

Ladakh: tradition and adaptation.

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Physical and political boundaries

Ladakh, the land of many (dakh) passes (la), is a region located in the North of India. Geographically it is delimited in the north by the Ladakh mountain range (part of Karakoram range) and in the south by the Zaskar range (part of the Great Himalayan Range). As with the rest of North-West India, the political borders of surrounding regions (Figure 1) are under dispute with Pakistan and China. Recently, tension in the region has escalated leading to clashes with China (Goldman, 2020) and with Kashmir population (Human Right Watch, 2019). In 2019 it changed from being part of Jammu-Kashmir and gained the status of Union Territory within the Republic of India and is now under direct control from the Central Government (The Jammu and Kashmir Reorganization Act, 2019, n39 of 2019).

Independently of the definition used (Kapos et al., 2000; Karagulle et al., 2017; Körner et al., 2017; Sayre et al., 2018), it is classified as a mountainous area due to its altitude ($> 2,550$ masl) and lack of high plateau (USGS, 2020) (Figure 2).

Demographic

Ladakh covers an area of $59,146 \text{ km}^2$ with a population of 274,289 (+12% from 2001, density $<5/\text{km}^2$) distributed in the two districts of Leh and Kargil (Census Organization of India, 2011). Despite its limited size, the population of Ladakh is very diverse in terms of ethnicity, language and religion. With a degree of generalization, three main groups can be defined. The first one (roughly 40%) characterized by Buddhist religion, Tibeto-Khanauri languages (Ladakhi, Bothi, Tibetan) with Tibetan alphabet and ethnically related to Tibetan populations. The second group (46%) characterized by Muslim religion, speaking Dardic languages as Purgi, Balti, Shina with arabic alphabet and ethnicity and culture more related to Kashmir, Punjab. The third group (14%) includes various Hindi, Sikh, Christian minorities (Census Organization of India, 2011).

Two thirds of the population live in rural settings (Census Organization of India, 2011) but the region is experiencing a migration towards the urban centres of Leh and Kargil (Goodall and District, 2004).



Figure 1:
political map of Ladakh
showing the boundaries
of contested territories
with Pakistan and
China.
Source:
mapsofindia.com

