Major Achievements of Decade (2012-2022) at ICAR-CAZRI RRS, Leh

भाकृअनुप
ICAR

ICAR-Central Arid Zone Research Institute
(ISO 9001:2015)
Jodhpur 342 003 (India)

Major Achievements of Decade (2012-2022) at ICAR-CAZRI RRS, Leh

ICAR-Central Arid Zone Research Institute
(ISO 9001:2015)
Jodhpur 342 003 (India)

Published by:

Director
ICAR-Central Arid Zone Research Institute
Jodhpur – 342003 (Rajasthan) India
Phone : + 91 291 2786584, + 91 291 2788706
E-mail:director.cazri@icar.gov.in
Website: www.cazri.res.in

Contributors:

R.K. Goyal

Dipankar Shah

Mahesh Kumar Gaur

M.B. Noor Mohamed

Changchuk Lamo

Jigmet Stanzin

Stanzin Landol

भारतीय कृषि अनुसंधान परिषद
कक्ष क्र. 101, कृषि अनुसंधान भवन–II, नई दिल्ली–110 012, भारत
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
Room No. 101, Krishi Anusandhan Bhavan-II, Pusa, New Delhi 110012, India

डॉ सुरेश कुमार चौधरी
उप महानिदेशक (प्राकृतिक संसाधन प्रबंधन)
Dr. Suresh Kumar Chaudhari
Deputy Director General (Natural Resource Management)

Foreword

Agriculture in the cold arid region of Ladakh, which covers an area of about 7 million ha, is a challenging proposition as this region endures extreme weather conditions, soils with very low organic matter, very less precipitation and high evapotranspiration rates. The ecosystem, being very fragile, is extremely vulnerable to climate change. The agricultural practices in the region are mostly traditional. The total dependance on irrigation water from glaciers makes the agriculture more vulnerable to climate change. The soil and terrain also differ from place to place with almost zero top soil depth at certain places. To address the area specific issues for sustainable development of agriculture and animal husbandry in the cold arid region, Regional Research Station (RRS) of ICAR-CAZRI was established in 2012 at Stakna, Leh. The research thrust of RRS, Leh is focused on product processing, agroforestry, land and water management and documentation of ITK's. Under extremely harsh conditions, team at RRS, Leh has been learning and contributing to the development of the region through its various research and extension activities.

I am happy to know that CAZRI-Regional Research Station, Leh is bringing out a publication on research, extension and developmental achievements, during the period from its inception in 2012 till 2022. I would like to congratulate the staff of Regional Research Station, Leh for focusing attention towards problems of cold arid agro-ecosystem. This compilation will provide source of knowledge and practical information on cold arid region.

I would like to congratulate the editors for compilation of "Major Achievements of Decade (2012-2022) of RRS, Leh, UT-Ladakh" for the benefits of present and future generation of agricultural community.

(S.K. Chaudhari)
Deputy Director General

Ph.: +91-11-25848364 Fax: +91-11-25848366 Email: ddg.nrm@icar.gov.in Website: www.icar.org.in

INDIAN COUNCIL OF AGRICULTURAL RESEARCH
NRM Division, Krishi Anusandhan Bhavan-II
IARI Campus, Pusa, New Delhi 110012, India
Tele.: 011-25846457
Email: adgagroandaf@gmail.com

Rajbir Singh
ADG (AAF&CC)

Message

This decadal document of the CAZRI-Regional Research Station, Leh, it is both a moment of reflection and a celebration of the remarkable journey it has undertaken over the past decade. Established in 2012 with the vision of advancing research and development in one of the most unique and challenging environments, RRS Leh has emerged as a beacon of scientific inquiry and research in the high-altitude cold arid region.

This document chronicles challenges, accomplishments, and the significant strides RRS Leh have made in our research endeavors. Over the past ten years, the dedicated team has worked to address critical issues related to cold arid region.

Work of RRS, Leh has always been guided by the principles of excellence, relevance, and collaboration. Through meticulous research and innovative approaches, we have sought to harness these opportunities while mitigating the challenges faced by the region's ecosystems and inhabitants.

The support and collaboration from various stakeholders, including government bodies, local communities, and research institutions, have been crucial to initial years of RRS, Leh. achievements. Their partnership has enabled RRS Leh to foster a broader understanding of the region's environmental and socio-economic dynamics.

Currently, RRS Leh is only ICAR presence for working for cold arid region in India. I hope this document serves not only as a record of past efforts but also as a source of inspiration for future research and collaboration.

I believe the RRS Leh will continue to drive forward the frontiers of knowledge and ensure a resilient and thriving future not only for the Ladakh region but cold arid regions of other states too.

(Rajbir Singh)
Assistant Director General (AAF & CC)

भाकृअनुप–केन्द्रीय शुष्क क्षेत्र अनुसंधान संस्थान
(भारतीय कृषि अनुसंधान परिषद्)
जोधपुर - 342 003 (राजस्थान), भारत
ICAR-Central Arid Zone Research Institute
(Indian Council of Agricultural Research)
Jodhpur - 342 003 (Rajasthan), India

डॉ. ओम प्रकाश यादव
निदेशक
Dr. O.P. Yadav
Director

Message

Indian cold arid zone spread over 7 million hectare area of which 72% lies in Ladakh UT. The climatic conditions over the cold arid zone which is located at an altitude of 8000-18000 ft. are distinctly different from those observed in the hot arid zones of the country. The Ladakh had highest aridity index of 83%. Due to its high altitude, Ladakh is always freezing cold and dry for most of the year. The rainfall is as low as 100 mm annually as it lies in the rain shadow of the Himalayas. The main source of water for agriculture and other allied activities is glacier melt water in small streams and rivulets. Due to extreme weather conditions, cropping season is limited to May-September with a few crops (peas, potato, wheat, onion) with very low productivity. To address the location specific agricultural problems of cold arid region of Ladakh, ICAR has established Regional Research Station (RRS) of the Central Arid Zone Research institute (CAZRI) at Stakna-Leh in the year 2012.

