



Sustainability of Agro-pastoralism in Highlands of the Trans-Himalaya: Transformation in 200 Years

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Abstract

Being located in the historical silk trade route of Central Asia, the agro-pastoral practices in combination with trade and commerce have been an age-old unique feature in the trans-Himalayan landscape of Ladakh. Agriculture in Ladakh, “the cold desert”, differs from the mainstream Himalayan regions in having almost no forest support and severe climatic constraints which allow cultivation only in irrigated fields during summer months. Based on the secondary literature and field-based ground truthing through repeated surveys, this study gives an overview of the (i) main features of traditional agro-pastoral system of Ladakh, (ii) environmental constraints, and (iii) transformation in practices due to socio-political changes. The agro-pastoralism in Ladakh includes the (i) cultivation of a mix of agronomic (barley, wheat, pea), horticultural (apple, apricot) and fodder crops (alfalfa) in irrigated field using glacial melt water and underground channels in lower areas (2700-3500 m asl) during summer months, and (ii) pastoralism in higher areas (above 3500 m asl). The local communities use animal dung, human faeces and leaves to prepare manure to fertilize crop field soil. The frequent conflicts and wars, rapid increase in tourism, introduction of Public Distribution System (PDS), and formation of Ladakh Autonomous Hill Development Council (LAHDC), Leh have substantially affected agro-pastoral system of Ladakh and the age-old culture based on community-level cooperation and reciprocity. The external changes include the development of army-based settlements and infrastructures, strengthening of transportation facilities, transition from traditional to cash crop cultivation, collapse of trade, shrinkage



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of Changpas' pastures, and shifts of salt collection from Tibetan lakes to Tso Moriri lakes. The tourism (since 1974) has transformed the primary sector-based economy (the contribution of primary sector being 84.65%) into the one dominated by tertiary sector (the contribution of tertiary sector being 71.02%) within a few decades. Concurrently, the PDS system has contributed to the changes in food consumption choices of local communities, and to the loss of interest in managing age-old agro-pastoral system. The abandonment of farming and pastoralism have already begun. Given the remoteness and security sensitivity of the region self-reliance for food could be important and not to be comprisable issue.

Introduction

Despite the tough terrain, climatic uncertainties and wild-life conflicts, mountain communities have dependent on agriculture and pastoralism for centuries to their livelihood security. In the Himalayan region, traditional crop cultivation, pastoralism, animal husbandry and forest-related enterprises, form an integrated production system for livelihoods.^{1,2} However, in recent decades, traditional agricultural practices have been rapidly declining throughout the Himalayan region as a consequence of rapid socio-economic development, increased population pressure, and habitat destruction.³

The traditional agricultural system of Ladakh is a unique representative of the trans-Himalayan agriculture where humans have been managing crop cultivation in extremely harsh conditions for centuries. Establishing soil and biological processes for growing crops against the extremely cold and arid conditions is a challenging task and often a losing cause. Subsistence agriculture and livestock rearing have been a major component of the traditional farming system in the trans-Himalaya since time immemorial.⁴ Geographically, the region is characterized by rugged topography along with the small irrigated patches, mainly confined to the lower portion of valleys.⁵

Surprisingly, this cold desert has a long unbroken and rich cultural history of trade along with agriculture and pastoralism. It is generally believed that the nomadic pastoralists were the earliest inhabitants of Ladakh and they originally migrated from Kham province of Tibet during 8th century.⁶ In this remote region, the trade and commerce developed as early as the 8th century and it became a transit emporium in early 19th century.⁷ Some of the big monasteries

became the major regional traders during Namgyal dynasty as a consequence of Tibet's political and cultural prominence.⁸ The nomadic pastoralists and Aryan agriculturalists were interdependent for trading wheat, barley and other food products in exchange with salt, milk, butter, wool and pashmina fibres.⁹ Despite the environmental constraints, the agriculture and pastoralism activities had ensured a sustainable food production system for the local population as well as for the caravans of livestock that passed through or came to Ladakh for trade.^{2,5}

In contrast to much of the Himalayas where agriculture is largely rainfed and dependent on the monsoon rain, the cultivation in Ladakh has entirely been dependent on irrigation because of extreme aridity. The cultivation of crops is possible only during summer months (April to September) due to harsh winters being too cold for plant growth. The fodder was needed for livestock, mainly for agro-pastoral communities during the extremely cold winters when natural pastures were not available for grazing due to snow cover.¹⁰

The geo-political and administrative events of mid-20th century played a major role to foster the development and modernization in life-style as well as the indigenous practices of Ladakh.¹¹ The construction of Srinagar-Leh and Manali-Leh Highway, permanently stationed massive army after Sino-India Conflict in 1962 and II, III Indo-Pak wars in 1965 and 1971, respectively, led to the connection of Ladakh with the world system,¹¹ and monetization of economy of the region.⁵ The increasing population growth (from 1,05,291 in 1971 to 2,74,289 in 2011;^{12,13}) and introduction of tourism industry in 1974,^{14,15} led to the shift from subsistence agriculture to cash-crops, use of

fertilizers, and modification of local food consumption patterns.^{4,11,15} All these key driving factors contributed to rapid urbanisation and livelihood diversification in Ladakh,^{2,5,6,11,16} and elsewhere too (e.g., in similar landscape of the Indian Central Himalaya).¹⁷ The main objectives of this study are: (1) to identify the changes of agricultural patterns of last 200 years for which documented information is available; (2) to understand the functioning of agriculture and pastoral systems in harsh conditions of dry and arid region; and (3) the resilience of the two systems on the face of various difficulties including the collapse of trade due to 1962 war. We have attempted to find out the features of traditional knowledge which sustained agriculture/ pastoralism in highly inhospitable conditions, and on the face of frequent disruptions by external forces viz., wars, conflicts, political events and climate change induced hazards. With regard to cultivating crops, we hypothesize that local communities pooled together their knowledge and resources to create organic and biotic structures conducive to plant growth in a sterile environment. We shed light on the impact of changing scenario on the human heritage developed since time immemorial.