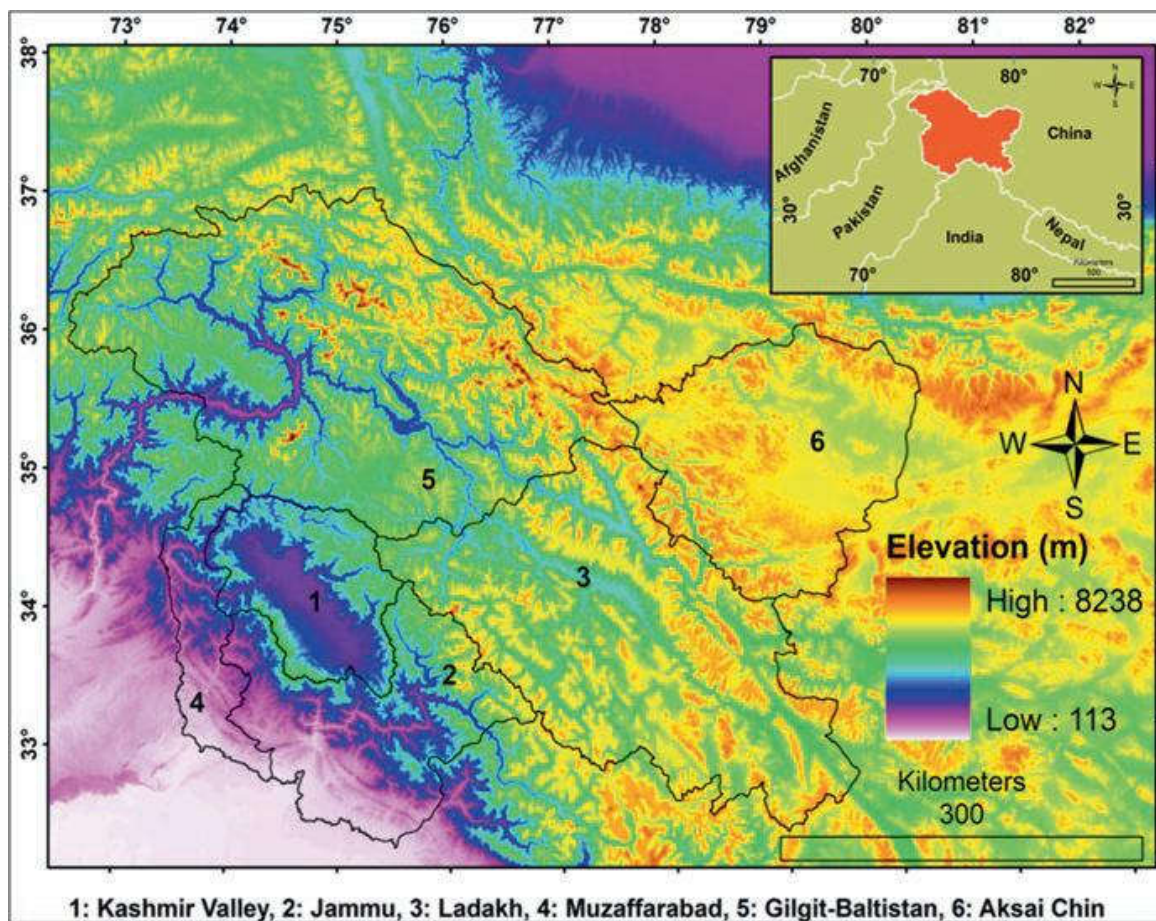


Figure 2: elevation map of Ladakh and surrounding areas. (Dar 2020, p 130)

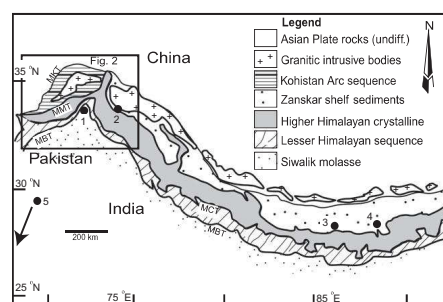
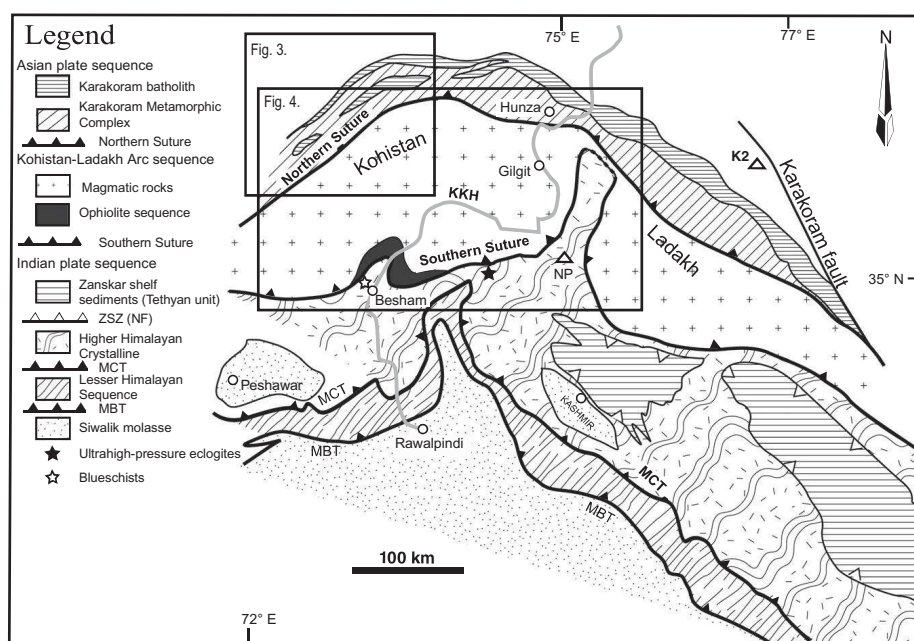


Figure 3: Simplified geological map of the Northwest Himalaya showing major tectonic units of the Indian Plate, undifferentiated rocks of the Kohistan-Ladakh Arc sequence, and the southern margin of the Asian Plate. (Rehman 2011)



Orogeny and landform.

