A SOCIO-ECOLOGICAL ANALYSIS OF A TYPICAL MOUNTAIN AGRO-ECOSYSTEM IN CENTRAL HIMALAYAS: A FOCUS ON CHAMOLI DISTRICT IN UTTARAKHAND, INDIA

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Mountain agro-ecosystems in Indian Central Himalayas have been analyzed and their productive performance in the district of Chamoli has been discussed. The existing agro-ecosystems in the Himalayan mountains encompass all the major components in organic linkages with each other. The distinctive features of these agro-ecosystems could be helpful in addressing inherent fragility of the Himalayas and acquiring agricultural sustainability in the region. A forest, the core component of the mountain agro-ecosystems, serves as a natural fertilizer repository and is phenomenal for enhancing sustainability of mountain agriculture but ecological degradation of the forests in the region averts this opportunity. As a result, the overall productive performance of mountain agriculture is poor, as has been revealed from the agricultural performance in the Chamoli district of Central Himalayas. It has been inferred that ecological amelioration of the forests can help realize the productive potential of agriculture in the Himalayas.

Introduction

Mountains, especially the Himalayan mountains, constitute one of the most fragile ecosystems on planet Earth. However, their ecological and environmental functions are vital for the mainstream world constituted largely of the plains. Never before in the history has Indian agriculture been as vulnerable and uncertainty-ridden as it is today. A glimpse of the dynamics of Indian agriculture reveals that it has systematically deviated away from its very base, that is, the environment—the prop that nourishes all biological resources. Today's agriculture is valued against the prices it fetches from the market, especially the global market. Its contribution to human health and welfare, ecological integrity, resilience of nature, etc. are grossly neglected[1 - 6]. Mountain agriculture, in fact, has many more attributes than the mainstream global economy can appreciate.

Agriculture in Indian ethos has not just been a source of livelihood, human survival, progress and sustainability, but also a way of life, a potent symbol of a civilization, a culture and a philosophy. With the retrogression of agriculture, we are also bound to witness crumbling of Indian ethos reflected in basic Indian philosophy, the agro-ecophilosophy[6]. Making agriculture healthy, vibrant and sustainable is not only necessary but also an imperative of a healthy, vibrant and sustainable society. It is also an imperative of our destiny.

This paper attempts to analyse mountain agro-ecosystems in the Indian Central Himalayas as of today with a focus on district Chamoli in the Uttarakhnad State of India, as one of the representative regions depicting all typical features of an agro-ecosystem.

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Materials and Methods

The socio-ecological analysis of mountain agriculture pertains to the Indian Central Himalaya which is fairly representative of the entire Hindu Kush-Himalayan Range extended into the boundaries of eight countries of South Asia, namely Afghanistan, Pakistan, Tibet, India, Nepal, Bhutan, Bangladesh and Myanmar. Nestled almost in the centre of the Hindu Kush-Himalayas, the Indian Central Himalaya (30.33^0N 78.06^0E) is part of the Indian Himalayan State of Uttarakhand that came into being on November 9, 2000 as the 27th State of Republic of India. Spread over a geographical area of 53483 km^2, the State is divided into two divisions, namely Kumaun and Garhwal and has 13 districts. Agriculture is the mainstay of the people in the State.

The Chamoli district (30.42^0N 79.33^0E) on which the study focuses lies in the Garhwal Division and from the perspective of land use and socioeconomic considerations is an ideal representative for the purpose of socio-ecological analysis of mountain agriculture. More of the features of Chamoli District have been discussed in the next section.

Primary information was collected on the spot. Oral testimony, rural appraisal and personal reconnaissance with the agro-ecosystems and farmers' culture have been crucial in the whole analysis of the mountain agro-ecosystems. Secondary data relating to various socioeconomic parameters of District Chamoli was derived from a large body of government records in the State of Uttarakhand.

Result and Discussion

Mainstream Agriculture vs Mountain Agriculture: The fragile mountain ecosystems witness very high degree of biodiversity. Further, mountain ecosystems play very crucial role which the mainstream plain areas cannot. Mountain ecosystems are altogether different from those of the plains and so is mountain agriculture. Despite massive agricultural transformations having taken place all over the world, mountain people have not transformed their agriculture to an appreciable extent. Mountain agriculture, despite intensive institutional intervention, by and large, stays traditional. The cropping systems accommodate biodiversity of plants, both at species and genetic levels which change according to the type of an agro-ecosystem. Some of the striking characteristics of the mainstream and mountain characteristics are shown in Table 1.