Materials and Methods

Study Region

Trans-Himalayan Ladakh landscape (32° to 36°N Latitude and 74° to 80°E Longitude), is situated on the western edge of Himalaya, at altitudes exceeding 3000 m asl. It is bounded by Tibet Autonomous Region of China in northeast, and Jammu & Kashmir and Pakistan in the northwest. The cold and dry Ladakh is sparsely populated with density of 4.6 per sq. km.¹⁸ The habitations are scattered in the vast landscapes, mainly in the irrigated valleys and the Indus river along with its tributaries, the Shyok and the Zaskar, as a blessings to the region.

Several communities viz., *Argon*, *Beda*, *Boto*, *Changpa*, *Dards (Brokpa/Drokpa)*, *Gara* and *Mon* inhabit the trans-Himalayan region of Ladakh, collectively called *Ladakhi*.^{2,19} The Boto was the dominant community of affluent agro-pastoralists, while the *Garas* (blacksmiths), *Mons* (musicians/carpenters) and *Bedas* (musicians/beggars) were other communities, who are losing their traditional occupations rapidly and switching to agro-pastoralism and other non-farm activities.

The two main religions, Buddhism (66.40%) in Leh and Islam (76.87%) in Kargil, have played an important role in the cultural development of Ladakhi landscape.^{12,13} They celebrate the onset of sowing and harvesting of agricultural season as Saka and Sruhla festivals.²⁰ Barley, wheat, buckwheat (millet), and vegetables (potato, pea, turnip, etc.) are the principal agricultural crops, while apricots and apple are major horticultural crops in the region. Located within the expansive rain-shadow of the Tibetan Plateau, the region gets 50-300 mm/yr annual rainfall, which is scanty and mainly occurs in the form of snow.²¹ However, from 1991 to 2000, the rainfall has increased at the rate of 0.127 mm/yr during summer, and at the rate of 0.42 mm/yr during winter possibly under the influence of climate change.¹⁸ The mean annual temperature ranges from -40°C in winter and 35°C in summer season.²² Due to the high elevation and low humidity (6-24%), the global solar radiation (6000-7000 W/m²), is among the highest in the World.²²

Methods

Data were collected from both primary survey and secondary sources. We did an extensive literature survey to collect and review 166 published studies (152 research articles and 14 books) spanning from the documentations of European travellers such as William Moorcroft, Alexander Cunningham, A.H. Francke, and various research scholars from the pre-colonial era to 2023 C.E. As many as 44 studies dealt with traditional agriculture, self-sufficiency and their food security,²³ studies with the socio-political, socio-cultural development and modernization of Ladakh and 17 studies with grazing pastures, pastoral practices and their conservation. Apart from these, studies are related to the horticultural and fodder crops (15), traditional irrigation practices and management (14), nutrient availability of soil and their health status (11), climate change (10), biodiversity (09), trade patterns and relations of Ladakh with other countries (08), tourism in Ladakh (08), migration & urbanization (04) and farmland abandonment in Ladakh (03). Data from the District Census Handbooks of Ladakh,^{12,13} Statistical Handbooks of Leh and Kargil district,^{23,24} and Digest of Statistics of J&K²⁵ were also used.

We validated the data of secondary sources to an extent by undertaking field-based ground truthing

and frequent field surveys in 2022. They included three villages of Leh district in the month of May to September, i.e., Da-Bima in Sham valley (lower irrigated agriculture belt with cultivation of two crops), Tiggarr in Nubra valley (middle irrigated agriculture belt with one summer season crop), and Korzok in Changthang valley (high altitude pastoral belt) occurring in altitudinal range from 2700 to 2900 m, 3100 to 3300 m, and 4300 to 4600 m asl, respectively. Da-Bima is an Aryan village, which is situated in the Sham valley, lower part of Leh and is characterized by the irrigated-double cropping agricultural system (grain as first crop and millet as second crop), and cultivation of horticultural crops, namely apricot, apple, and walnut. The Tigger village, which is situated in Nubra valley, is characterized by irrigated-single cropping pattern (wheat and vegetables dominated) and one of the largest producers and suppliers of cash crops such as potato, onion, tomato, and cabbage to the army personnels through cooperative marketing society of farmers. Another village, Korzok is situated at the high altitude of Changthang valley and associated with semi-nomadic pastoralism practices. Traditionally, the people of Changthang valley, are known as *Changpas* (nomads), who live in rebo (tents made from yak wool) and herds sheep, goats, yaks and horses to varying degrees. Their major economy is generated by selling the pashmina of goats and wool of sheep. However, in present the people have their permanent houses and also cultivate barley, peas and some green vegetables in their fields and kitchen gardens.

Results and Discussion

Crops, Natural Vegetation and Role of Livestock

In the early 18th century Ladakhi farmers cultivated agronomic (barley, wheat, cabbage, local turnip, and lettuce), horticultural (apple and apricot), and fodder crops (alfalfa) on their small landholdings (~ 0.81 ha). Since there was no cultivation during winters, the farmers usually stored the leaves of cabbage and sliced turnip apart from grains. Because food grain yield was not enough, the people consumed wild vegetables such as leaves of wild onion and chaulai, and wild fruits i.e., Russian Olive (*Elaeagnus augustifolius*), locally called *Sarsingh*.^{26,27} The community has developed methods to process and eat what was available and could be grown during summer months, thus stretching food base much beyond the conventional edible list species.