The 19.7 ha area in Stakna under rocky-stony foothills has been converted into 72 of cultivable terraces. A canal joining Igoo and Phey villages provides water to research farm on rotational basis. Station now has a full-fledged office building with required amenities. The research thrust area of station include development of area-specific farming practices for cold arid regions and to act as repository of information on the state of natural resources and desertification process and its control.

During last decade (2012-2022) station has done a commendable job in infrastructure development and demonstrating proven various agro-technologies in Leh and Kargil districts under TSP. The station has developed linkages with line departments and local administration for management of research activities.

The compilation "Major Achievements of Decade (2012-2022) of RRS, Leh, UT-Ladakh" is a good effort to document the diverse work undertaken by RRS, Leh. I congratulate entire team for their tireless efforts for putting entire information in this document and hope this bulletin will serve as baseline information for future research to scientists, academicians and other stake holders.

(O.P. Yadav)
Director

Contents

Historical Background, Physical Environment and Thrust Areas

The Regional Research Station (RRS), at Leh is one of the five research stations of ICAR-Central Arid Zone Research Institute (CAZRI), Jodhpur, established in 2012 at Stakna (Fig. 1), Leh of Ladakh (UT) to address specific issues for sustainable development of agriculture and animal husbandry in 'Cold Desert" region of India covering an area of 7 million ha. Ladakh is situated at an altitude of 2,900 m to 5,900 m asl. It is one of the coldest places of Trans Himalayan region having unique agro-climatic characteristics.

Ladakh is a high-altitude desert. The mean aridity index of this cold desert region (Jammu & Kashmir) is 83 as compared to Rajasthan (78) and Gujarat (76). The region has a climate characterized by almost lack of rainfall, intense insolation (exposure to Sun's rays) and great diurnal and annual range of temperature. The deficiency of rainfall in the region owes to its location in the rain shadow zone of Greater Himalayas towards south, Karakoram towards north and Tibetan plateau in the east. The climatic characteristics range from the burning heat in the day to freezing point at night.

The region on the north flank of Himalaya (Dras, Suru valley and Zanskar) experiences heavy snowfall and remains virtually unapproachable from the rest of the country for several months. During the summer, the mean temperature ranges between -3°C to 30°C and in winter it is from -25°C to -15°C. The short but warm summers enable farmers to grow few grain and fruit crops. Rainfall occurs twice a year, June to September by south west monsoon with average precipitation of 41 mm and October to May from westerly with average precipitation of 53 mm.

Fig. 1 Location map of Leh in Ladakh region (Source: Survey of India website)

As per 2011 census, the population of Leh district was 1,17,232 with a very low density of population (3 persons per sq. km). Majority of population (76.17%) is rural. The biggest ethnic group is Buddhist having 81.18% of population, followed by Muslim (15.32%) and Hindus (2.99%). The main occupation engaging the working force is cultivation, agriculture labour, household industry and other works. Since September 1995, the Ladakh Autonomous Hill Development Council (LAHDC) is the main development agency of the district.

The Leh-Ladakh region forms a part of inner Himalayas, with a series of ranges having varying elevation. The whole of this region is mountainous with three parallel ranges; the Himalayas, the Zanskar, the Ladakh and the Karakoram and three major valleys; the Shyok, the Indus and the Zanskar. Geologically, majority of these mountains are composed of igneous and metamorphic rocks - granite, gneisses and schist. Elevation wise, an assessment indicates three major zones; 68% of the total land of Ladakh lies in 5000 m above sea level, unfit for vegetation and livlihood, 5.8 % land lying between 4500 and 5000 m zone, is primarily meant for grazing and activities of agriculture is confined to below 4500 m in height. The town of Leh is confined to below 4500 m elevation zone. It is a wide valley formed by the mighty Indus River that flows across Ladakh (Fig. 2).

Fig. 2 Geographical Location of Leh-Ladakh region in India

The eco-system prevailing under such physiographic conditions is very fragile and vulnerable to climate change, tectonic disturbances and topographical limitations. Low temperature of the area during most part of the year accompanied with scanty rainfall, low humidity, higher evaporation, transpiration and soil erosion hazards pose constraints for agricultural production. It has a rocky/barren topography and soils of the region vary from gravelly and sandy loams as on the alluvial fans to sandy and silt clay loams as on the Indus plains. The local population survives on limited cropping and largely depends on natural resources for meeting their basic needs due to small land holdings.

Establishment of CAZRI Regional Research Station: Acquisition of land for establishing this RRS was completed in 2012 followed by a formal stone laying by Sh. Rigzin Spelbar, the then CEC, LAHDC and Dr. S. Ayyappan, the then Secretary of the Department of Agriculture Research and Education (DARE) and Director General of ICAR on August, 18 2012. Research facilities and *central office cum laboratory building* at RRS-CAZRI, Leh were inaugurated by Shri Narendra Singh Tomar, Hon'ble Union Minister of Agriculture and Farmers Welfare on December 21, 2020.

Thrust Areas

- Repository of information on the state of natural resources and desertification
- Development of area specific farming practices for cold arid regions

Location

The research station is located at Stakna at a distance of about 30 km away from Leh city on Hemis Road at North latitude of 33°58'18" and East longitude of 77°41'49". The total area of the Research Station is 19 ha. July and August are the hottest months with mean maximum temperature of 29°C and mean minimum temperature of 16°C while December and January are coldest months with mean maximum and minimum temperatures being 1°C and -13°C, respectively.