The Himalayan range is the result of the collision between the Indian and Asian Plate. The timing of the collision is still object of debate (Hu et al., 2016; Khan et al., 2009; Rehman et al., 2011) with estimates ranging from 100 to 40 Ma. Isostatic adjustment following the collision begun 20 Ma lifting the newly formed Himalayan batholith. The currents height was probably reached between 2.5 to 1.8 Ma (Powell and Conaghan, 1973). The isostatic movement created three main thrust lines visible in Figure 3. A geological map is shown in Figure 6. For a more detailed one refer to Phillips (2008). The region is still geologically active and has experienced earthquake as in 2008 and 2015.

The landform of Ladakh is predominantly dominated by glacial processes causing the “U” shaped valley (Figure 4) typical of the region reaching a width of 4 km near Nyoma. Fluvial activity created additional features as gorges, strath terraces, glacial outwash plains. More recently (25-17 ka) eolian activity contributed by creating dunes and sand ramps as seen in Figure 5 (Juyal, 2014; Kumar and Srivastava, 2018).



Figure 4: East-west trending glacially carved “U” shaped valley near Kabardung La. Note the present Kabardung Glacier sticking to valley headwall. (Kale 2014, p. 119).



Figure 5: Obstacle dune near Leh and (Kale 2014, p. 124).

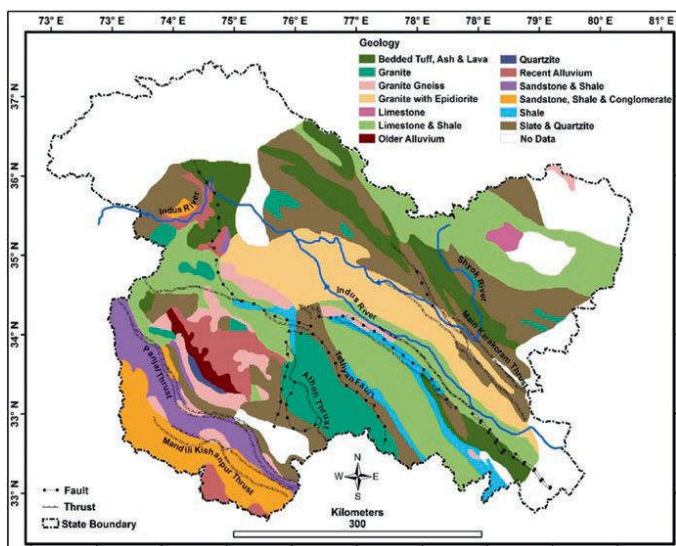


Figure 6: geological map of Ladakh and Jammu & Kashmir state (Dar 2020, p.135)

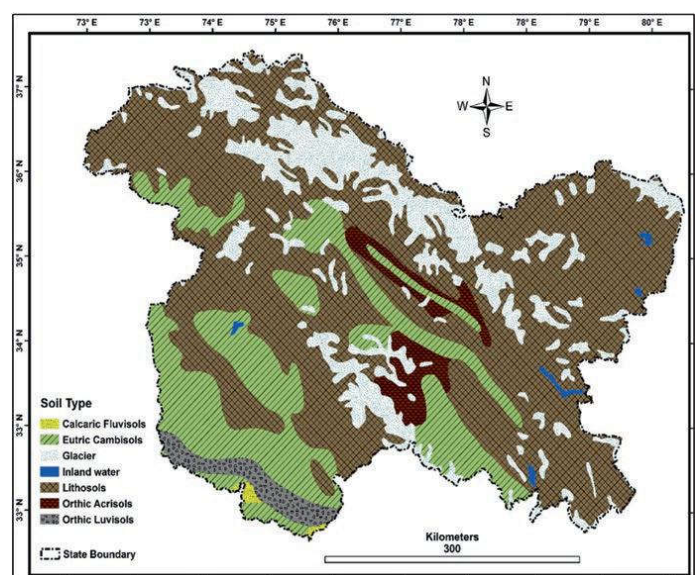


Figure 7: soil types of Ladakh and Jammu & Kashmir state (Dar 2020, p.149)

