

Grazing and rangeland management: Trans-human adaptations by *Brokpa* community in fragile ecosystems of Arunachal Pradesh

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This study reports the *Brokpa* herder's knowledge and strategies of using and managing rangeland ecosystems of Tawang and West Kameng districts of Arunachal Pradesh. Study was conducted with 60 herders in 6 villages dominated by *Brokpa* community. Based on conventional and participatory socio-ecological research methods, the results indicated that, traditional yak-herding system play a pivotal role in maintaining the culture and economic insurance to *Brokpa* community. Burning activates the growth of grasses and vegetation. In the traditional seasonal migratory system, yak grazing is done in the alpine pastures for four months (June to September) while at middle hills (3,500 – 4,500 m amsl) grazing takes place from March to May, as the yaks migrate up to the high pastures and again on their return during October and November. The winter (December-February) is spent on grazing at lower altitude (< 3000 m amsl). On a specified barter point in the hills, exchange of yak and sheep milk products with grains (maize, barley, buckwheat, finger millet and wheat) are done with villagers. The compatibility of yak based livestock production systems with existing ecosystem diversities and lifestyle of *Brokpas* are intricately related with their livelihood, and ensure the sustainable use of rangelands. Yak husbandry of *Brokpa* faces stress caused by climate variability and other environmental factors. Such stresses have caused in declining the yak population and weakened the dynamics of rangeland ecosystems, although, *Brokpa* are trying to adapt with local adaptive strategies. To sustain yak based livelihoods and rangeland ecosystems, integration of informal and formal knowledge is urgently required to co-produce adaptive knowledge.

Keywords: *Brokpa* community, *Monpa* tribe, Rangeland ecosystem, Traditional knowledge, Yak, Sustainability

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The risks of production and survival require highly adaptive management approaches in rangeland ecosystems¹. This may include conserving and evolving compatible animals' breeds² and natural resources which sustain ecosystem services. For quick responses to unpredictable natural events, rangeland resources and livestock management are closely associated with the predominant social structures³. The pastoralists generate their technical and organizational knowledge by moving their herds across fairly large areas^{1,4}. Effective pastoral natural resource management is based on a sound knowledge of local user groups of their environment. The migratory communities who live in fragile ecosystems and access natural resources from diverse land use

systems needs every day contingent and long-term plans to sustain their livelihoods. Pastoral systems are defined as a particular form of range-livestock production systems, in which more than 50 % of all household income is derived from livestock or livestock products, and a substantial part of the diet is derived from home-produced meat, blood and milk⁵. In this way, the interaction of pastoral communities with their ecology and climate, established through trans-human dynamics, shape the social-ecological systems.

This study reports grazing and rangeland management practices and livestock (yak and sheep) based livelihood adaptation by the *Brokpa*, an ethnic group of *Monpa* tribe of Arunachal Pradesh, India. The traditional knowledge of using and managing rangeland ecosystems have for centuries been an

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integral part of culture, livestock production and economy of *Brokpa* pastoralists⁶. Pastoral livestock production systems remain the principal livelihood activity in West Kameng and Tawang districts of Arunachal Pradesh. Herd mobility, rangeland use and management regimes are used by the *Brokpa* to exploit key resources at a larger scale for improving the productivity of yak, sheep and other animals, thereby sustaining the utilization of scattered rangeland vegetation throughout the year. The applicability of traditional knowledge under uncertain climates, and ecological and socio-economic constraints is important for pastoral livelihood systems in Arunachal Pradesh⁷.

This research presents a deeper understanding of the *Brokpas*' traditional knowledge and institutions applied in accessing and managing rangeland ecosystems to sustain their livelihoods. Study was carried out with objectives (i) to know traditional practices on management of rangeland resources and (ii) to understand adaptive practices on livelihood dimensions of *Brokpa* around yak and sheep.