TABLE 1: Some features of mainstream and mountain agriculture (Singh et al., 2014)

Features	Mainstream agriculture	Mountain agriculture
Farming system	Absent	Present
Fragility	Moderate	High
Marginality	Low	High
Inaccessibility	Least	High
Diversity/ heterogeneity	Minimum	High
Niche/ comparative advantage	Poor	Rich
Adaptation capability	Poor	High
Complexity	Less	High to extreme
Vulnerability	high	Moderate to high
Resilience	Low	High
Water use efficiency of crops	Poor	High
Inputs	External	Internal
Productivity	Moderate to high	Moderate
Sustainability	Poor	High

Earlier, some prominent mountain scholars have attempted to bring to the fore the distinguishable features of mountain agriculture. The present socio-ecological analysis comes out as a validation of the features of fragile mountain agro-ecosystems as elucidated by these mountain scholars [6 - 9].

Components of a Mountain Agro-ecosystem : A mountain agro-ecosystem (or farming system) comprises uncultivated land (often forest or rangeland), cropland (the cultivated land), livestock and households as its integrated parts (Fig. 1). Uncultivated land serves as a natural reserve of biodiversity, energy (e.g., fuel wood), water (that flows

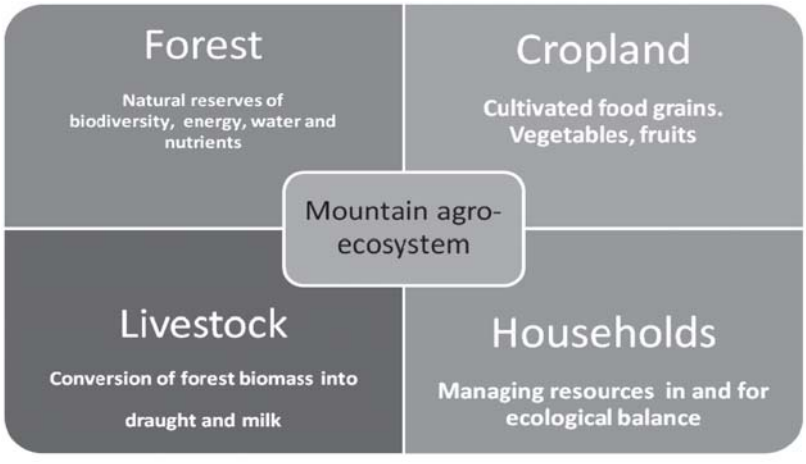

Fig. 1: Components of a typical mountain agro-ecosystem (Source Singh et al., 2014)

in the form of rainfed rivers, rivulets or springs) and nutrients. This is the largest component of a mountain agro-ecosystem. Forests are ecologically more stable than the croplands, hence more resilient and less vulnerable. They do not require an input of nutrients or water. The water received through precipitation is conserved and brought into hydrological cycle by the forests. Forests are rich reserves of nutrients that also nourish croplands.

Forests are capable of regeneration. If forest products are exploited judiciously, they would be capable to regenerate themselves. Higher the measure of biodiversity in a forest ecosystem, greater would be its role in nourishing the croplands. In addition to the ecosystem functions vital for the sustainability of an agro-ecosystem, a forest is also capable of producing very large number of edible food products, such as wild fruits, buds, flowers, seeds, beans, mushrooms, etc. apart from valuable medicinal plants and several other plants of economic value.

Cropland is the land area of an agro-ecosystem that serves to produce cultivated foods. This land is constantly nourished by the nutrient stock in a forest ecosystem, either directly (such as through the input of mulch/ forest floor litter) or through livestock (through manure application).