Facilities

Research farm

The overall farm area of RRS-Leh is 377 kanal (19 ha) which have been divided into 3 blocks with different number of terraces in each. The total number of terraces are 72, out of which one has been walled. After filling the top soil, 14 terraces are cultivable at present and 3 terraces of orchard, 2 terraces of silvi-pastoral system and 2 of agroforestry are in place. The source of irrigation is from Igoo-Phey canal which lies in the north of the farm and a bore well is located at the nursery block. There are 3 ponds at different locations of the farm (Fig 3, 4). More than 3000 plants of willow and poplar have been raised along the boundary and under silvi-pastoral system. An underground cellar is in place to store the germplasm seeds during winter months.

Conference hall

The research station has a conference hall to conduct scientific meetings and farmers' trainings with a seating capacity of 20 persons and is equipped with state-of-the-art audio-visual facilities (LCD projector, TV, computer, etc.).

Fig. 3 Regional Research Station-Leh, 2015

Fig. 4 Regional Research Station-Leh, 2021

Library

The RRS Leh has a good collection of books on different subjects. The library is subscribing national and international journals related to various disciplines of agriculture and allied sectors.

Laboratory

The laboratory is equipped with the instruments to carry out basic measurements and analytics like spectrophotometer, micro-processor-based pH system, multiparameter (pH/EC) analyzer, trinocular digital phase microscope, pulper machine, refractometer, plant canopy analyser, M. binocular stereo zoom microscope vision plus, precision weighing balance and several other basic equipments like hot plate, hot air oven, camera and GPS, etc.

Weather station

The research station has an automatic weather station to record basic weather parameters like soil and air temperatures, relative humidity, wind velocity, wind speed, sun-shine hours, rainfall. The data is utilized for the benefit of farmers of this region and research purposes.

Research Achievements

Natural Resource Management

Biophysical survey of Leh and Nubra valley and vulnerability assessment

During the initial years of RRS, Leh establishment, a biophysical survey was carried out in 12 villages of cold arid regions of Leh-Ladakh and Nubra valley for understanding the natural resources and vulnerability of the region (Fig 5). Information was collected on 30 parameters for physical, vegetation and socio-economic conditions.

On the basis of physiography and terrain characteristics, villages have been grouped under three situations;

i. Mountainous terrain with deep to very deep valleys at higher altitudes between 3590 m and 3897 m above MSL (Umla, Saboo, Stakmo and Nang).

ii. Central rocky uplands with raised flood plains of river Indus having rock/boulder-gravel-sand filled surface at moderate altitudes between 3146 m and 3270 m MSL (Nimoo, Rambirpore, Stakna and Chuchot).

iii. Villages, Phey and, Spituk located on a gentle lower flood plain of Indus River at a lower elevation of about 3200 m above MSL.

Khardung and Hunder are the two other villages located in the Nubra valley. At landscape scale, all these villages form part of dominant rocky landscape with assemblages of rugged mountains, gravel terraces, alluvial fans and Indus riverbed. Umla, Saboo, Stakmo and Nang are situated on steeper mountainous slopes with narrow valleys, therefore, settlements are elongated. The terrain slope is steeper (maximum 9.5% at Umla to minimum 8.05% at Stakmo). The roads along the narrow stream and the croplands on different slopes and terraces are covered with rock fragments and boulders of various sizes, indicating hazardous impact of 2010 flood. All these villages faces road blockage and consequently restricted movement of essential commodities. The good croplands have turned into wasteland at many places. Economically, it costs more to clear the rock boulders from their fields. The possible reasons are slope failures, rock detachment from hill slopes and subsequent transportation, make these villages more vulnerable to flash floods and landslides in the order Saboo>Umla>Nang>Stakmo. Saboo receives more snowmelt water from its upper catchment, while in case of Nang and Stakmo, the glacial discharge is diverted towards Nubra valley. The thick flood-flow deposits at several places between Thikshey and Shey indicate the impacts. Water scarcity is a perpetual problem and people correlate this negative balance of water resources with decreasing snowfalls during last decade, and therefore decreasing glacial discharge. Phey and Spituk are the villages on the low flood plains, nearer to Leh and Choglamsar and face least of problems except their vulnerability to occasional floods and sand and dust movement.

The villages (Nimoo, Rambirpore, Chuchot and Stakna) are on or nearer to Indus flood plains, therefore subject to problems of flood water which is occasional. Nimoo and Chuchot are big villages and are least vulnerable with better opportunity of agriculture, market and infrastructural facility. Areas of Chuchot closer to Indus River are increasingly being impacted by water logging and salinity. However, about 40%

area of Chuchot is barren land filled with aggraded rock boulders and rocky waste. Chuchot is irrigated with water of Indus River. It has considerable plantation and pasture area along the bank of Indus. The village enjoys the Igoo-Phey irrigation canal facility but due to disputes, the potential for agriculture is yet to be effectively utilized. Rambirpore has the advantages of location on a comparatively low and flat plain. However, barren lands with wind erosion and sand movement are few of the problems. Absence of substantial glaciers for few last decades has impacts on the snowmelt water is the major problem of concern. Though agriculture is the major occupation (>80%), people are also engaged in service and tourism sector (Fig. 6-23).