Unlike much of the Himalayas, people in trans-Himalayan Ladakh had little natural vegetation for fuel and fodder. Some woody species that grew naturally such as *Populus* spp., *Salix* spp., and *Juniperus excelsa* used as a fuelwood by the local people. Some species of shrubs such as *Hippophae* spp., *Eurotia* spp., *Ulex* spp., and *Artemisia* spp. occurs in high altitude areas and used as a fuelwood.²⁸ However, during winter season the people majorly relied on animal dung in the form of dried dung pellets for cooking and heating energy. When all these resources were not enough to meet their requirements, people used to move to the high-altitude grazing pastures to collect the dried animal dung during summer season. This practice still exists in some of the villages of Ladakh.

In the event of fodder scarcity, the farmers used tufts of *Artemisia* spp., *Hyssopus* spp., *Echium* spp., *Chenopodium* spp., etc., as a fodder for their cattle, sheep and goats during summer season, while they were fed the leaves of willow species, stalks of cereal crops, dried alfalfa (*Medicago* spp.) and oats (*Avena sativa*) during winters. The Alfalfa, the oldest cultivated leguminous forage crop of the region, is perennial, rich in protein (25.9%) and low in fibre content (2.13%). It was mainly grown as a secondary crop in the lower valleys along river side areas of Ladakh (below 4000 m asl). In the high-altitude areas of Changthang (above 4000 m asl), the people cultivated oats (*Yukpa/Ukpa*) as a high-quality annual cereal fodder crop, which contains 11-15% protein with rich dietary fibres. Alfalfa and oats, both are drought tolerant crops, having ability to grow with 450-900 mm and 80-100 mm water per season, respectively.^{29,30} The advantages of adopting perennial crops like alfalfa are several, including less ploughing, soil disturbance and low nutrient input. Traditionally, the local people of Ladakh also consumed the fresh new green leaves of alfalfa and used as a green vegetable, until the introduction of new vegetables. However, presently alfalfa is only a major source of fodder in the region.

Converting Practically Sterile Soil into Organically/Biotically Rich Soil System through Canal Irrigation

Unlike the mainstream Himalayan region characterized by terraced farming, soil with slightly acidic to neutral pH and rich humus content, the agriculture of Ladakh has been developed around creating

almost a new top soil layer by using all the possible organic matter resources including human faeces combined with animal dung. The alfalfa cultivation which produced nitrogen rich organic matter; tree leaves and other plants collected and deposited in crop fields, which brought down soil pH from 7-9 to around 6.5-7.³¹

The soil system that was developed during 10th century in Ladakh from the neighbouring regions through canal irrigation, known as “*Yur-ba* or *Kuhls*”.³² It has a rich tradition of managing water through an intricate network of canals, which divert glacial melt water from streams to agricultural fields ensuring the water availability for the plant growth during summer season. This irrigation system without terraces differs from the rainfed agriculture of the main Himalayan regions, in which crops were grown in terraced crop field. Even *Kuhls* can be seen

today in main town of the Ladakh, i.e., where water flowing to downstream crop fields during summers. Apart from this, to enrich soil by controlling weed the farmers ploughed the field twice before sowing and this practice still exists in the region. The ploughing was done by male dzo ox (hybrid of male yak and common cow) in low altitudinal belt i.e., below 3500 m asl and by Yak in high-altitude belt, where semi-nomadism and nomadic practices prevalent. The comparative account of agriculture system of the mainstream Himalayan region and trans-Himalayan Ladakh is depicted in Table 1, which sheds light on the distinct patterns and diversity of agricultural system shaped by geographical, climatic, and cultural factors within the Himalayan region, and also highlighting the importance of local knowledge and practices in sustaining livelihoods in diverse ecological settings.

Table. 1: A comparative account of agriculture systems of the mainstream Himalayan region (excluding shifting cultivation of North-Eastern Region) and trans-Himalayan region, Ladakh

Mainstream Himalayan region	Trans-Himalayan region, Ladakh
About 80% typically rainfed agriculture	Exclusively irrigated (snow melt) agriculture, as there is hardly any rain
Rapid soil formation in the warm and moist conditions with high biotic activities but high erodibility due to high monsoon and steep slopes; rapid rock weathering in young mountains	Soil formation process extremely slow in the cold desert with little biotic activity
Soil with slightly acidic to neutral pH and rich in organic matter or humus content	Soil with highly alkaline pH (7-9) and less organic matter; hence local people enrich soil by mixing animal dung and human faecal material
Terraced agricultural field on steeper slopes Three crops grown in two years including the first crop rice along with legumes and cereals (May to Sept), second crop wheat and mustard from Oct to April followed by the finger millet and legumes sown during the rainy season from May to Oct.	Largely, flat land with few terraces Typically, one crop in one year: barley, wheat, pea as food crop and alfalfa as a major fodder crop
Traditionally, organic agriculture with heavy forest and livestock dependency but rapidly eroding	Traditionally, organic agriculture with little support from outside, hence dependency on cultivated trees and livestock; animal dung mixed with human faecal material used as a source of manure
Typically, livestock rearing includes cow, buffalo so relatively slow stocking density and declining	Agriculture with animal husbandry by rearing the yak, <i>dzo</i> and <i>dzomo</i> (male and female hybrid of yak and cattle, respectively), cattle, horse, donkey,