Mountain agriculture is a mixed agriculture and gives prominent place for the livestock. Livestock play crucial role in transferring nutrients from a forest/ rangeland ecosystem to a cropland. A rich body of literature on mountain agriculture reveals the many distinguishable facets of mountain agriculture[1,3,5,10 - 13]. The cropland is more fragile than the forests since the cultivated food crops depend on the nutrients of top soil, not on deeper layers of the soil as the trees in the forests do. Therefore, in order to maintain soil fertility, the top soil is replenished with the nutrients from outside the cropland. Livestock also help in recycling of nutrients into croplands. Their main contribution is to supply draught power needed for ploughing, leveling, puddling, inter-culture operations, etc. apart from yielding milk as one of the most important food items for human beings[14]. In addition, they also serve as crucial part of the local cultures and as a cushion against socio-economic fluctuations. Livestock role is vital for the very sustainability of mountain agriculture.

A village is a cluster of households owned by farmers, the custodians and managers of an agro-ecosystem. Why should the households be regarded as a component of an agro-ecosystem? Because the households are the major consumers of the nutrients moving with foods cultivated within an agro-ecosystem. Farmers have been at the heart of the evolution of Indian agriculture. Mountain farmers are a rich repository of Indian wisdom. They are equipped with the knowledge and technologies by means of which nature and its biodiversity are conserved, enhanced and sustainably utilized. The farmers have never kept their farming systems in static state. They have been changing themselves and their systems as per specific circumstances, in accordance with time and space[15]. They have evolved strategies as per the local specificities that can cope up with adverse circumstances.

Organic Linkages among Agro-ecosystem Components : The farming system the local farmers have developed is characterized by organic linkages among all components (Fig. 2). Self-containment is another key feature of the mountain farming system in that nutrients are produced within the system (not to be imported from the market). These flows (of nutrients, water/ moisture and energy) are indispensable for the very ecological integrity of the farming system.

The uncultivated land, i.e., the land covered with forests/ rangelands, is the most critical component of a mountain agro-ecosystem. It serves as a natural fertilizer factory for the cultivated land (cropland). Productive performance as an attribute of a farming system, critically depends on the size and quality (type of the forest) of the uncultivated land.

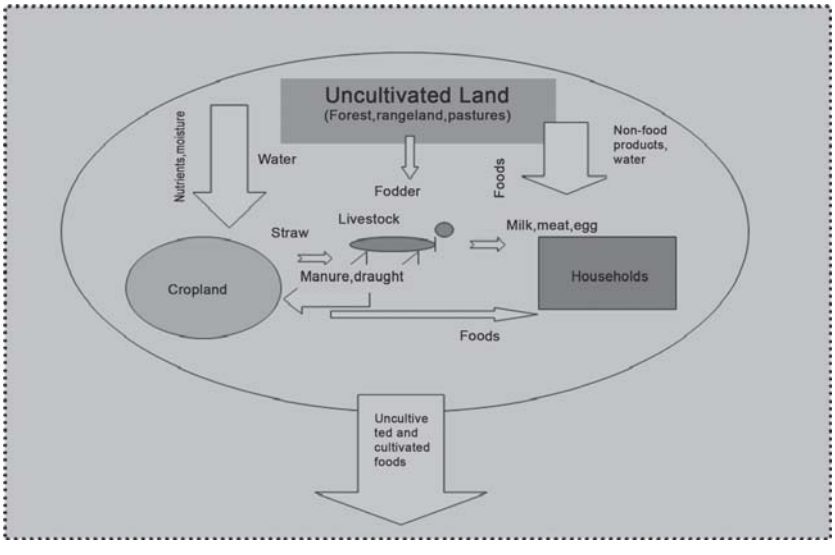

Fig. 2: A mountain agro-ecosystem: linkages between components/ subsystems, nutrient and water flows maintain ecological integrity and sustainability of the food production system (Source: Singh et al., 2014)

Energy in the form of fuel wood and fodder are the major produce of the uncultivated land. Households extract necessary fuel wood from this area for use as energy source for cooking foods and keeping houses warm during winter season. Tree leaves and grasses growing in the uncultivated area are fed to livestock. Livestock also often graze in the rangelands/ grasslands of the uncultivated areas. Thus forest nutrients contribute to the maintenance and production of domestic animals. A proportion of these nutrients is transferred to the cultivated land through manure. Thus livestock serve as a living bridge between ecologically more stable forest ecosystem (the uncultivated land) and more fragile ecosystem (the cultivated land). Livestock are also fed crop residues to come from the cultivated land and a proportion of these nutrients is recycled into cultivated lands. Livestock contribute their labour (draught power) to prepare fields for cropping in the cultivated area. Their produce – (mainly milk from buffaloes and cows), wool from sheep and meat from goats – is utilized in the households of a farming system. Minor produce from the forests (such as a variety of wild foods like fruits, edible leaves, buds, flowers, thalamus, roots, underground stems, mushrooms, pods, seeds, honey etc., and herbal medicines are also consumed by the households.