Soil

Thick soil cover is limited to valley bottoms and belong mostly to Eutric Cambisols and Lithosols with presence of Orthic Acrisol (Figure 7). They have a coarse grained structure, low water, high organic matter, high pH, relatively high N and P concentration. Organic matter, N, P, ammonia, nitrates increase with elevation with highest value in alpine zones and lowest in deserts (Doležal et al., 2018).

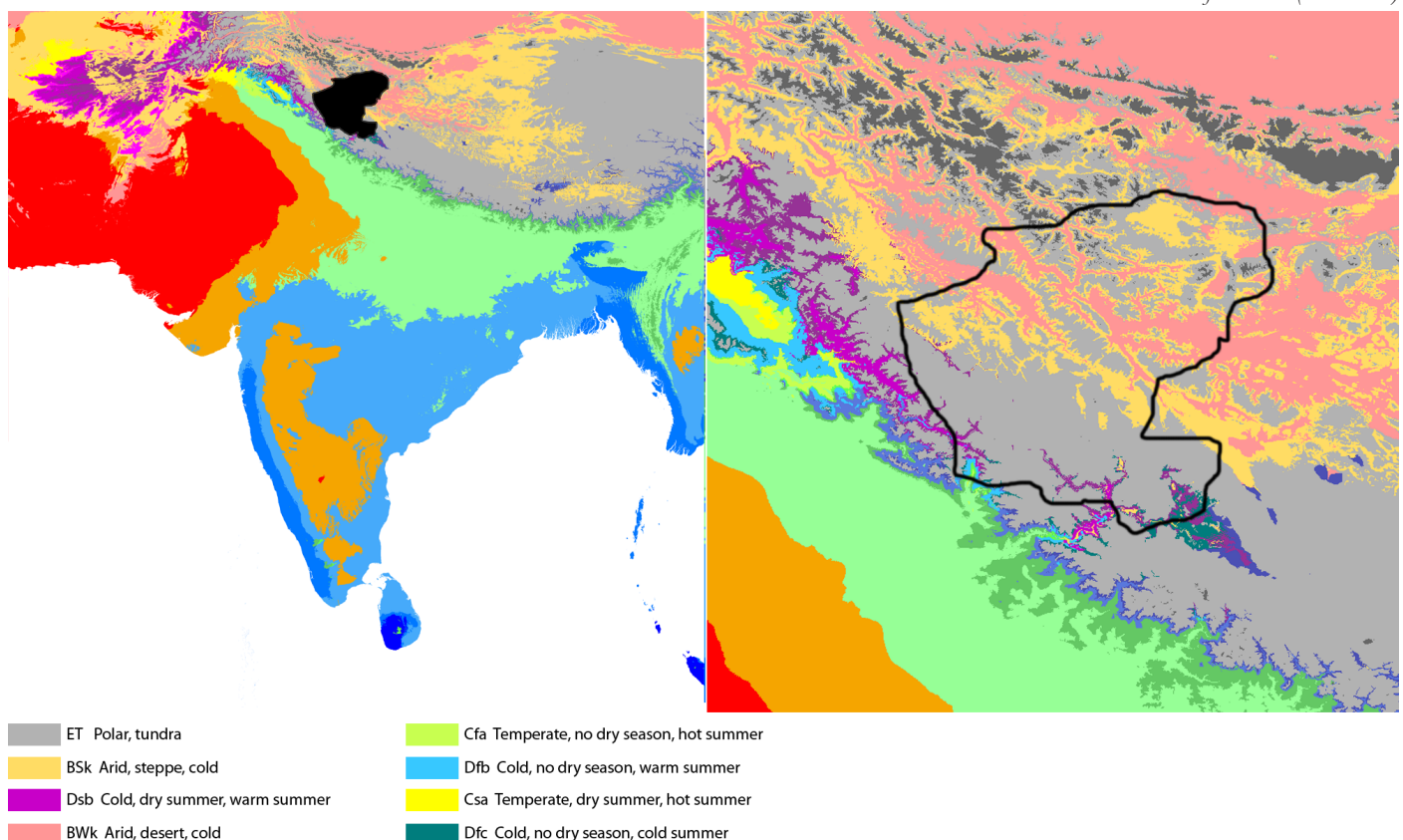
Water

The Indus and Shyok are the two main rivers crossing the region in parallel and divided by the Ladakh Batholith. The average discharge of the Indus in Leh $198.3 \pm 45.4 \text{ m}^3/\text{s}$ (August, year 2002–2006) (Thakur and Singh, 2018, p. 55). The hydrological system also allowed for the development of wetlands (Gujja et al., 2003). Water availability is a key element in Ladakhi society since it limits agriculture and is a possible source of energy (Nüsser et al., 2019). Water management (Angchok and Singh, 2006) has always been strongly linked with political and socio-economic factors (Müller et al., 2020; Nüsser et al., 2012). In the coming years, increasing demand and climate change will create a stress to the water system (Wangchuk, 2018) that will require new management practices blending traditional and contemporary approaches.

Climate

Following the Köppen-Geiger classification, the climate of the region could be classified as: polar (Figure 8) and arid with limited presence of temperate climate (Beck et al., 2018). Low precipitations ($<500 \text{ mm/year}$) are caused by the Zaskar range blocking the northward movement of the Indian Summer Monsoon. The altitude and continentality generate rigid winter temperatures and high annual temperature excursion (-27 to $+25^\circ\text{C}$) (Chevuturi et al., 2018). Latitude (34°N) influences solar radiations, reducing day-length annual excursion, and