<p>Use of bullocks for ploughing purpose traditionally</p> <p>The livestock grazing is nomadic migratory in nature i.e., seasonal movements between their summer settlements in higher altitude (3000-4000 m) and winter settlement (up to 1000 m). Collection of biomass from forests as agricultural fodder for livestock, forest floor litter, firewood and others</p> <p>The presence of fuelwood and fodder resources are enough, however, due to the extensive use of these resources created unsustainable pressure on the forests.</p> <p>Forest fire common in lower ranges</p> <p>Outside food grain supply from</p> <ul style="list-style-type: none"> -strong and easily accessible through PDS -better self-reliance because easy supply from nearby places <p>Traditional Crops</p> <p>Rice, barley, wheat, millet, pulses, mustard, and maize</p> <p>Cash Crops</p> <p>Potato, tomato, onion, cauliflower, capsicum, spinach, cucumbers, pumpkin, kidney beans in central Himalaya; cardamom and mandarin in north-eastern Himalaya</p> <p>Horticultural Crops</p> <p>Peach, pear, plum, apple, apricot, walnut in central Himalaya; pineapple, citrus, apple, pear, peach and banana in north-eastern Himalaya</p>	<p>ponies, sheep and goats; high livestock density in pastoral system</p> <p>Use of yak, dzo, and horse for ploughing purpose traditionally</p> <p>Generally, the high-altitude pastoral systems are remote and the local people are day-to-day connected with pastures such as collection of animal dried dung, fodder, and wild vegetables. Dependency on trees cultivation viz., poplar, willow, etc. for biomass collection</p> <p>The fuelwood and fodder are scarce; hence agro-forestry practices in the form of agri-silviculture system with boundary plantation of willow and poplar species serve as the main source of fuelwood and fodder; dry animal dung also used as a fuelwood, while dried alfalfa and crop residue are the source of fodder in winter season mainly, when there is no vegetation.</p> <p>Fire negligible</p> <p>PDS exists but area of food grain supply is</p> <ul style="list-style-type: none"> -remote -low self-reliance <p>Barley, wheat, buckwheat (millet), pea, mustard, raddish, turnip and lettuce</p> <p>Potato, onion, cabbage, cauliflower, leafy vegetables such as mungol, palak, etc.</p> <p>Apricot-centred, apple, and some contribution from walnut</p>
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Fine Tuning of Pastoral Practices with Ecological Parameters and Nativity in Dietary Composition

The Changpas were mainly concentrated in Rupshu-Kharnak, Samad, and Korzok areas of high altitudinal belt where conditions were too harsh to permit any agricultural activities. During winter season, the Changpas of Rupshu moved to Skagjung, a large pasture land with low altitudes, less snow and more of grasses.⁹ The average family size of Changpas was 05 individuals¹⁰ and each family was able to keep 500 to 1000 heads of livestock.⁹ This ethnic group is adapted to deal with valid ecological

conditions including harsh conditions of pastures. Among the Changpas the extent of nomadism varied from entirely nomadism to entirely settled agriculture. Between these two end points were semi-nomadism and agro-pastoralism.³³ They occupied different altitudinal ranges and differed in the size and composition of livestock that they managed.

All the Changpas herds sheep, goat, yak and horses and in return, they get milk, butter, dung, meat, pashmina and wool. Meat has been a major component of Changpas' food. Their daily diet

consists of fresh and dried meat of sheep, goat and yak as well as the fermented ethnic milk products i.e., *sri* (colostrum), *chhurphe* (dried cheese), *maar* (butter), *jho* (curd), etc. Because of the cold and dry environment, microbial growth is slow resulting in a longer shelf life for milk products. The local people generally prefer female yak (*demo*) milk products over that *zhomo* milk (hybrid of female yak and common cow) due to high content of protein (4.0-6.0%) and fat (5.5-7.5%) in yak milk.³⁴ During harsh winters, they also eat *thukpa*, which is a traditional food made from wild vegetable, *Za-Chod* (*Urtica hyperborea*). Apart from this, they use yak for carrying heavy burdens such as tents, blankets, carpets while sheep and goats were used for carrying light burdens, especially for the rice trade between Kullu and Ladakh.⁶ In this way, the traditional agro-forestry system of Ladakh exists in the form of agro-pastoral systems.

Trade in Association with Agro-Pastoralism and Silk Routes

There is a long history of trade in Ladakh, associated with 'Silk Route', which is a series of routes that traders used to travel from China to eastern Europe. The trade in the western Himalayas through Ladakh was well established by the 16th and 17th centuries, and it peaked during the Dogra and British rule in the 19th and mid-20th centuries, respectively.^{7,35} At that time, the Leh was the transit emporium where Indian traders met their counterparts from Baltistan, Tibet, Russia and other Central Asian towns such as Yarkand, Kashgar, and Khotan. Thus, both internal and external trades operated in Ladakh region for centuries. The internal or local trade was established between the nomadic pastoralists and the Aryan agriculturalists, by barter grains with salt and animal products, such as milk, butter, wool, etc., and formed the backbone of village-level economy.

The external trans-Himalayan trade occurred in three different ways through Ladakh: (1) trade with Tibet (2) Indo-Central Asian trade in Ladakh and Kashmir, and (3) the local trade with Baltistan (now Skardu). Through external trade with Tibet the various articles such as brick-tea, tea-cups, salt, silver, gold, etc., were imported from Tibet to Ladakh while china-silk, cotton, goat skin and furs, barley, apricot, etc., exported to Tibet from Baltistan, British India, Kashmir and Ladakh. According to Warikoo,⁷ approx.

15,000-19,000 kg/year of dried apricot exported to Tibet from Baltistan in early 1870s and later on its quantity increased to about 55,000-60,000 Kg/year by 1940s. Concurrently, the export from Central Asia to Ladakh and Kashmir involved hemp drug, shawl wool, raw silk, ponies, etc, while local Balti's people traded Indian cotton cloths, Yarkandi leatherwares, and some quantity of Yarkandi and Tibetan wool.