Wherever there is a dense natural forest as a component of an agro-ecosystem copious amounts of water are naturally stored in it and released as small rivulets which is used for irrigation of crops in the cultivated land and for domestic purpose. Thus water is also a 'produce' of a mountain agro-ecosystem which should be regarded as one of its extraordinary nature. However, due to intensified ecological disruption of the natural forests, the forest-linked water cycle is breaking down resulting in acute water crisis in many mountain areas.

Farming Situations : There are as many as nine farming situations identified on the basis of verticality and slope-orientation in the Indian Central Himalayas. These are as follows[6]:

1. Valley irrigated
2. Valley rain-fed
3. Lower hills North slope
4. Lower hills South slope
5. Mid-hills North slope
6. Mid-hills South slope
7. High Mountains North slope
8. High Mountains South slope
9. Alpine pastures

Each of the farming situations serves as a specific ecological niche for producing specific foods and for specific functions. These farming situations help create a diversity of ecological niches in the mountains, each niche with specific environmental setup is conducive to to produce specific crops (cereals, coarse cereals, pseudo-cereals, oilseeds, vegetables, fruits, medicinal and aromatic plants, etc.). If a situation suits to cultivation of cereals, the other will be appropriate for vegetables or fruit production. This diversity of farming situations puts the mountain areas in comparative advantage in respect of the plains.

TABLE 2: Land use (in hectares) in Chamoli district

Land use (hectares)	2008-09	2009-10	2010-11
Total reported area	851764.00	851764.00	851764.00
Forests	506100.00	506100.00	506100.00
Cultivable barren land	71116.00	71100.00	71095.01
Current barren land	308.00	210.00	82.00
Other barren land	697.00	566.00	87.00
Degraded and non-cultivable land	10302.00	10280.00	9203.00
Land use other than agriculture	61209.00	61209.00	61211.00
Grazing land	27865.00	27849.00	27860.00
Area under orchards, trees and shrubs	141500.00	141490.00	141510.00
Net sown area	32667.00	32960.00	34616.00
Area sown more than once	14424.00	16685.00	18237.00
Total sown area	47091.00	49645.00	52853.00
Rabi (winter) season	16397.00	16719.00	18245.00
Kharif (summer) season	30694.00	32926.00	34608.00

Source: District Economics and Statistical Office Chamoli (2012)

Agriculture Scenario of Chamoli District : Chamoli district in Indian Central Himalayas (the Uttarakhnad State of India) is one of the representatives of typical mountain agriculture. A general land use in this district is as in Table 2. The land use, in order to understand its dynamics, has been shown over a period of three years. Some other valuable information relating to Chamoli district (Table 3) portrays a glimpse of agriculture in a nutshell.

If we look at the cultivated area devoted to various food grains, a picture of disproportionate area allocation is clearly visible (Fig. 3). Of the total food grains, cultivated area shared by cereals (rice, wheat and coarse cereals) is

TABLE 3: Some important data relating to agriculture in Chamoli district

Particulars	2009-10	2010-11
Forests area of the total reported area (%)	59.42	59.41
Net sown area of the total reported area (%)	3.87	4.06
Crop intensity (%)	150.62	152.68
Cash crop area of the total net sown area (%)	8.81	8.81
Average yield of food grain crops (quintal per ha)	12.11	13.37
Fertilizer application (kg per ha)	0.25	0.23
Per capita food grain production (kg)		
Cereals	144.06	178.49
Pulses	4.47	155.36
Net irrigated sown area of the net sown area (%)	5.48	4.99
Total irrigated sown area of the total sown area (%)	6.86	6.21

Source: District Economics and Statistical Office Chamoli (2012)