Research methodology

Study area

This study was conducted in West Kameng and Tawang districts of Arunachal Pradesh. Arunachal Pradesh is a state of North eastern India and bestowed with unique culture and biodiversity supported by alpine, temperate, sub-temperate, humid and sub-humid climates. High dependence of local communities on natural resources and their deep interactions with ecosystems have evolved unique biocultural diversity. Most of the tribe in the state practice *jhum* (swidden agriculture) except few including *Monpa* who practice permanent agriculture. Local communities access forest and aquatic resources to adopt combined strategies with agricultural systems in order to sustain their subsistence farming systems. *Brokpa* act as herder/pastoralists, while *Monpa* practice rainfed agriculture (cereals, pulses, fruits and vegetables using local landraces and few improved varieties in fruit and vegetables) along with yak and sheep husbandry. Still barter system in hilly terrains of study districts connects livelihoods of *Monpa* living at lower altitude and *Brokpa* at higher altitude.

Research design, sampling and methods of data collection

The explanatory research design was adopted to explain the recorded data and draw inference from the

study. To achieve the objectives of research, West Kameng and Tawang districts were sampled purposively based on the existence of rangeland practices among *Brokpa* community. From the circle Tawang (Tawang district) and Dirang (West Kameng district), 6 villages, 3 from each were sampled randomly. Before the village sampling, an informal interaction with elders of *Brokpa* was held with the help of language experts and community leaders (at least one in each village). From each village, 10 *Brokpa* (pastoralist, thus total 60) having the age of more than 40 yrs and knowledge of livestock rearing and overall natural resources were selected randomly from a list provided by the Village Extension Workers. Key communicators and elders of villages were contacted through local experts and resource persons to make them understand about the objectives of this study. *Brokpa* respondents interacted freely after the lead taken-up by local experts and community leaders associated with this research (DT). A copy of photographs taken-up in groups with *Brokpas* was provided to them to further enhance rapport.

Focus group discussions (FGD) were organized to record the data on dynamics of maintaining and using rangeland ecosystem. This method also helped to record data on adaptive practices on yak, explored from elder *Brokpas* of each village, and then was pooled together. Interview schedule with open ended questions was applied to a conventional mixed sample. The aspects covered were the informal rules, customary laws, institutions, adaptive practices (before and after the year 2000) livelihood dimensions, and economic aspects of rangeland based livestock production systems. To have a comprehensive knowledge of local grazing land, participant observations were also made with some key knowledge holders over a period of three months at different intervals and places. Event ecology method was applied to record herders' perception and knowledge about recent environmental phenomenon and their correlation with uncertainty and livelihood adaptations around yak and hybrid cattle (*tzo/dzmo*). Following earlier collaboration with *Brokpa* community leader, study continued in online mode and telephonic conversation held and WhatsApp message were exchanged with key knowledge holders to further improve the data recorded during field study and solve the technical issues. Summary of key results were shared with key knowledge holders to validate the facts recorded from fields. Prior informed

consent (PIC) was obtained from the community for sharing and publishing their knowledge system. While seeking PIC, respondents were explained about purpose of research, potential benefits associated with community and the environments.

Results

Herd movement, grazing and traditional management of grazing land

Results indicated that yak is reared in sub-temperate and temperate climates of Tawang and West Kameng districts by the *Brokpa* community. Yak plays an important role in the religious and cultural life of both the social groups. They exclusively depend on yak for their food security under uncertain environments at higher altitude where practicing improved agriculture is still a challenge. Fragile ecology put both the groups at higher risks to sustain their subsistence economy. By living at higher altitude *Brokpa* have created a network of winter and summer camps where they drive their yak and sheep for grazing. Difficult terrain and poor road communication are major problem faced by the *Brokpa*. Many winter camps are reached only by walking for one to two days from the nearest road point. Summer camps are even more remote and access to school and medical services present great difficulties for the *Brokpa* community. Majority (85 %) of *Brokpa* reported that grazing followed by lopping and providing mixed resources from other plant and crops resources are major feeding system. The adaptation on yak and hybrid cattle (*tzo/dzmo*) of various ages varies among *Brokpa*.

The traditional yak management system of *Brokpa* community follows an open seasonal migratory system. This system is confined to particular areas due to expanding landscapes under horticultural crops, rights on territorial boundaries by other tribes (like *Mije*) and their restrictions placed on movement of yak and access of land resources. Therefore, selection of grazing land is becoming a challenge for *Brokpa*. The criteria like proximity to the water sources, sufficient exposure to sunlight (8-10 h a day), topography and amount of grass in the grazing land are used for selection of grazing land. The grazing lands are selected near the water resources (tributaries, small and big rivers and lakes) where soil is light black with high percentage of clay and organic matter, and full of vegetation for grazing of local breeds of yak, sheep, goat, horses and yak. Every grazing land is named in local parlance based on the name of hills, rivers, lakes and forest.