The Srinagar-Leh-Yarkand route was the principal trade route of Central Asian trade and provides an extensive supply of sheep and goat wool to Kashmir shawl industry which was largely imported from Tibet, Yarkand, eastern Turkistan and some areas of Ladakh i.e., Rupshu, Rodokh and Changthang. This trade sustained not only the Kashmir's shawl industry, but also provided the avenues of employment to skilled and unskilled workers of Ladakh and Kashmir. But the external trade with Tibet and Central Asia ceased after the opening of Russian overland trade with Xinjiang in 1949, followed by the incorporation of Tibet in the People's Republic of China in 1950.³⁶ The closure of the external trade had a severe impact on Ladakh's economy. However, the local people only partially benefited through external trade. Firstly, because most of them were illiterate and poor, hence mostly worked as a pony-drivers, porters, suppliers of pack animals, and few owned their own business.^{7,36} Secondly, because of the limited landholdings the people could meet only their own needs. Therefore, indigenous trade remained small compared to external trade.^{9,35}

The trade, however, also affected the agricultural patterns of Ladakh. The farmers of Leh and the nearby villages situated along the trade routes started the cultivation of alfalfa in their grain fields, which led to decrease in the production of barley and wheat. Through the large-scale cultivation of alfalfa, the agriculturists profited by leasing out their grass fields to traders and pony drivers.⁷ Due to the influence of international trade after-mid-18th century the diverse cultivation started in low-altitude areas i.e., ~2800-3200 m asl and the people started growing pea, pear, walnut in Khalsi, Nimoo, Nurla villages along the bank of Indus river, and mulberry and vine cultivation in Garkaon (Aryan) village, situated near to Baltistan area. The cultivation had been adopted from the Baltis people who cultivated

it for their own consumption as well as to sell to traders to increase their earnings. In brief, the trade through barter system was the major factor to sustain the food security of local communities till mid-20th century.

Impact of District Formation on Crop Cultivation

The establishment of the separate district of Ladakh in 1901, included Skardu, Kargil and Ladakh as three tehsils, resulted in an increased cultivation of fruits like apple, pear, mulberries, as well as

vegetables like cabbage, cauliflower, potatoes, etc., under their home gardens and orchards of Skardu and Kargil's villages. Skardu, the winter capital of Ladakh, became the largest production and trading hub of fresh apricots, sun-dried apricots, apricot kernels and oil, apples, etc., and played a vital role in increasing the economy of villagers of Skardu.³⁷ However, after the Indian Independence and first Kashmir war in 1947-1948, Skardu came under the illegal occupation of Pakistan, administered Gilgit-Baltistan.

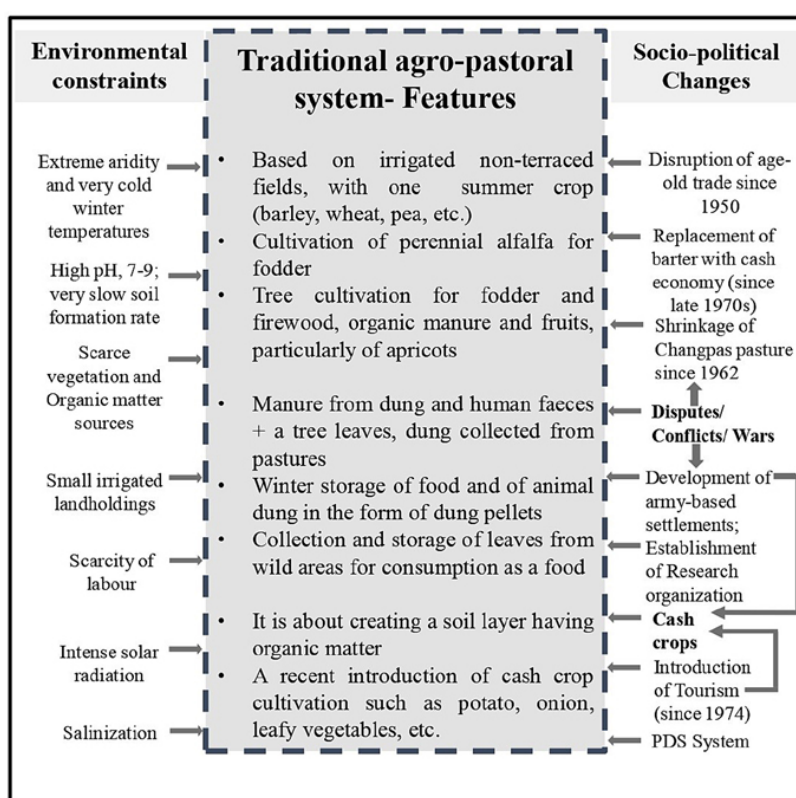


Fig. 1: A schematic representation of the main features of traditional agro-pastoral system of Ladakh and the factors affecting it.