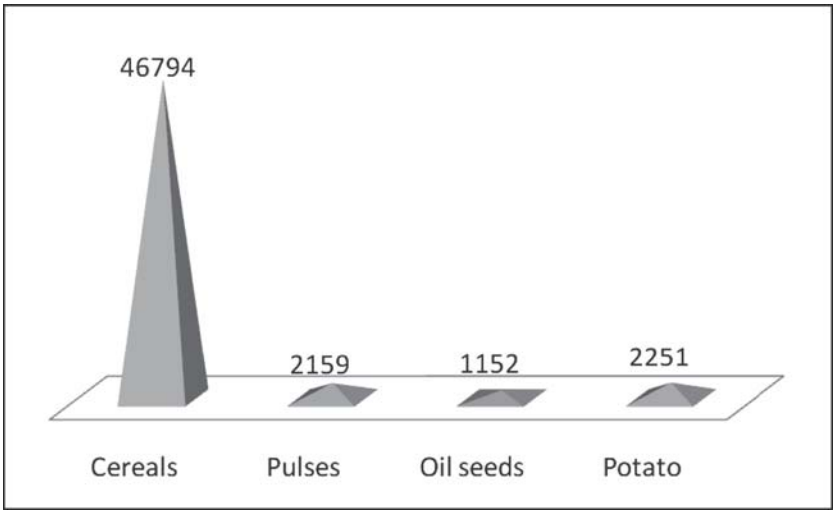

Fig. 3: Area (ha) allocated to different food grains in district Chamoli in 2010-11 (Source: based on District Economics and Statistical Office Chamoli, 2012)

as high as 90%. Pulses and oil seeds were allocated only 4% and 2% of the total cultivated area, respectively. Thus, total area devoted to food grain crops (cereals, pulses and oilseeds) in district Chamoli during 2010-11 was as high as 96%. Some 4% area was used for potato cultivation (Fig. 4).

Disproportion in the allotment of cultivation area for different food grains and important energy and vegetable crop potato will inevitably have bearing on the disproportionate production of these crops, and consequently on nutrients to be made available to the

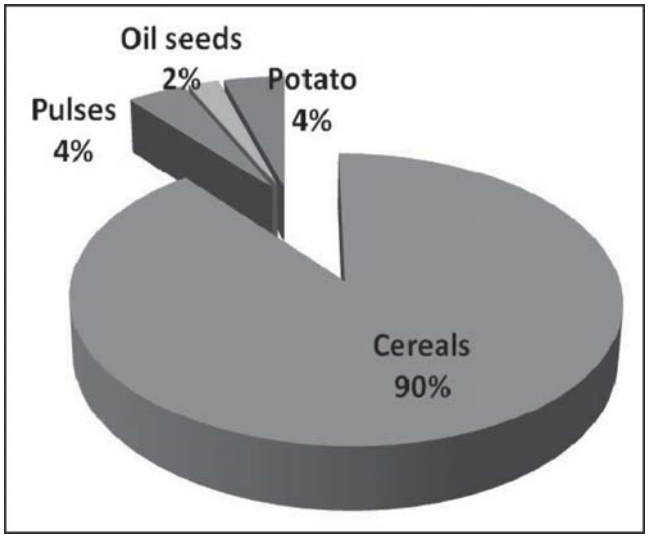

Fig. 4: Proportion of cultivation area allocated to different crops in Chamoli in 2010-11 (Source: based on District Economics and Statistical Office Chamoli, 2012)

population.

Average productivity of major crops in Chamoli district (Table 5) is very poor compared to the values obtainable in mainstream agriculture in the plains. Average productivity of cereals (13.59 q/ha) is higher than that of pulses (8.71 q/ha), in the year 2010-11. Productivity of oil seeds is still very poor, with average 6. 53 q/ha, as in 2010-11 in the district of Chamoli. Lower productivity of crops in the mountains might be attributable to many factors, such as inherent environmental (e.g., lack of irrigation facilities) as well as managerial ones (e.g., low rates of fertilizer application). Comparative productivity of the crops over three consecutive years in the district becomes clearer through graphical representation (Fig. 5)