Phey and Spituk are located on the active flood plains of Indus, therefore, more vulnerable to flood hazards like 2010. The other hazards are in the form of dust and sand concentration during March to April. These two towns are nearer to Leh and Choglamsar and have access to infrastructure and market facility. At Phey, people only reported about water scarcity but they are good agricultural entrepreneurs. At Hunder and Khardong villages of Nubra valley, people are more vulnerable to socio-economic and infrastructural constraints. Along with difficult terrain, remote locations cost the people more travel expenditures. Agriculture is the main occupation but labour cost makes the system more of a subsistence based. Productivity of major crops, potato, barley and pea is limited due to old traditional system and lot of farming is carried out using Dzo. However, people enjoy the benefit from the tourism. Other problems are the decreasing snow falls and lesser glacier structures.

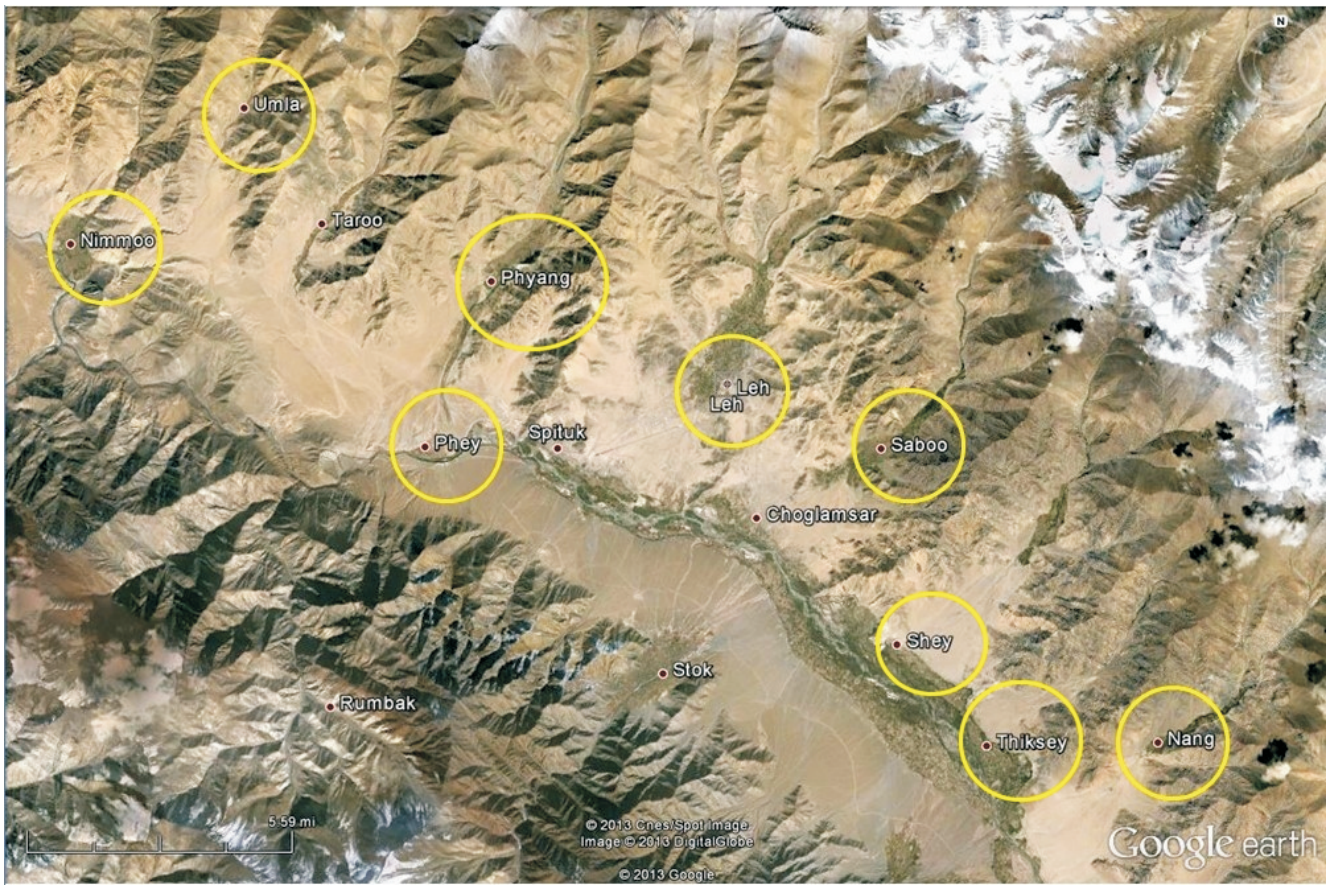


Fig. 5 Villages selected for biophysical survey and vulnerability assessment

Fig. 6 Erosion and land degradation:
A common scene in many parts of region

Fig. 7 Stabilized obstacle sand dunes at Shey village:
Indication of aeolian activity

Fig. 8 Sea buckthorn is an economically
important shrub in Leh region

Fig. 9 Terrace farming in Leh valley

Fig. 10 Dzo: An important domesticated animal

Fig. 11 Animal husbandry practices

Fig 12. Apricot orchards at Leh

Fig 13. Apricot farming and value addition: adding to economy of local people

Fig. 14 Snow melt water received from mountainous terrain is the main form of water resources