Impact of Indian Independence and Subsequent Wars on Agro-Pastoral Practices of Ladakh

The socio-political changes that showed after the independence and due to wars included (i) several developmental activities including growth of transport and advancement of agricultural activities to provide food locally to army; and (ii) increasing constraints on pastoral activities and salt collection. The factors which affecting the traditional agro-

pastoral practices of Ladakh is shown in Figure 1. The Indian Independence and Kashmir war in 1947 and 1948, led to the increased number of defense establishment and subsequently impacted almost every sector in Ladakh.^{11,37} The Sino-Indian border dispute escalated into a military conflict in 1962 over the uninhabited region of Aksai Chin and marked the beginning of an era of enhanced geo-strategic and geopolitics of Ladakh. The Sino-Indian (1962) and

Indo-Pak border (1965 and 1971) wars had both positive and negative impacts on the local people of Ladakh. This includes the massive investment in road construction, which resulted in the formation of Srinagar-Leh and Manali-Leh Highway in 1962 and 1989, respectively, and both served as a landmark for the extension of communication and transportation facilities for Ladakh. The deployment of armed forces led to the creation of various off-farm employment opportunities to the local population. The government initiated various developmental programs, set-up industries and encouraged tourism in Ladakh. Several afforestation programs, such as Van Mahotsav were started on an extensive scale by involving the local bodies and individuals to start tree plantations, for which they received both subsidies and free plants.³⁵

The establishment of Field Research Laboratory (FRL) in 1962, which was renamed as Defense Institute of High-Altitude Research (DIHAR) in 2008, offered a new direction to make the hostile terrain of cold desert of Ladakh reasonably green, and

ensure the fresh food availability to the deployed troops. DIHAR established the first greenhouse in Ladakh in 1964 and introduced new vegetables such as kale, parsley, celery, okra, and green vegetables namely, palak, lettuce, swiss-chard, etc. As a result, on an average 733 greenhouses with an area of 4.43 ha being set up annually in Leh district and more than 65 types of vegetables, including 20 types of green vegetables cultivated through greenhouse technology.³⁸ These developmental changes and crop diversification processes led to the decrease in the interest of local people in traditional crop cultivation and crop storage methods for harsh winters, and subsequently resulted in a significant transition from subsistence agriculture to cash, horticultural and fodder crops cultivation in the region.^{5,39} This transition has not only fulfilled the need of army and other consumers, but it has also improved the nutritional uptake of the local people, increased the income of local farmers and saved a large chunk of expenditure incurred on transportation of food.

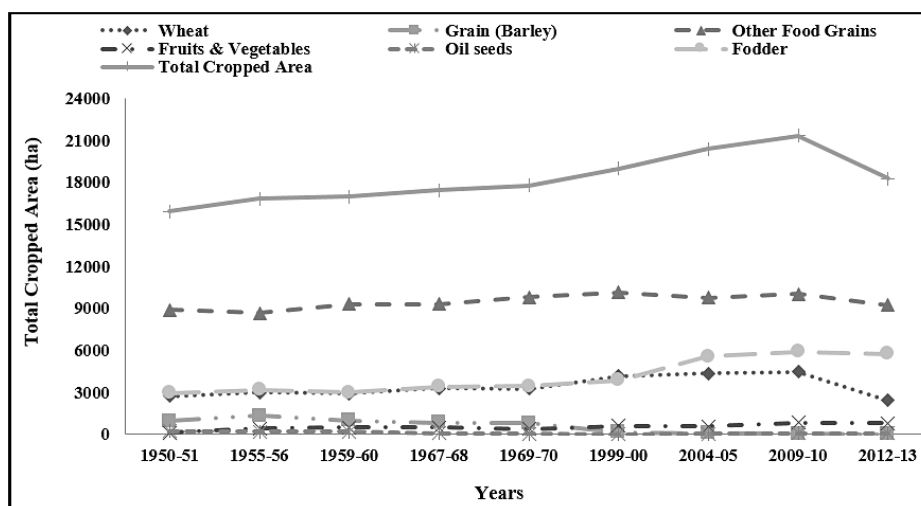


Fig. 2: Pattern of sowing area of principle crops in Ladakh from 1950-51 to 2012-13.⁵

Mechanization of agriculture and related development The spread of green revolution in India also impacted the traditional agriculture of Ladakh in late 1990s. Agriculture has become more mechanized with the use of labour-saving devices such as tractors, power tillers, and threshers, etc. The supply of high yielding variety seeds of cereals and vegetables as well as chemical fertilizers and pesticides increased

in the region. It led to the increase in sowing area under wheat i.e., 4,187.1 ha to 4,458.04 ha and fruits and vegetables from 623.69 ha to 841.62 ha during 1999-2009. As a result, the total cropped area increases from 19,005.49 ha in 1999 to 21,361 ha in 2009, in which the major portion was constituted by other food grains including grim (*huskless* barley called *Sherokh*), peas, garas, bakla (broad beans)

and trumba (buckwheat) followed by fodder and wheat crops, respectively, as depicted in Figure 2. The sowing area of fodder crop increased by approx. 2,000 ha due to the decrease in cultivation of husked barley (*Nas Swa*) and other food grains by 0.63% and 6.44%, respectively, over the last 10 years. In 1998, the annual consumption of nitrogen and phosphate fertilizers reached 2,000 and 1,000 tons, respectively, in Leh district.⁴⁰ However, there is also a rise in the interest in traditional organic farming methods as a specialized practice.

According to Norboo and Dolma,⁴¹ the land under non-agricultural use has more than doubled from 2001 to 2010 i.e., 6.44% (2,908 ha) to 13.68% (7,073 ha) of total reporting area. The increase in abandoned land could be due to the abolishment of polyandry custom in early 1940s resulted in the increased number of nuclear families and dismantle of large estates owned by the monasteries;⁵ hence the increment in small landholding areas (below 0.5 ha), i.e., 41.19% in 1983 to 62.66% in 2011, while landholding with above 0.5 ha area decreased from 58.81% to 37.34% in 1983 to 2011. However, the total cropped area decreases from 2010 to 2012 i.e., 21,361 ha to 18281.01 ha, respectively due to the flash flood in Leh on 6 Aug, 2010 which resulted in food shortage. Even, the Departments of Food and Supplies, Leh, faced the difficulties in providing rations after roads had been cut due to massive flash floods.⁴²

Effect of Public Distribution System (PDS)