mitigating temperatures (Barry, 2008; Whiteman, 2000). Areas above 3600 m are mostly covered with snow and with approximately 6100 glaciers in the basins of Shyok, Zaskar, Upper Indus (Dar and Khuroo, 2020, pp. 148, 164). Glaciers in the area are following different trends regarding their size (Schmidt and Nüsser, 2017) with a decrease in the Central Ladhak Range and stability in the rest.

Figure 8: climate zones of Ladakh (Beck 2018)



Biodiversity and conservation

Ladakh has an important role regarding biodiversity recognized by the establishment of 15,000 km² of protected area (Goeury, 2010). This includes Hemis National Park, Karakoram and Changtang Wildlife Sanctuary and four conservation reserves in Tsomoriri, Norrichain, Pangong Tso, Hanley Marshes. The region belongs to the Trans-Himalayan ecosystem characterized by flora and fauna with low distribution densities and high adaptation to elevation and aridity (Geneletti and Dawa, 2009).

Due to anthropogenic expansion, several floral and faunal species (Dar and Khuroo, 2020, chaps. 37, 38) are under threat in Ladakh. Particular attention in conservation should be given to medical plants (Phani Kumar et al., 2011) and wildlife (Fox et al., 1994). In recent decades steps were made toward the understanding and achievement of natural conservation both from a legislative (Dar and Khuroo, 2020, chap. 42) and implementation (Goeury, 2010) point of view. Activities such as eco-tourism aim at creating synergies between conservation, economic practices and communities (Anand et al., 2012; Vannelli et al., 2019). Several challenges still exist (data paucity, funding, awareness, contrasting legislation) but Ladakh seems to have defined its contemporary identity in a close relation with its natural environment whose preservation would be beneficial for all actors of societies (Wester et al., 2019, chap. 6).