Fig. 15 The snow sourced water is distributed through well planned canal system

Fig. 16 The Indus river near Shey-Choglamsar villages

Fig. 17 Waterlogged areas near Choglamsar

Fig. 18 Typical cold arid trees; salyx and poplar

Fig. 19 Vegetables grown and sold in the local market

Fig. 20 Interaction with SHG (Self Help Group) women

Fig. 21 Access to drinking water is still a problem in some part of Leh town

Fig. 22 Problem of storage of fodder- need for improved technology

Fig. 23 The crop fields and irrigation system

Altitudinal variation on soil properties

Study was carried at Stakmo village of Leh district with the objective to find out the spatial variations in soil properties under climate change scenario for consecutive two years (2016-17 and 2017-18). A total of 38 soil samples were collected along different altitude. Studies revealed that under the state of weathering process and continuous abrasive disturbances, the spatial variation in soil properties have been changing due to various biotic and abiotic factors *i.e.*, topography-induced micro-climate differences, altitude, parent material and vegetation types. The micro-climatic variations with altitude dramatically influenced the weathering rates and leaching intensity, resulting in changes on soil properties. Correlation coefficient of soil samples of Stakmo village indicates that the soil physical properties and pH had a positive and non-significant association except for Zn (-0.028) and Mn (-0.215) whereas with Fe it showed a negative but significant relationship (-0.344) with EC. A positive but non-significant relation was observed except for with Zn (-0.123) and Mn (-0.140) with which they showed a negative but non-significant relation and with organic carbon, a positive and significant relation was observed with N (0.351), P (0.467), Zn (0.540), and Mn (0.310) whereas a positive but non-significant relationship was observed with K, Cu, and Fe.

Micro and macro nutrients had significant positive correlation with altitude gradient. Percentage of available N, Cu and Fe content in the soil increased with the increase in altitude and the rate of correlation coefficient was 0.542, 0.213 and 0.028, respectively whereas with P, K, Zn and Mn showed a negative correlation -0.201, -0.266, -0.158 and -0.293 respectively with altitude gradient. The N content of the soils were low and average was 133.54 kg ha^{-1}. This is majorly due to the low clay content in the soils, where the major textural classification being sandy loam, whereas P was available in medium range with the average being 10.61 kg ha^{-1}. K content was high (average of 633.91 kg ha^{-1}). The study revealed significant impact of altitudinal changes on physico-chemical properties of soil that has effects on plant phytochemistry and genetic diversity of plants of Stakmo village of Leh.

Remote sensing of snow and ice cover

Extent of snow cover is considered as one of the important indicators of climate change in cold environment. Two exercises were carried out using remote sensing data products.

(1) Landsat-8 OLI and Sentinal-2 satellite data were used for the precise snow cover mapping of Leh district for October 2015, 2016 and 2017. The key objective of the study was to find out an effective extraction of snow cover distribution area method using Normalized Difference Snow Index (NDSI) and Normalized Difference Snow Thermal Index (NDSTI) (Fig. 24 and 25). The snow cover was extracted by using NDSI, NDSTI index and the threshold value was considered as 0.4.

The exercise could classify the image into Fresh snow, Dirty snow, Blue Ice, Forest Vegetation, Waterbody, Snow + Shadow, Shadow, and Unclassified classes.

The change detection matrix for 2015, 2016 and 2017 was produced using area by area (square kilometre) method using Maximum Likelihood classification (MLC) and Support Vector Machine (SVM) classification. The fresh snow converted in to snow+shadow area was covered by mostly waterbody, shadow and dirty snow (Fig. 26).

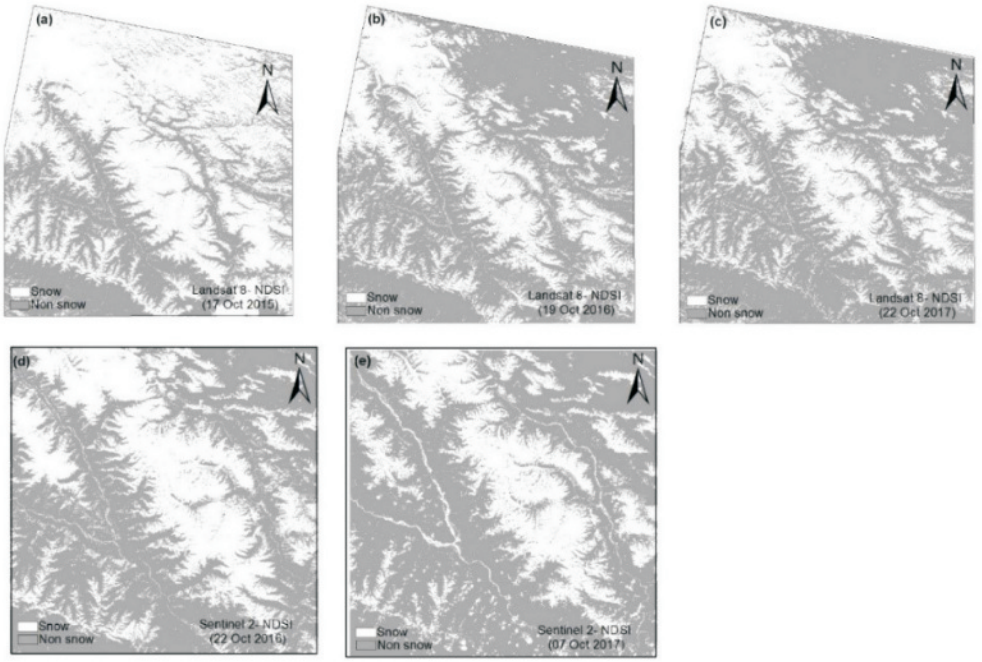


Fig. 24 Optical properties of snow and non-snow classified image using Normalized Difference Snow Index (NDSI) method