Brokpa moves their herds throughout the year to optimize utilization of the rangeland resources for maximum meat and milk production. Movement of herds for example in Chhander village (3500 m) starts in May. *Chhongri* (moving yak herds) grazes in the plain grazing land for next 2-3 months (June-August) at 4300-4700 m amsl. The base camp is made at around 4000 m amsl. During September, *Chhongri* comes down below the camp to the nearest forests (rich in flora) for grazing where wind velocity is less and temperature at low elevation is relatively high. If the *Chhongri* continue to graze at higher elevation where temperature has gone down by this time, the low temperature is perceived to be harmful for the pregnant animals, and might result in abortion. At the end of September, the *Chhongri* is taken to the base camp to see and count the number of animals. *Chhongri* stays here for 2-4 days, and then *Brokpa* moves slowly with their herds towards Chhander where they try to reach by 1st week of October. While moving *Chhongri* in May, *Brokpa* carries rice [local landrace, flour of local maize, bong (flour of local barley), *phaphda* (flour of buckwheat) and *rakkshi* (bear prepared from local barley through distillation)].

During grazing, *Brokpa* plays a game called *Parashaw*. About 2 to 3 persons play in this game, and looser give 1-2 either yak or sheep or silver coins (*Betang*) to the winner. Before start of *Chhongri*, *wang* (worship) takes place for 5 days (once in a year) on *purnima* (full moon period). At the end of *wang*, one yak is offered (*chhedar*) to animals' God, and is set free. Before setting free, yak is massaged with ghee, milk and decorated with flowers. If the God accepts this yak, the *ghee* and milk drops off from his/her body when he/she shakes his/her body. The offered yak is neither touched nor beaten by anyone, even if he/she enters into agricultural fields of *Monpa* (only they have crop land, *Brokpa* does not have land). It is believed that if offered yak is not accepted by the God of *wang*, blood will come out from his/her mouth. If *chhedar* is she, then after offering, milking of such yak is not done. The priest called *Dropan* practice this *wang*, and he decides when to offer a yak based on the dream. The old and previously used yak can be used for meat. The *Dropan* establishes links between human and God, as believed by *Brokpa* and *Monpa*.

Since long, time *Brokpa* people have developed location specific holistic strategy of sustainable management of rangelands and improved livelihoods

in high altitudes of West Kameng and Tawang. Rotational practice is adapted to sustain productivity of rangelands. Horse is not allowed in common grazing lands, because of his/her teeth which uproots grasses and deteriorate grazing lands. In addition, yak and sheep herds browse the vegetation, stomp the soil, transport seeds of wild species and fertilize the land. All of these enhance sustainability of rangeland ecosystems. The elder *Brokpa* sees and conducts ecological skirting, which includes identifying and classifying plants and accurately assessing the water-holding capacity of distant pastures. They then draw up movement of herds on the basis of this report.

The altitude based seasonal grazing strategy is adapted by *Brokpa*. In the traditional seasonal migratory system, yak grazing is done in the alpine pastures (4500 m amsl and above) for four months from June to September (Fig. 1). Grazing is done in the mid hills (3500 – 4500 m amsl) from March to May as the yaks migrate up to the high pastures and again on their return during October and November. The winter (December to the end of February) is spent on grazing at below 3,000 m amsl. During summer the sheep and goats are moved towards the mid hills where grasses are available in plenty. The sheep return back to the foot hills during the winter in search of grasses. More than 80 % of surface area is under rainfed ecosystem and a great extent of this consists of rangelands, largely inhabited, cared for and used by the *Brokpa* pastoralists until the recent external influences began to upset their equilibrium with the natural resources on which they depend.