The advent of PDS system in 1980s led to the change in dietary as well as trading patterns of agriculturalists and nomads of Ladakh. For example, the rice became the everyday items on the household menu; and some people left their traditional agriculture because the easy availability of grains for food. It led to the decrease in the sowing area of husked barley and other food grains including huskless barley, pea, bakla and buckwheat from 2000 to 2012 by 0.8% and 2.94%, respectively. The trading between the agriculturalists and nomads decreased rapidly, which contributed to the weakening of the relationship of reciprocity and barter system between the agriculturalists and pastoralists and increases the exchange of cash economy.^{6,9}

However, the Sino-Indian border dispute negatively impacted the Changpas life by closing the border between Ladakh and Tibet Autonomous region and the people's movement into and trade with Tibet came to a sudden end. As a result the Changpas of Rupshu lost their permit/access to collect the salt and borax from the Mindum and Gyaltsse Lake of Tibet, and shifted their traditional salt collection activity from the Tibetan lakes to the Tso-Kar Lake of Ladakh. The other effect of the war was the change in the annual migratory cycle of Changpas due to the incorporation of traditional grazing pastures i.e., Skagjung under the Chinese authority and the heavy influx of Tibetan refugees into Ladakh with their livestock. The loss of grazing pastures (in the form of territory of around 37,500 km² lost due to border conflict of 1962;⁴³) resulted in the return of Changpas of Korzok and Samad to their hereditary rangelands of Korzok and Tso-Kar basin, respectively. The return of Changpas of Samad led to a conflict between the communities of Samad and Kharnak over the pasture rights which was resolved through an agreement in 1982.⁴⁴

The immigration of Tibetan refugees and their animals after 1962 doubled the household and livestock numbers in the Changthang region. The number of households of Rupshu increased from 80 to 212 by 2006 (72 in Samad and 140 in Korzok villages) and that of livestock from 40,950 to 67,500 livestock between 1977 and 2006.^{43,45} The increased number of livestock led to the intense competition for grazing pastures and water, resulting in separation into smaller number of herds and frequent movement from place to place because of forage shortage. According to Chaudhuri,⁹ the Changpas of Korzok found alternative winter pastures in Thagajung, while others moved to Sumdo village which was situated at an altitude of 3500 m asl and adopted agriculture. Most of the nomads reduced their herd size i.e., 200-300 livestock/ family.

Transition from Nomadic Sheep Wool to Pashmina Goats

Till early 19th century the sheep was far more valued than goats and were largely used for the transport of wool and flocks. Concurrently, the major quantity of pashmina was supplied from western Tibet to Kashmir through Ladakh under the Treaty

of Leh in 1842 which continued till 1959.^{6,46} But with the closure of border between Ladakh and Western Tibet after Sino-Indian war, the Kashmiris turned to Ladakhi nomads for raw pashmina and it increased the pashmina goat value in Ladakh and it became the most valuable trade item.¹⁰ Furthermore, the demand for sheep wool declined with its replacement with synthetic fibres. Data of Sheep Husbandry Department shows that the number of goats increases by 24,000 in three years from 2005 to 2008, whereas the number of sheep decreases by 15,000.⁴⁵ The price of raw pashmina wool increased five-fold between 1993 and 2000, i.e., from Rs. 300-475/Kg to Rs. 1,500-1,700/Kg; hence it made the economic value of goats far superior than sheep.⁶ Thereafter, the government started facilitating the pashmina production by providing incentives in the form of goat kidding shed facilities, supplementary feed during severe winters and subsidized food provisions brought from plains of India to pastoralists.

Shift from Barter Economy to Tourism-based Local Economy

Tourism in Ladakh (i) profoundly changed the composition of economic sectors, and (ii) brought in its fold also nomads. Introduction of tourism in 1974 marked the beginning of a new phase of non-agrarian income sources. A number of local people set-up their own business in the form of hotels, restaurants, travel agencies and shops. Therefore, the tourism which provided only 4% direct employment in 1970s, contributed nearly 50% to GDP of Ladakh around 2010 and led to the economic trivialization of agriculture sector.^{47,48} Interestingly tourism was mostly international in the beginning (95%), but became mostly domestic (96%) by 2022. The number of international tourists increased by only 20,000 from 527 in 1974 to 21,258 in 2022, while the number of domestic tourists rose to about 0.51 million by 2022, as shown in Figure 3.

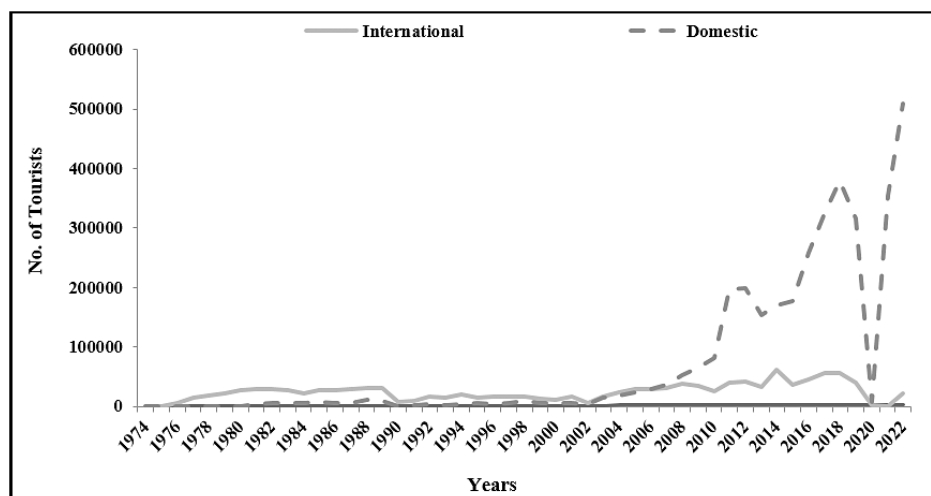


Fig. 3: Influx of International and National tourists in Ladakh from 1974-2022.^{14,15}