Flora

The flora is almost entirely of Holarctic affinity. The region can be divided into three subareas: Karakorum Province (1) with a very sparse Central Asian Flora; the south and western area (2) with a generally depauperate, but still relatively large, share of Himalayan herbs and shrubs; the south-east (3) with a Tibetan flora and the region within the disputed borders (Changtang Province) with a depauperate Tibetan Flora (Behera et al., 2014; Doležal et al., 2018; Khatoon et al., 2008). No precise up-to-date checklist of Ladakh's flora exists. Estimates of vascular plants range from 611 to 1250. The species richness is governed by elevation, culminating at 4500–5000m.

Forest coverage is very limited, reaching only 1.47% (2,489 km²) of the territory (MEFC, 2019). Most of the forest are anthropogenic and consist of poplar, willows, *Juglans regia*, *Prunus armeniaca* that are grown to provide food, fodder and timber. The existing natural forests can be classified as Himalayan Dry Temperate (HDTF) and Subalpine (Singh, 1987). Different vegetation belts exist: desert and semidesert (up to 4200m), alpine steppe (up to 4700 m in the west and 5400 m in the east), a narrow alpine grassland occur and subnival vegetation (5200–5700m). Medicinal plants are present and represent an important element in the flora and livelihood of the area (Joshi et al., 2006; Lamo et al., 2019). Most people still use them for health purposes by consulting local doctors (amchis). Their cultivation is promoted and seen as an economic opportunity.

Fauna

Regarding fauna, 1,561 species/subspecies including protozoa and animalia have been recorded of which 33 mammals and 276 avifauna species have been reported (Shawl et al., n.d.). As a term of reference, for India as a whole, 100,000 species were recorded (Chandra et al., 2018). The fauna includes flagship species as hangul (*Cervus elaphus hanglu*), markhor (*Capra falconeri*), snow leopard (*Panthera uncia*) and Asian black bear (*Ursus thibetanus*). Several species (71) are under threat or near threat of extinction. These include 33 species of birds, 26 species of mammals, 5 species each of reptiles and fishes and 2 species of amphibians (Dar and Khuroo, 2020, chap. 38). The main causes of threat are habitat loss and fragmentation, poaching.

Agriculture and industry

Agriculture is the main sector by occupation (~70% of the population). The growing season is short (May–September) and fields are mostly mono-crop with some double crop in Khamtsi and Nubra. In the district of Leh, out of 10,000 hectares of cultivated land the main cultures are barley (4288 ha), wheat (2776 ha) and fodder (2161 ha). There is an increasing interest in horticulture (apricots, apples and seabuckthorn) aiming at creating goods (fruit, dried fruit,

juices) to be sold to tourist and export to the national market (LAHDC, 2015). The cultivable land is limited (~0.3% (Fox et al., 1994)) by water location and availability. Irrigation is provided by canals/khuls (Angchok and Singh, 2006).

Animal husbandry is another important pillar for the livelihood of the local population. It is common for households to combine a mixed mountain agriculture and animal husbandry to mitigate risks and ensure livelihoods (Figure 9). Various development programs have been launched trying to fill the demand-supply gap. The main uses are for milk production, meat, wool and as labour in the case of yak, dzo, horses and donkeys. The wool from pashmina-goat is an example of high-value production that is increasing but not without trade-offs and consequences on natural resources (Namgail et al., 2010; Sabharwal, 2016; S. A. Wani et al., 2018). Industry and manufacturing play a minor role, mostly targeting local demand.

In the past decades, two trends can be observed in land use: remote areas tend to remain fairly the same

(Dame and Mankelow, 2010) while connected areas tend to expand (Dame et al., 2019; Nüsser et al., 2012). This expansion is creating a higher vulnerability to floods (Dame et al., 2019; Ziegler et al., 2016). Generally most of the land is made of rocky sloped terrain with vegetation along water courses (Figure 10) and limited cultivated land (<1%) surrounding villages (Joshi et al., 2005).

Transport infrastructure

Transport infrastructure is limited. Access to the region is given only by two roads (from Srinagar and Manali) that are closed during winter months. Roads are essential for imports of goods from India. In Leh an airport with daily connections to Delhi exists and the Army base of Nyoma has an airstrip. Mobile phones and signals are increasingly available while internet is mostly available in Leh and Kargil with unstable and poor connection reaching more remote areas.