For grazing of yak, *dzomo*, cows and sheep, there is a private and common system. Every hamlet has its own community grazing land. Many clusters of hamlets also select one common grazing land, which is managed by entire community. Different rules and

norms designed by community members are strictly followed in managing the common grazing land, such as group grazing and avoiding over grazing or unseasonal access. If any pastoralist is violating this rule and entering into grazing land of other hamlets, then there is a chance of conflict. The conflict associated with grazing is resolved by *chhopa* [indigenous informal institution governed by the elder members of community and headed by *Gaon Burha* (community leader)]. To settle the conflict, firstly the suffering person consults old age persons and *Gaon Burha* of respective hamlet. The matter is placed before the *chhopa* with justifiable proof. After looking to the gravity of conflict, *Gaon Burha* takes consensus decision taking into the confidence of jury's opinion and imposes fine to the guilty. This fine may vary from ₹ 1000 to 5000 and even go up to ₹ 10,000. During 1940's and 1950's, the fine was imposed in terms of local grains (maize, barley, finger millet and wheat) and breed of animals (sheep and yak).

Notwithstanding existing economic difficulties, pastoral communities produce about 8-10 livestock products and 25-30 % ethnic foods (in mixture with local crop and wild edible resources). *Brokpas* living in far-flung areas like *Naga GG*, *Thembang* and *Somteng* are still solely depend on the rangeland based livestock production systems. While, the same community living near to the town has started joining the army, developing their own enterprise, etc thereby a change in pastoral life and livelihood system. The number of *Brokpa* depending on yak based livelihoods is declining over the years due to expansion of plantation crops (apple, peach, plum, etc.) in the mid and high hills and desire among the younger generation to lead an easier and more comfortable life style, as reported by the respondents.

Rejuvenation of rangeland and grasses

Periodic burning of grazing land in the mid hills (1980 to 2285 m amsl) is a common practice in the *Bokpa* community for rejuvenation of grasses and their higher productivity. Since, this altitude is predominantly covered with pine trees, the chance of fire accident is more. In the grazing land situated at lower altitude (between 6000-6500 ft amsl), a group of *Brokpa* set together the fire by spreading the dry forest leaves and grasses. To avoid the fire accident they make fence using stones and green leaves. Before lighting the fire, they worship to please the God of respective grazing land (ecosystem). Burning

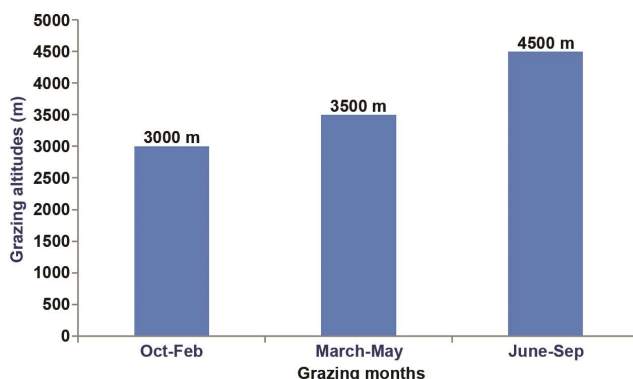


Fig. 1 — Grazing of yak at varied altitudes

activates the growth of grasses and vegetation. During scarcity, bushes and shrubs are coppiced to feed the yak. The dominant species in alpine grazing lands belong to the genus: *Carex*, *Juncus*, *Agrostis*, *Festuca*, *Kobresia*, *Poa*, *Rhododendron*, *Potentilla*, *Primula* and *Danthonia*.

Socio-cultural institutions around rangeland

A meeting (*brokpozomo*) of *Brokpa*'s held every year in April (in March according to Buddhist calendar) on a full moon day for distribution of grazing grounds. One representative from the respective village attends the meeting with traditional beverage *rakshi* (prepared from local barley through distillation). For ensuring the stable supply of grasses, *lemm* (grazing lands) are used in rotation. One can move his herd and return back to the same piece of grazing land after a span of 8 yrs. This practice is maintained to sustain grazing resources. The cross cultural relations of *Brokpa* of Tawang, West Kameng and Bhutan also influence the rangeland utilization and management. There are 8 famous and potential grazing grounds, viz. *Shimduneng*, *Naka* and *Yemkong*, *Gangbra*, *Bemghar*, *Gangdo*, *Morong*, *Kromling* and *Chhuming*, near the Tawang town. The nomenclature of these rangelands is based on nature or nearby mountain, etc. For example, *Bemghar* is the name of a mountain; *Shimduneng* is a pilgrimage (a stone like a cat). Sometimes grazing lands are demarcated by stones called *Dhota*. If *chhongri* of one hamlet grazes in grazing land of another hamlet, warning notice and one week grace period is given. If it grazes afterwards also, then *chherin* (a tax) is taken in form of ghee and *churpi* (wet cheese). Amount of these milk products are decided after bargaining. Sometimes, a *Brokpa* may take yak of one hamlet(s) to move for grazing in another hamlet's grazing land (*Nyaykhor*), and for this he receives yak ghee and or *chhurpi* as rent.

