, rheumatic pain	tree
Momordica charantia L.	Cucurbitaceae	Karela	lf, sd, fr, rt	diabetes, eczema, malaria	herb
Momordica dioica Roxb. ex Willd.	Cucurbitaceae	Kankora	wp	asthma, piles, headache, delirium	herb
Pisum sativum L.	Fabaceae	Matar	sd	diabetes	herb
Psidium guajava L.	Myrtaceae	Amrood	bk, lf	throat infection, diarrhoea	tree
Raphanus sativus L.	Brassicaceae	Muli, mula	lf, sd	fever, liver disorder, bronchitis	herb
Rhus parviflora Roxb.	Anacardiaceae	Saunla, Tungla	lf	cholera	shrub
Rubus ellipticus Smith	Rosaceae	Hinsalu	rt, fr	dysentery, malaria, stomach-ache	shrub
Sesamum orientale L.	Pedaliaceae	Til	sd	aphrodisiac, body-ache, dysmenorrhoea	herb
Solanum tuberosum L.	Solanaceae	Aalu	tuber	burns, skin irritations	herb
Spinacea oleracea L.	Chenopodiaceae	Palak	lf	kidney stones	herb
Toona ciliata Roem.	Meliaceae	Tun	bk, fr, lf	antiseptic, bronchitis, fever, dysentery	tree
Vigna mungo (L.) Hepper	Fabaceae	Urd	sd	indigestion	herb
Vitex negundo L.	Verbenaceae	Shiwali	st, fl, lf	arthritis, sprains	shrub

lf – Leaf; sd – seed; fr – fruit; fl – flower; bk – bark; wp – whole plant; st – stem; rh – rhizome mainly dependent on the water supplied by tankers. But it was difficult to supply even the drinking water to the villagers away from the roadside. All the villagers unanimously admitted that the fertility of land had decreased over the years due to scarcity of water and climate change. In the past couple of years, the rainfall was highly unpredictable, and generally, it was low, which led to the low productivity.

The area of agro-forestry land has been reduced due to several reasons including the migration of people in search of quality life standards. It was noticed that most of the present agro-forestry techniques as practiced by farmers were poorly managed and in the majority of cases, the trees were neither protected nor replanted. Similar observations were made by Dadhwal et al. (1989). In some cases, the use of chemical fertilizers on the rainfed agricultural land by some farmers of the nearby district led to dry up the indigenous agro-forestry system. The use of chemical fertilizers and pesticides on the rainfed land is not considered suitable for the production of crops in the long run and also negatively affects the agro-ecosystem and surrounding biodiversity (Kala 2007b). Recently in June 2009, there was a report on sudden death of 10,000 parakeets in the nearby district of Garhwal – Udham Singh Nagar, which was associated with the use of pesticides on the farmlands.

Earlier, farmers had alternative ways of cropping, changing the crop sown to varieties that needed only a few showers to mature, like millet. But currently due to years of stress migration, people were losing the will and the indigenous knowledge to invest in rainfed agriculture. Due to instant shrinking of the agro-forestry land area, the available standing crops were repeatedly destroyed by wild animals such as wild boar, monkey and porcupine. Since a major part of the agricultural land has been now left barren, the concentration of damage by wild animals increased on the available land under agro-forestry system.

Within the past less than a decade, some of the crops cultivated previously have become locally extinct from the study villages. *Setaria italica* (L.) Beauv. (Koni) was such a crop, which was no more cultivated now but 10 years ago each family had produced about 10 kg *Setaria italica* per year. It was matured 15–20 days before *Echinochloa frumentacea* and was one of the important crops of the Baranaja system of Garhwal. The dishes prepared from *Setaria italica* had a high nutritive value. Besides, *Sorghum vulgare* Pers. (locally called Jundla) was also cultivated by the villagers in the past, about 2 decades ago, but now its cultivation was also stopped. There were different landraces of rice and two of them were the major landraces – reddish and white seeds. Generally, the red landrace of rice was cultivated by the farmers as it had several advantages including the high nutritive value. It was also less damaged by wild animals such as wild boar due to its spiny grains, which were unpalatable and uncomfortable to eat. The landraces are the product of continuous selection, breeding, experimentation and on-farm conservation of mountain farmers, and local extinction of these landraces is the cause of concerns to continue the traditional Baranaja system of mixed cropping.

An indigenous agro-forestry system not only supports the livelihood through production of food, fodder and firewood but also mitigates the impact of climate change through carbon sequestration (Pandey 2002, 2007). In the agro-forestry system, the soil is enriched through continuous biomass flow (bedding material in the animal sheds, fodder and mulch material, for example) from the surrounding forest areas (Gautam, Singh 2005). The system of tree growing in combination with agriculture needs to be maintained, especially in the hills with an important view of maintaining the land stability and protection from soil erosion. For sustained development in the region it is important to continue organic farming for enriching soil and soil depth. Being a centuries old locally adaptive system, it is one of the promising areas of land use. The indigenous knowledge developed over the centuries by the hill farmers on the variability of sowing and harvesting of crops at various elevations is an example of mitigating the impact of changing climate. The agricultural crops are supported by trees on the rainfed land, which receives low rainfall, by retaining the moisture content in the soil and atmosphere.

Since the 1970s the total cropped area in India has remained static at around 140 million, and according to the National Agricultural Policy, India must achieve a growth rate of 3–4% per annum in the sector. The shrinking agro-forestry system in the hills of Uttarakhand may enhance the problem of meeting the country's requirement for food security. The National Agricultural Policy should include and address the core issue of hill agriculture, which is mostly organic and rich with indigenous crops diversity, for its continuity. Besides, the agro-forestry system sequesters a sizeable amount of carbon and helps in mitigating the global climate change. Hence, it is important to encourage the farmers for continuing the tradition of agro-forestry. The hill topography, soil ecosystem, land fragility and environmental heterogeneity may not substantiate mono-cropping, hence the Baranaja system of mixed cropping should be continued.

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