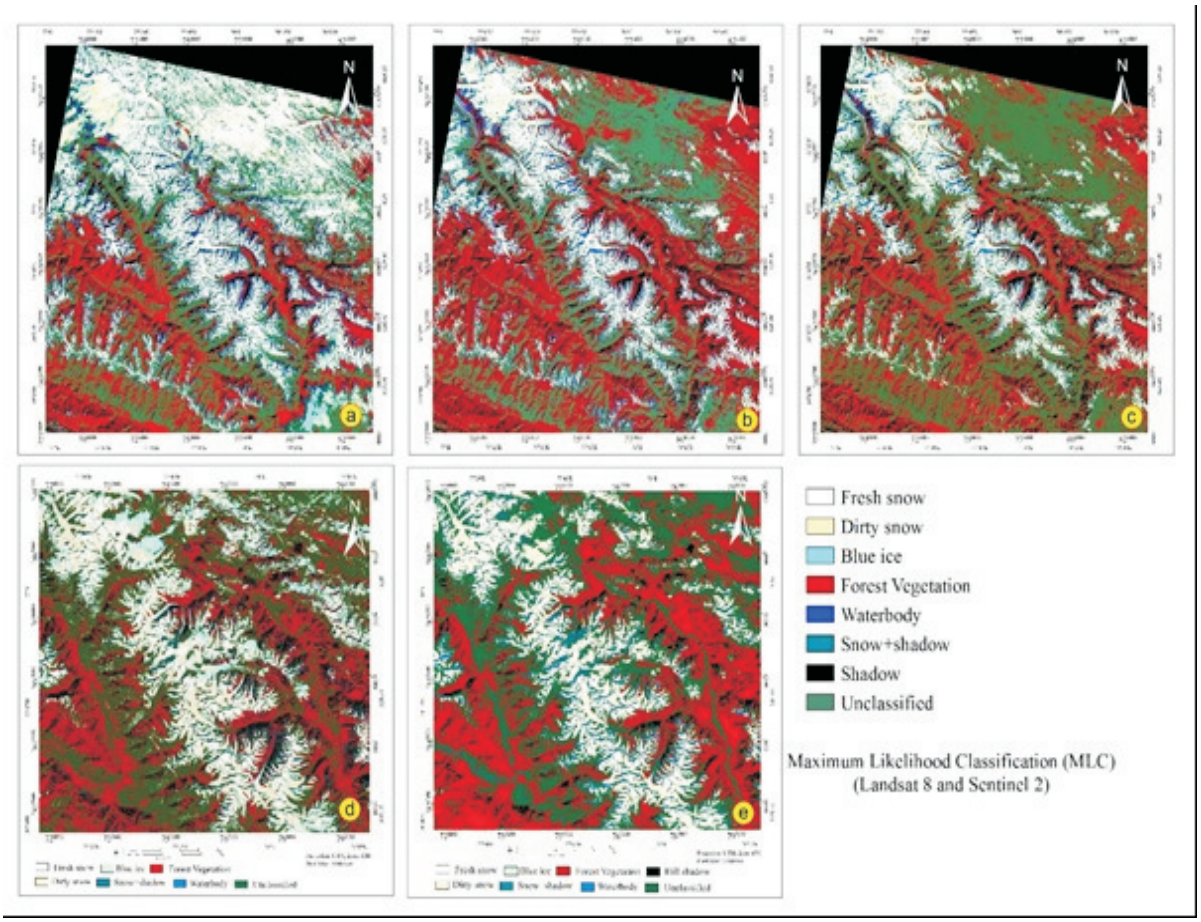


Fig. 25 Maximum Likelihood Classification (MLC) map using Landsat-8 and Sentinel-2 data

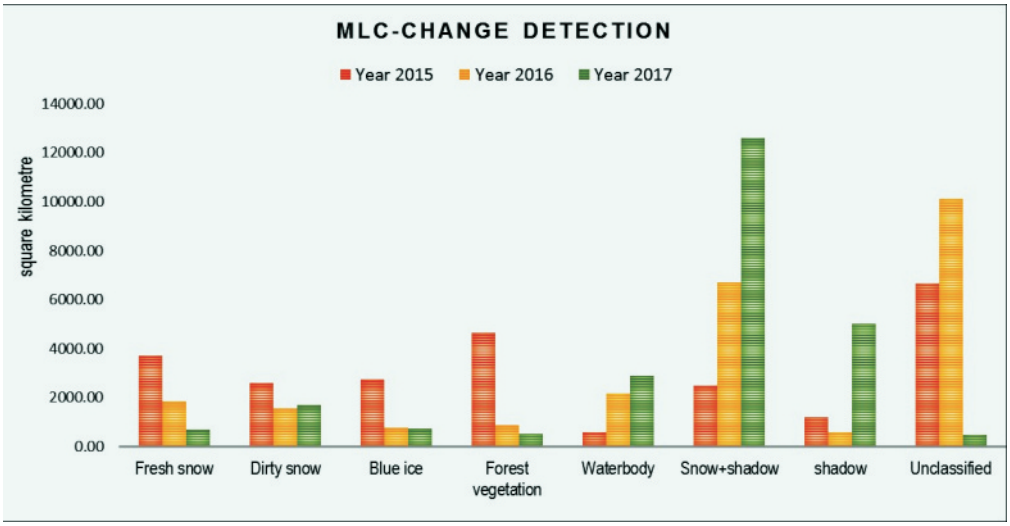


Fig. 26 Change detection map part of Leh district, India

The accuracy assessment of supervised classification using MLC and SVM accuracy with Sentinel-2 optical image was found to be 94.40%. Landsat-8 image depicted 80.88% accuracy of snow and ice. Temporal changes of snow and ice in the year of 2015 to 2017 showed gradual decline in snow cover area.

(2) Another exercise enabled extraction of database on the extent of snow cover area over Leh prepared from MODIS data downloaded from the Earth Data website from 2012-13 to 2018-19. Using remote sensing, raster data was reclassified and extent of snow cover area was calculated (Fig. 27). During 2018-19 period, there was maximum snow cover during September to November (40 to 50% area) which subsided during December and January months and again increased during February, 2019 (Fig. 28 and Table 1).