Grazing tax and tenant systems

A yak herder pays a royalty for the grazing right in the alpine area, if he is not a member of the clan that has the rights to the area. Any number of herders is permitted to graze their animals, irrespective of the carrying capacity of the area, provided this is not opposed by the other occupants. According to the customary rights, the grazing land owner has the right to fix the *charen* (*cha* means grass and *ren* means tax). The tax given by *Brokpa*'s through the *charenpa* (person/representative of grazing land owner who collects tax) to the grazing land owner varies from

place to place based on the types and amount of grasses and shrubs. In return, milk, ghee, *churpi*, etc is given to grazing land owner depending on types, age and number of livestock. For example, yak below the age of three years are excluded while deciding the total fee for a piece of grazing land. No fee is charged over *galang* breed of yak because it is kept as bull for breeding purpose and owner of grazing land may also use it. For grazing of one adult sheep, 14 *hrang* (2 kg) wool is taken per year from the sheep owners or an equivalent amount of money may also be charged. For horse, ₹ 30.0, yak ₹ 45.0, goat ₹ 10.0 and sheep ₹ 10.0 per year are charged as fee. The fee can be charged in forms of *churpi* and ghee.

Local environmental changes and adaptive practices of Brokpa

During 1960s, *bumla* rangeland ecosystem (near Tawang district) was very famous for higher productivity of grasses and survival of *Brokpa* community but entrance to the area is now banned after the construction of an army base for security reasons. This is one of the factors for a decline in yak population in the area. For example, the *Gaon Burha* of *Chander* village (West Kameng district) has reported that previously a *Brokpa* family was having on an average 40-50 yak, but now it has reduced up to 15-20 and in some cases up to 5. Reasons suggested for the decline in size of the yak population include socio-economic causes, one of which is a desire for an easier and more comfortable lifestyle on the part of the younger generations.

The other factors including climate variability have further caused local changes in yak husbandry. Recently, due to perceived climatic variability some changes in the local indicators are being observed by *Brokpa*. They perceive that rate of melting snow at hills top is increased, number of rainy days is decreased, snowfall pattern is changed (shifted to much higher altitude), incidence of health in yak and cattle ((*dzo/dzmo*) is gradually increasing, events of flash flood increased with high risk of landslides, population of local fishes in river decreasing (they correlate with even distribution of rainfall), problems in fermentation of *chhurpi* and other traditional alcoholic beverages, and storage of *chhurpi* at 1830-2135 m amsl at room temperature affect keeping quality. Further, *Brokpa* herders are facing problems of accessing grasses and fodders due to less rainfall. Sometimes they face problem of high temperature at lower altitude (2135-3048 m amsl.) and are now compelled to climb at higher altitude for accessing

grasses and drive yak in cooler environment at the cost of more travel time, higher labour and energy requirements. Climate variability was a reason to evolve a new yak breed by *Brokpa*, namely *mithak* by making a cross between *mithun* (*Bos frontalis*, male) and yak (*Poephagus grunniens*). The male *mithak* is relatively more compatible to harsh and warmer climate, and physically stronger than yak (Fig. 2). Female *mithak* is also more productive in terms of milk (Fig. 3) as compared to earlier local breed (See details of this breed in Singh 2012)². These *mithak*'s after multiplication has been distributed to the needy *Brokpa* of about 60 households to enhance their adaptive capacity against climate variability. In addition, to respond few other changes led by climate and other anthropogenic process, *Brokpa* have adapted their local strategies to sustain livelihoods (Table 1).