Among all the crops wheat recorded the highest production (21943 MT), followed by rice (17532 MT) during 2010-11 in the district of Chamoli. The next crop with large production was finger millet (14964 MT) and then the barnyard millet (4731 MT). Barley and maize registered 2889 and 175 MT production during 2010-11 in the district. Total cereal production was 63583 MT. Among the pulses the highest production recorded was that of black gram (318 MT). Pigeon pea, lentil and pea recorded only meager production in the district during this period (53, 20 and 19 MT, respectively). Total pulse

TABLE 4: Area under major food crops (ha) in Chamoli district

	2008-09	2009-10	2010-11
Rice			
Total	11714.00	11673.00	12407.00
Irrigated	1646.00	1793.00	1729.00
Wheat			
Total	13756.00	14235.00	15295.00
Irrigated	1572.00	1580.00	1537.00
Barley			
Total	1438.00	1628.00	1925.00
Irrigated	10.00	31.00	1.00
All cereals			
Total	41667.00	43127.00	46794.00
Irrigated	3239.00	3404.00	3267.00
Black gram	366.00	402.00	365.00
Lentil			
Total	42.00	85.00	33.00
Irrigated	-	1.00	-
Pea	3.00	11.00	27.00
Pigeon pea	164.00	110.00	114.00
All pulses			
Total	2229.00	2284.00	2159.00
Irrigated	28.00	1.00	-
Total food grains			
Total	43896.00	45411.00	48953.00
Irrigated	3267.00	3405.00	3267.00
Rapeseed/ mustard			
Total	504.00	479.00	668.00
Irrigated	11.00	-	5.00
Sesame	16.00	22.00	35.00
Soybeans	350.00	390.00	436.00
All oil seeds			
Total	1152.00	898.00	1152.00
Irrigated	11.00	-	5.00
Potato	2251.00	2908.00	2251.00

Source: District Economics and Statistical Office Chamoli (2012)

production in the district during 2010-11 was only 1896 MT. Total production of oil seeds was only 756 MT, with soybeans, rapeseed/ mustard, and sesame having produced only 435, 309, and 6 MT in the district during 2010-11. Total production during this period in the district was 23175 MT (Fig. 6).

TABLE 5: Average yield of major crops (quintal per ha) in district Chamoli

Crops	2008-09	2009-10	2010-11
Cereals			
Rice	13.13	11.83	14.13
Wheat	8.91	12.54	14.35
Barley	9.56	13.25	15.01
Maize	6.44	6.44	8.91
Finger millet	15.08	14.44	14.86
Barnyard millet	14.60	13.87	14.08
Total cereals	13.08	12.37	13.59
Pulses			
Black gram	7.87	7.87	8.71
Lentil	3.00	5.88	6.80
Pea	3.00	3.75	7.14
Pigeon pea	4.76	4.76	4.66
Total pulses	7.52	7.24	8.78
Total food grains (total cereals + total pulses)	11.37	12.11	13.38
Oil seeds			
Rapeseed/ mustard	4.00	4.02	4.63
Sesame	1.80	1.80	1.60
Soybeans	10.25	10.24	9.98
Total oil seeds	6.37	6.66	6.53
Potato	105.02	118.78	102.95

Source: Compiled from District Economics and Statistical Office Chamoli (2012)

As a development block is the development unit of a district in India, it would be worthwhile to look at and analyse important development indicators of the Pokhari development block of Chamoli. Important data relating to agriculture of this block are presented in Table 6.

Land use data (in hectares) as shown in Table 5 is of crucial value for i) understanding overall current agricultural situation in the development block, ii) realizing maximum potential of production through the operating land use, and iii) planning an appropriate perspective-based development intervention in the future.