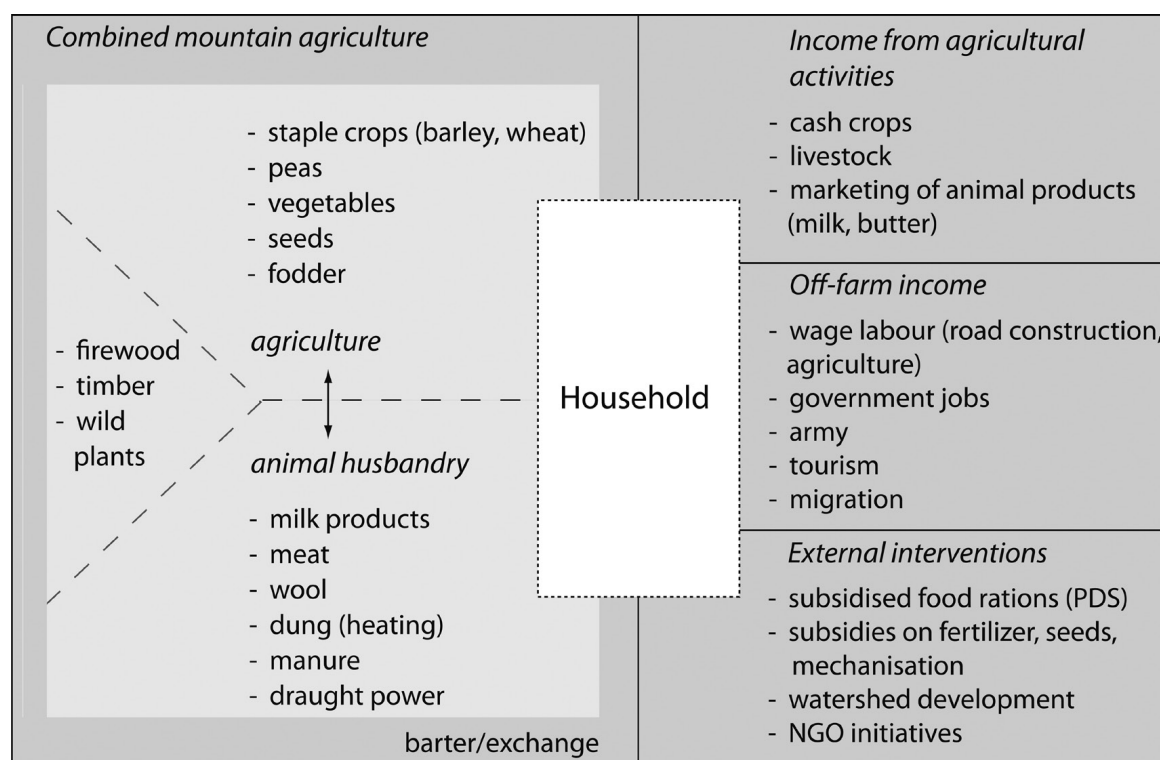


Figure 9: economy of a household in Zaskar region. It can be observed how differentiated the income and livelihood is. This allows for mitigation of agricultural risk and seasonal variation. (Dame 2011)

Tourism

Since Ladakh opening in 1974, international and mostly national tourism has increased in the past three decades (Geneletti and Dawa, 2009; Pelliciardi, 2016). There are three main type of attractions: nature and wildlife, adventure activity and religious sites. This phenomenon creates opportunities for the local economy but also additional threat to the environment (Geneletti and Dawa, 2009; Goswami, 2018; M. A. Wani et al., 2018) and to society wealth distribution (Rajashekariah and Chandan, 2013). To address these issues there is a growing number of initiatives aiming for more sustainable and pro-poor tourism (see The Ladakh Ecological Development Group (LEDeG), SECMOL, Snow Leopard Conservancy, Ladakhi Women's Travel Company).