Fig. 2 — *Mithak* (male) cross of male mithun and female Dzomo: Breed for climate adaptation (developed by Darge Tsering)



Fig. 3 — *Mithak* (female) cross of male mithun and female yak: Breed for climate adaptation (developed by Darge Tsering)

In recent past, climate variability problem is further aggravated due to compounding impact of banning of burning indigenous grasses nearby and in between forest by the state forest department. The grasses are burned to traditionally enhance their productivity. Some community leaders such as *Gaon Burha* of *Chhander* has been very much instrumental in between *Brokpa* community and state forest officials to pursue in withdrawing the ban from burning, however, he could not succeed in it. Simultaneously, he has also motivated *Brokpa* herders to have controlled burning of grasses in order to avoid forest fire, and reviving traditional practice of cleaning high depth mulch and organic matter nearby living trees in forest to avoid forest fire. On the issue of impact of climate variability on yak, he stated that:

In November month the yak should have been around Namsu village (2286 m amsl), but still they are at Chhander (3354 m amsl) because climate is warm. I don't know what will be future of our yak breeds and livelihoods of Brokpas (Darge Tsering, Chhander, November, 2015).

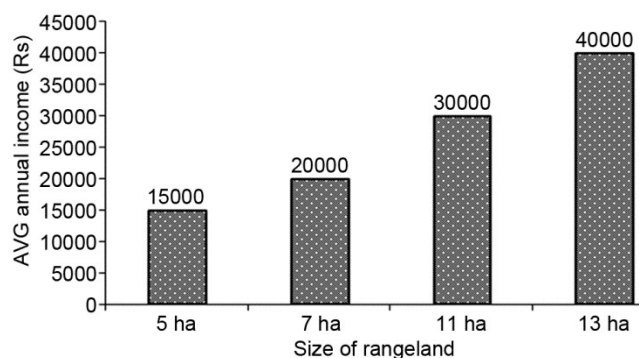
Livelihood dynamics of Brokpas

Rangeland ecosystems provide a substantial amount of household income through maintaining yak and hybrid cattle (*tzo/dzmo*) on it. Such income varies with size of rangelands (Fig. 4). Milk is processed into butter and *chhurpi* by individual herders using traditional methods. On an average the daily milk yield from a yak cow is 0.8 to 1.2 kg and highest yields were obtained from animals of 7-10 yrs age. A healthy and vigorous calf is given due care and proper rearing. The meat is kept inside its skin and is later supplied to the livestock owner. In case of surplus amount of yak meat, it is mixed with the *rakshi* and dried for later use. The skins of calf and adult yak are also used as container for preserving the *chhurpi* (cheese) and ghee. *Brokpa* harvests yak hair in May and June. *Brokpa* of Tawang never kills yak, but they sell live yak to slaughter houses. *Bangani* community from Seppa area do the job of slaughtering yaks. *Brokpas* perceive that slaughtering should be banned because of declining yak population. *Brokpa* sell only those yaks which remain out of the herds. They never sell weak and diseased she yak since they believe that she yak has provided them ghee and *chhurpi*, and they are equal to mother. Therefore it is the moral duty of *Brokpa* to allow such she yak to die naturally.

Making ghee, wool and *chhurpi* from yak milk is in vogue near Bhutan and Tibet borders of Arunachal