Livestock Resources : Livestock are an integral part of mountain farming systems in the Himalayan region. Himalayan farming communities, in fact, are the livestock-dependent communities. Livestock acquire special importance in mountain farming systems both on ecological and socio-economic grounds[16]. Availability of a variety of fodder plants stocked in widespread Himalayan

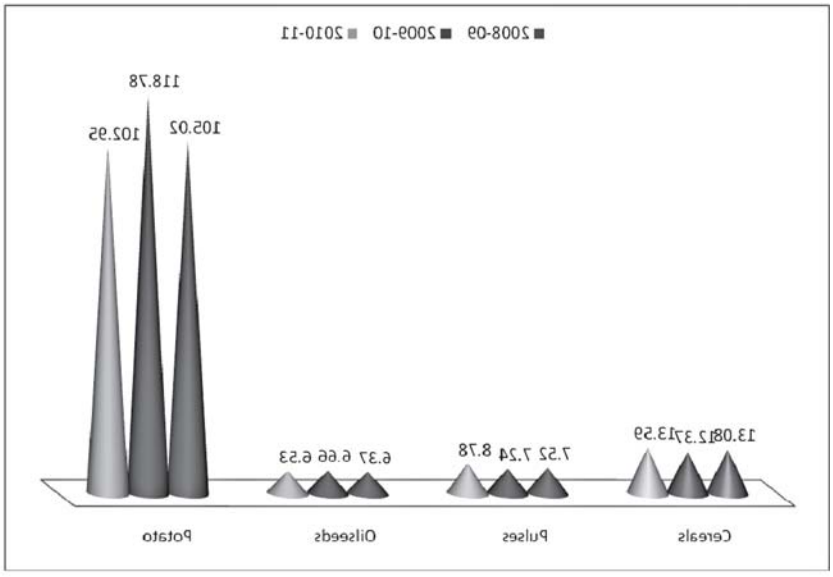

Fig. 5: Comparative average productivity (q/ha) of major crops in Chamoli over three years (Source: based on District Economics and Statistical Office Chamoli, 2012)

rangelands[5,17] most of which are parts of the common property resources[18] is the main reason of large livestock size (number per family) and population in the Himalayan region.

If we analyse the livestock population data of district Chamoli, we find that nearly half of the livestock population is comprised by cattle. The next highest proportion in the livestock population is that of goats (21%) and sheep and buffaloes comprise 15% and 14% proportion in the population, respectively, whereas horses and ponies comprise only some 1% population (Fig. 7).

Livestock sector in the Himalayan mountains of Uttarakhand, including in district Chamoli, faces many problems due

TABLE 6: Important land use related indicators of Pokhari development block of Chamoli (2010-11)

Particulars (unit)	Data
Total reported area (ha)	28449.00
Forests (ha)	9483
Cultivable barren land (ha)	2473.83
Current barren land (ha)	14.44
Other barren land (ha)	8.61
Degraded and unfit for agriculture (ha)	230.07
Land other than agricultural use (ha)	15229.50
Grazing lands (ha)	2210.00
Area under gardens, trees and shrubs (ha)	13910.00
Net sown area (ha)	4146.00
Area sown more than once (ha)	4510.00
Gross sown area (ha)	
Total	8578.00
Rabi (winter cropping)	4415.00
Kharif (summer cropping)	4142.00
Net irrigated area (ha)	332.00
Gross irrigated area (ha)	594.00
Irrigated land area (ha)	244.00
Area under major crops (ha)	
Rice	
Total	2248.00
Irrigated	259.00
Wheat	
Total	2605.00
Irrigated	320.00
Barley	
Total	408.00
Irrigated	0
All cereals	
Total	8356.00
Irrigated	507
Black gram	44.00
Lentil	4.00
Pea	7.00
Pigeon pea	12.00
All pulses	249.00
All food grains	
Total	8695.00
Irrigated	507.00
Rapeseed/ mustard	
Total	93.00
Irrigated	0.70
Sesame	
Total	2.00
Irrigated	0
Soybeans	
Total	51.00
Irrigated	0
All oil seeds	
Total	154.00
Potato	
Total	337.00
Irrigated	0

Source: Compiled from District Economics and Statistical Office Chamoli (2012)