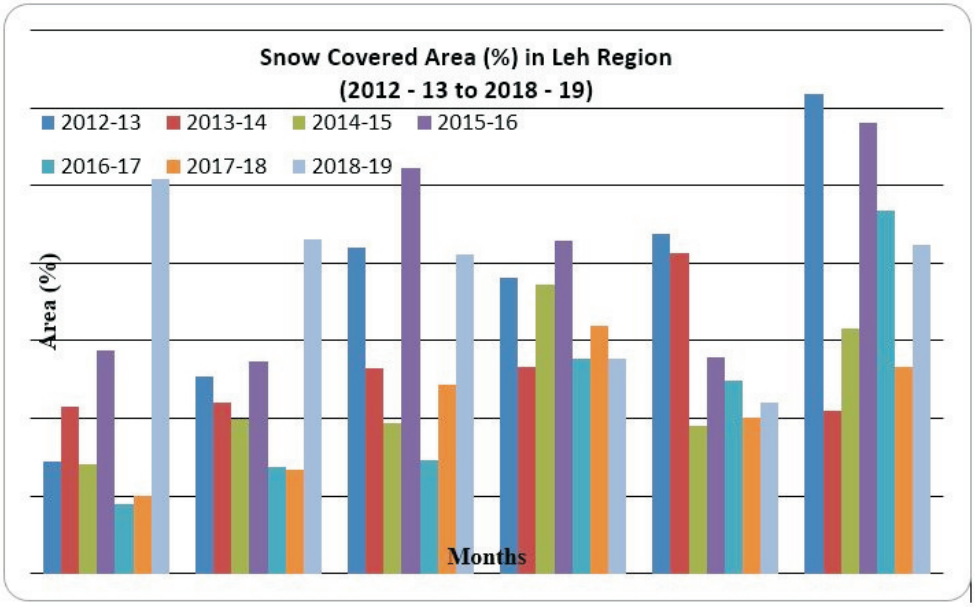


Fig. 27 Snow cover area in Leh region from 2012-13 to 2018-19

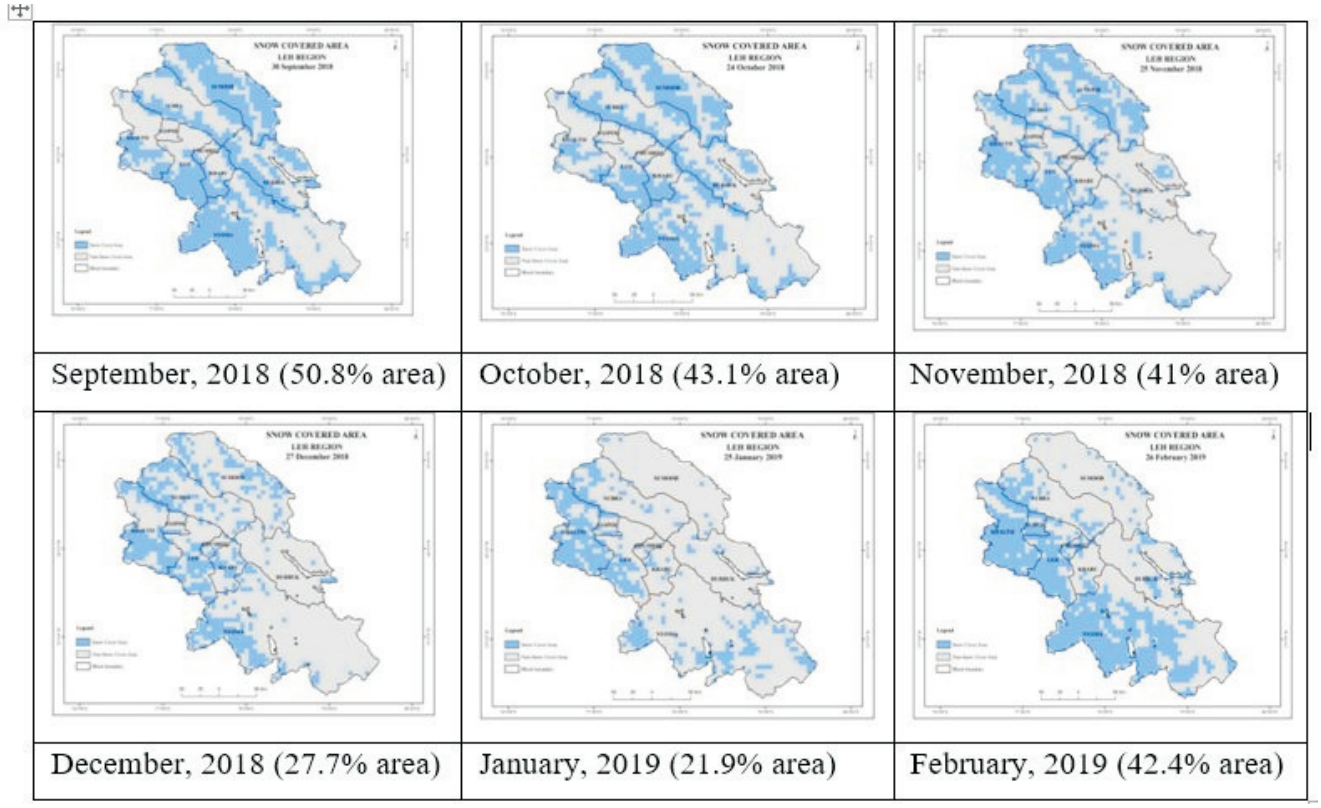
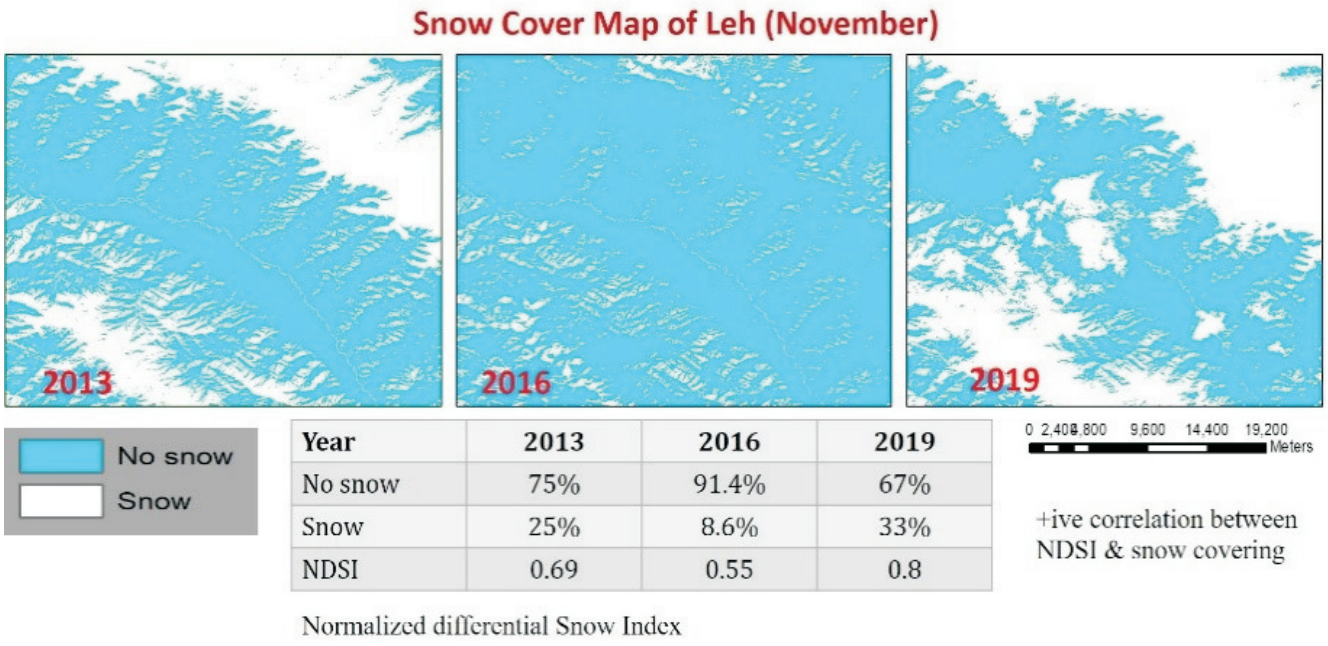