Table 1 — Adaptive strategies on yak before and after the year 2000

Aspects of adaptive practices	Before 2000	After 2000
Conservation of breed and progeny	Informal breeding, exchange of genetic resources from one region to another by <i>Brokpa</i> .	Interventions made by central and state governments in enhancing productivity of yak through formal breeding programme and maintaining vigorous breeds.
Weather forecasting	Forecasting of weather was exclusively based on indigenous bio-meteorology, direction of winds and experience of other atmospheric components. Grazing lands were selected for herd movement based on diversity of grasses, water availability, size of land, altitude variations, etc.	Still traditional practices of weather forecasting exist. A very little percentage of formal forecasting of weather based information reaches to <i>Brokpa</i> , that too after passing from various primary and secondary sources. Ultimately, <i>Brokpa</i> get at least 3-4 days old information about weather and climates.
Informal institutions	The informal institutions related to manage grazing lands, herd movement, rights over clan resources were predominant.	Minor change are noticed in common property institutional arrangement of herd movement and rights on grazing land due to changes in landscape and increasing trend of commercial agriculture by <i>Monpa</i> .
Grazing and feeding	Herd movement for grazing in varied ecosystems under sub-temperate, temperate and alpine climates. Yaks are supplemented by lopping and coppicing of grasses (bamboo), shrubs and tree oak species.	Scientific institutions are trying to train and motivate <i>Brokpa</i> for raring yak with combined practices of feeding i.e. grazing and stall feeding in order to enhance yak productivity.
Infrastructure for raring calf	<i>Brokpa</i> use pine tree trunk to construct animal shed/house. Such shed are more climate resilient for calf than modern shed as perceive by <i>Brokpa</i> .	The state government and scientific institutions use to prefer and recommend animal shed made of iron and concrete. Such sheds are not healthy for calf, that's why adoption rate of such shed among <i>Brokpas</i> are almost nil.
Health management	Only ethnoveterinary (medicines prepared from herbs, shrubs, and other ethnozoological resources) practices were followed to keep yak healthy. In addition, cultural and spiritual practices were followed to wish the yak healthy. Although, number of diseases were also noticed less than today, and animals were tolerant to slight to moderate level of climatic variability.	A number of diseases are increased due to abrupt climatic variability. In month of June and November, the state government used to have vaccinations for infectious diseases. Department of veterinary use to organize health camp with allopathic drugs to have check-up of yak health, and capacity building of <i>Brokpa</i> for using improved health practices. Though, in some cases due to unsatisfactory results, <i>Brokpas</i> are reluctant to go with modern health practices.
Yak based livelihood	<i>Brokpa</i> had strong network with <i>Monpa</i> farmers (who practice settled agriculture) to get cereal, pulses and oil based foods in exchange (barter economy) with ghee, wool, wet cheese (<i>chhurpi</i>), dried meat of yak and some plant based ethnomedicinal products. <i>Brokpas</i> were exclusively dependent on yak and sheep based livelihoods.	Socio-political changes have made <i>Brokpas</i> now aware about commercial economy. Some amount of yak based products is now sold in local market and few parts are still bartered with network members. Now <i>Brokpas</i> are opting seasonal jobs in local market, getting engaged as laborers and contractors in constructions and road works.

Fig. 4 — Role of rangeland ecosystems in average annual income for *Brokpa*

Pradesh. *Dum* (wool) is plucked from local breed of sheep around Tawang and Dirang. *Dum* sold in a unit of *hrang* (7 *hrang* = 1 kg) and is harvested from the local sheep and are used for weaving the sweaters, trousers, shirts, cap, etc. *Chola* (jacket) made of yak skin, *pakcha* (rain coat), cap from yak wool and shoes made of yak skin are quite popular livestock products. *Brokpa* are responsible for supplying the milk products and meat of yak in different villages after summer grazing. *Brokpa* residing around Tawang makes bags from yak wool and uses them for carrying food materials to agricultural fields.

On a specified barter point in the hills, exchange of yak and sheep milk products with grains (maize, barley, buckwheat, finger millet and wheat) are done

with villagers. Such barter practices of *Monpa* of Tawang and West Kameng, and sheep herders of Bhutan have been sustaining their livelihoods in fragile ecosystems. After using local maize (*thinang*) and barley (*bong*) for preparing fermented beverages like *lohpani* and *rakshi*, the residues (fermented maize and barley seeds) are fed to yak and hybrid cattle (*tzo/dzmo*). This traditional practice helps to increase milk production and immunity of an animal against disease and cold (yak and hybrid cattle- *tzo/dzmo* reared at 11000 ft amsl) as perceived by *Brokpa*. According to altitude levels, the knowledge of developing a local food product is changed. For example, *thung* fruit (crab apple, harvested from forest) is used to ferment yak milk in *chhurpi* preparation at lower altitude (in Dirang region), while *lohpani* (alcoholic beverage prepared from local maize) is used to ferment yak milk at higher altitudes such as in *Chhander* village (around 11000 to 13000 ft amsl). After the fermentation of yak milk, the water from milk is separated and stored separately and fed to yak for increasing milk efficiency. Earlier, the *Brokpa* community was accustomed to get only grains of indigenous crops in exchange of milk products, but now the milk products are sold in cash in the local market. This change has affected overall food habit of *Brokpa* as they were accustomed to consume the traditional foods based on maize, barley, buckwheat, finger millet, beans, wheat and wild edibles, but now they are consuming more fine rice supplied by government under PDS (Public Distribution System). This weakened dynamics of exchange of local grains and milk products has affected the local cropping systems of *Monpa* people.