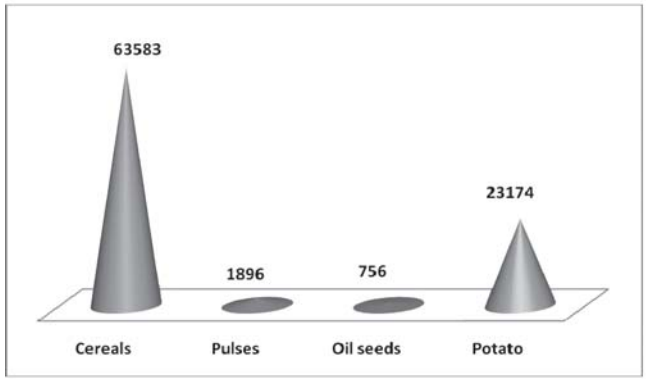

Fig. 6: Total production of major crops (MT) in district Chamoli during 2010-11 (Source: based on District Economics and Statistical Office Chamoli, 2012)

to which their productivity, despite high potential, is very poor. Impoverished forests/ grazing lands/ grasslands have enormous bearing on the productivity of livestock. For all green fodders livestock depend only on forest-based fodders, and acute shortage of greens is always observed in the mountains. The other source of fodders is crop residues which are of poor nutritive value. Inadequate health cover in the mountains is yet another problem the livestock sector has to face. High degree of inaccessibility results in difficulties in distribution of livestock products, especially milk. Lack of cooling chain to preserve milk for desired period adds to this problem. As a result, livestock owners cannot realize potential benefits from the produce of their livestock.

TABLE 7: Livestock population in Pokhari Block and Chamoli District (2007) [5]

Livestock	Pokhari Block	Chamoli District
Cattle		
Cattle (indigenous)		
Males more than 3 years	8063	65871
Females more than 3 years	6261	58962
Male and female calves	5714	53982
Total cattle (indigenous)	20038	178815
Cattle (crossbred)		
Males more than 2.5 years	40	366
Females more than 2.5 years	130	2327
Male and female calves	101	2049
Total cattle (crossbred)	271	4742
Total Cattle (indigenous + crossbred)	20309	183557
Buffaloes		
Males more than 3 years	58	651
Females more than 3 years	4186	36361
Male and female calves	1199	14945
Total buffaloes	5443	51957
Sheep		
Indigenous	1281	53536
Crossbred	430	4621
Total sheep	1711	58157
Goats	6771	80648
Horses and Ponies	190	4231

Source: Compiled from District Economics and Statistical Office Chamoli (2012)

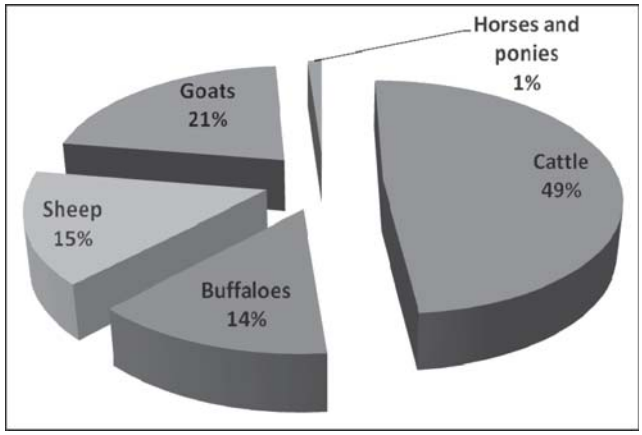

Fig 7: Livestock species composition in population in Chamoli district (Source: based on District Economics and Statistical Office Chamoli, 2012)

Conclusion

Mountain agriculture in the region of Indian Central Himalayas is altogether distinguishable from that of the plains' mainstream agriculture. With organic linkages among different major components (forests, cultivated lands, livestock and households), a mountain agro-ecosystem reveals its self-containment feature and embraces characteristics of what could be referred to as sustainable agro-ecosystem. However, due to ecological deterioration of the forest component of the uncultivated land, productive performance of this agro-ecosystem is not up to mark. This is clearly indicated by agricultural performance in one of the districts in Central Himalayas in India – the Chamoli district.

Uncultivated area in the mountains, which serves as a core component of a mountain farming system, should be covered with ecologically vibrant forests and the forest-cultivated land ratio should also be large enough. The larger the forest-cultivated land ratio the higher the productivity and sustainability of the farming system. Natural forests play crucial role in water cycle and in soil, water and biodiversity conservation and this has phenomenal influence on the performance and sustainability of a mountain agro-ecosystem. Such an agro-ecosystem would also play a

crucial role in enhancing carbon sequestration within the system and will contribute its bit to climate change mitigation. ❐

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