Climate change

The impact of climate change in the Western Himalayan Region (WHR) is still under debate. Several factors may be causing this situation: the complex topography

of the region creating significant localized climate variability, a paucity of well distributed data and weather stations, the use of different sets of input for the studies (Das and Meher, 2019; Namgail, 2008; Wester et al., 2019, chap. 3).

In the last century, within the WHR, there seems to be an increase in temperature of approximately 1.6°C (Bhutiya et al., 2007), no trend in winter precipitation and a decrease in monsoon precipitation (Bhutiya et al., 2010). Another study, based on changes happening in the city of Leh, confirmed the rising trend for temperature but did not confirmed the same results for precipitation. (Chevuturi et al., 2018).

Trends in the cryosphere cannot be expanded to a regional scale (Wester et al., 2019, chap. 7). A decreasing in size was identified in the Central Ladakh Range but an increasing one in the Shyok basin (Schmidt and Nüsser, 2017). Decreasing trends in the cryosphere have a significant impact on irrigation (Nüsser et al., 2019). These contrasting results mean that there is no single likely future and actions in the present and coming years may be crucial (Wester et al., 2019, chap. 4).

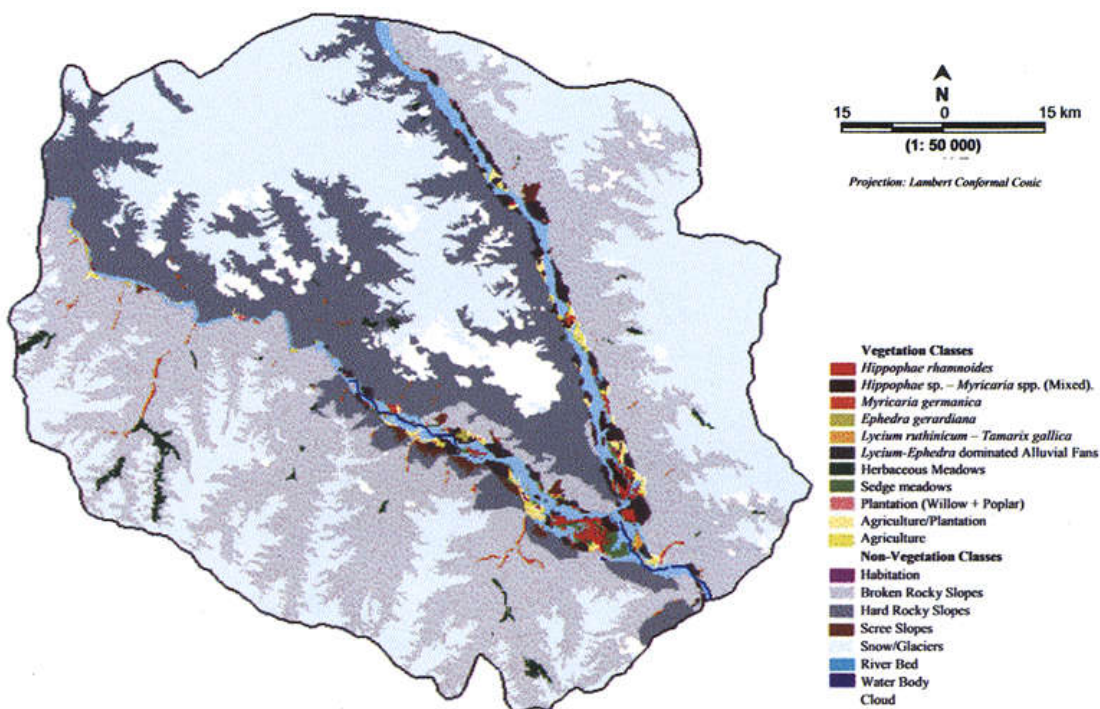


Figure 10: vegetation cover and land cover map of Nubra valley in 2001. The distribution and density of the different zones is a good reference for other remote areas of Ladakh: vegetation is scarce and next to waterways, agricultural land is minimal (<1%) and most of the land is made of steep rocky slopes.

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