Discussion

Key results indicated that yak reared in sub-temperate to temperate climates using local knowledge and practices by *Brokpa* represent an unique example of trans-human adaptation to fragile ecosystems of Dirang and Tawang region of North East India. Such trans-human intra-annual and inter-annual livestock movements in the region provide grazing resources and water, and also enable *Brokpa* to carry out organized skirting of the ecology⁸. Traditional grazing governed through informal institutions has been the backbone for sustaining pastoral adaptations in Arunachal Pradesh⁹, and this kind of rangeland ecosystems can sustainably be managed by local pastoralists¹⁰. The tenant system of yak rearing and rent practices between *Monpa* and

Brokpa could sustain cross-cultural knowledge exchange and bonds of survival in high risk prone ecosystems⁹. These practices enhance social-ecological resilience of *Brokpa* community.

Although, managing grazing land resources to sustain yak and hybrid cattle (*tzo/dzmo*) is relatively difficult because of high hills in the alpine region is difficult terrain with tiny grazing land size¹¹. Rotational grazing practices followed by *Brokpa* of Dirang and Tawang, are also followed by similar communities of Bhutan (neighboring to Tawang district)¹² which prove how similar kind of trans-human practices evolved even across the country. Decreasing grazing land size may lead to over grazing and thus in turn may results deterioration of the grazing land⁹, therefore demand even distribution of herd size. This may further aggravate with land use changes or some policy stress, e.g. ban by the forest department on grazing.

The practice of grazing and yak population is declining as reported by *Brokpa* community. This could include the factors socio-economic changes, climate variability erosion of community based occupation and desire of more lucrative jobs among younger generation¹³. In order to adapt climates of high altitude, and improve social status a group *Brokpa* leaders have opened schools for their children and maintain basic amenities in the school itself. Human and animal healthcare is looked after with using ethnomedicines based on plant and animals species. However, in recent past, few *Brokpa* women got trained in human health from district hospitals to provide basic services of immunization, looking after the normal child birth and providing pills and precautionary medicines to children and women. The geopolitical changes such as closing the Tibet border and thereby impact on closing grazing tracks of *Brokpa* might have also contributed sustainability of yak based system. For example the availability of new sources of breeding stock⁹, which is now being managed by *Brokpa* from local area and sometimes from Bhutan but at higher labour and cost basis, undermine the quality of yak breeds. Whether it is evolving new breed of yak, managing food resources from yak, sheep and rainfed agriculture through exchange with *Monpa* of applying the criteria of selecting gazing lands are concerned, all these are examples of resilience. The types of climatic, ecological and socio-economic changes experienced by *Brokpa* and their autonomous strategies needs to be calibrated to adapt and mitigate projected climate change, and likely global changes.

Conclusion

We can conclude that *Brokpa's* location specific knowledge and incremental learning about grazing land use and management and yak husbandry is an example of subsistence practice to cope up with the challenges imposed by the harsh climates in rainfed ecosystems. The rangeland is maintained and livestock are reared through local practices mediated by indigenous informal social and cultural institutions. Unfortunately, the pastoralists' knowledge and local institutions evolved for managing rangeland ecosystems are not well appreciated or understood by many researchers, planners and others interested in improving livestock production system in temperate ecosystems. For herders to realize the opportunities of further sustainable use and management, will require improved extension services to address animal health, adding value to local products and training the *Brokpa* herders in the areas of emerging challenges such as climate and socio-ecological changes. One serious threat to future of yak husbandry in Arunachal Pradesh is that the younger generation appears uninterested to shoulder the responsibilities and hardships of yak rearing due to many anthropogenic and policy factors. Therefore, such changes in livelihood pattern of young *Brokpa* is if not taken seriously, the conservation of yak related biocultural diversity will be at stake. An ensured approach of learning about improved livestock production in the temperate zone would required to be grounded with educational programmes, political will and encouragement through the livelihood and food security. An awareness campaign for general improvement in the educational level of *Brokpa* would also enable them to organize themselves not only to effectively conserve their biocultural and ecological knowledge and increase the value of their local products, but also forcing the government to include local livestock production system in the policies.

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