The three major drops have seen in tourism since its inception i.e., in 1990 because of Kashmir conflict, in 1999 because of Kargil conflict, and socio-political instability in 2002 after the attack on 11, Sep 2001 and 13 Dec 2001 (Parliament attack). After each disturbance, domestic tourism revived rapidly, but the proportion of international tourism kept on declining. Tourism almost collapsed in Ladakh during covid-19 pandemic in 2019 onwards. The

latest number of 2022 indicates that the number of tourists recovered rapidly and exceeding the pre-pandemic level of tourist. However, four episodes of disturbances in tourism in about 50 years is something that cannot be ignored.^{11,15}

Tourism brought about a massive shift from primary to tertiary sector of economy, as shown in Figure 4. In 1971, the primary sector constituted 84.65%

of total workers, out of which 77.66% were cultivators, 2.99% were agricultural laborers and 4% involved in other activities such as livestock, forestry, plantation, orchards and allied activities, while 3.6% and 11.76% constituted secondary and

tertiary sector, respectively. In 2011, the primary sector constituted only 27.21% of total workers, out of which 22.95% were cultivators, while tertiary sector increased to 71.02%.

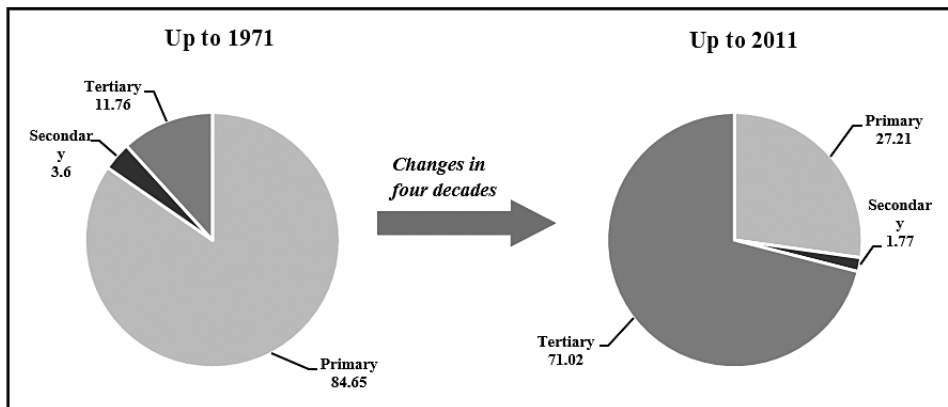


Fig. 4: Four decades of changes in the economic sector of Ladakh: from primary to tertiary sector.⁵

The high-altitude tourist destinations like Tso Moriri, Tso-Kar and Pangong lakes in the Changthang valley attracted many adventurous tourists and trekkers, and linked the nomadic and semi-nomadic herders to the rest of India and led to the shift from their traditional lifestyles. Many of herders out-migrated, bought land in and around Leh and settled there to look for other avenues of earning such as wage laborers, masons, contractors and tour guides, etc. Since 1980s, the outmigration started from Changthang valley and approx. 60-70 families out-migrated from Changthang (40 from Kharnak, 20-25 from Samad and 5-10 from Korzok;¹⁰). The several factors such as the loss of traditional pastures and influx of Tibetan refugees, loss of productivity in pastoral areas (40-45% average deficiency of fodder,⁴⁹); and increased availability of education and health system are responsible for outmigration of Changpas and it has the significant socio-cultural, economic, strategic and ecological ramifications.^{6,50}

Conclusion

Despite being the rugged terrain and inhospitable conditions i.e., the extreme temperature, scarce natural resources, water scarcity, limited agricultural land and poor soil profile, the local communities

in Ladakh evolved indigenous agricultural and pastoral practices by collecting organic ingredients from all possible sources including human excreta. A capacity of local people to take advantage of ecosystem services of pastures located in sky through hardwork and drudgery and to cope with hazards, both natural and man-made (like wars and conflicts), is the key tenet of the sustenance of the system, which they developed over centuries. The agro-pastoral complex that enabled the people to live with nature for centuries is now under the stress of different changes than the people had seen before. However, changes in agriculture such as use of labour-saving machines are positive, while the use of chemical and cash crops is direct on slaught on organic agricultural system.

Tourism has raised income, at least of some urban; the rapid shift from primary sector-based economy to tertiary economy represents a huge change in the tenet of carrying capacity and age-old and extraordinarily rich culture and heritage. It already impacts the crops grown and use of chemicals, pastoralists who came in touch with outside people interested in adventures tourists. Cultivation of cash crops requiring large amount of input of different nature (chemicals, polyhouses, water, etc.) and

development of urban connection of pastoralists, disruption of age-old style of internal trade and withering away of cooperation and reciprocity. Abandonment of farming and shift from rural to urban life are recent change in Ladakh. Being extremely remote and harsh environmental conditions, this trans-Himalaya cannot afford to further reduce its self-reliance in food.

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The authors do not have any conflicts of interest.

Data Availability Statement

We have not included any data in a publicly accessible repository.

Ethics Statement

This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Author Contributions

- **Harshita Joshi, Subrat Sharma:** All the Conceptualization, investigation and methodology was undertaken.
- **Prachi Joshi:** finalized the analysis and interpretation of the data.
- **Harshita Joshi, Subrat Sharma and Prachi Joshi:** The manuscript was prepared. **SUBRAT Sharma And Prachi Joshi:** The supervision of manuscript was undertaken.

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