Fig. 28 Extent of snow cover over Leh region (September 2018 to February 2019)

Table 1. Extent of snow cover area in Leh from 2012-13 to 2018-19

Months	Years						
	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19
September	14.50	21.48	14.13	28.84	9.01	10.02	50.85
October	25.37	22.12	19.88	27.40	13.70	13.38	43.12
November	42.00	26.39	19.46	52.29	14.66	24.25	41.04
December	38.06	26.71	37.31	42.91	27.72	31.93	27.77
January	43.76	41.36	19.03	27.93	24.84	20.04	21.96
February	61.73	20.90	31.56	58.10	46.75	26.55	42.43

Snow cover maps of Leh was prepared for November month of three different years showed that in year 2019 NDSI values were high compared to 2016 (Fig. 29). In 2019 snow cover was 33% whereas in 2016 it was only 8.6%. More snow melting indicates the higher temperature prevailed during summer. If snow cover is more at the end of summer season, it would act as reserve for the next summer and expect more water in next crop season.



Year	2013	2016	2019
No snow	75%	91.4%	67%
Snow	25%	8.6%	33%
NDSI	0.69	0.55	0.8

Fig. 29 Snow cover map of Leh (November)

Inventory of frost heave landforms

Frost heaves are typical landforms of cold climatic region with a typical undulating morphology and their association with grazing resources. These features are best known as wintertime uplift of the ground. A survey was carried out on the occurrence, types and use of frost heaves (upward swelling of soil during freezing conditions caused by an increasing presence of ice as it grows towards the surface) at various places of Leh and Nubra valleys. A common feature is their systematic growth under marshy, swampy or at places with abundant surface or subsurface water flow. Under wetland conditions, these surfaces act as excellent grazing lands, under dry and desiccated conditions, the topsoil of the landform turns amorphous and degraded with no grass or vegetation. The survey found two dominant patterns of their formation; single or complex. The shapes were found to be rounded, elongated or massive. In a spring site and under a pastoral or grazing land use system at Saboo, the heaves were clustered and massive, were 5 m long, 0.8 m wide and 1 m high while the small and single heaves measured 0.35 m long, 0.3 m wide and 10 cm high. The narrow and elongated heaves measured 1.8 m long and 18 cm high. At Stakmo, under boulder filled surfaces, the heaves were 0.8 m long, 20 cm high but their circumference was maximum 2.2 m. Typical vegetation associated are *Kobresia, Astragulus, Glaux* spp., *Taraxacum* spp., *Cirsium arvense, Carex* spp. It was also noted that *C. arvense*– the invasive weed is capturing the frost heaves and reducing the possibility of preferred flora from heaves (Fig. 30, Table 2).

Frost heave lands: undulating morphology

Frost heave lands as grazing lands

A complex frost heave

A degraded form of frost heaves showing desiccated conditions

Fig. 30 Frost heaves in Leh region; normal and degraded types and patterns

Table 2 Vegetation distribution over frost heave lands at different locations

Region	Village/surface type	Location (Longitude (E) and Latitude (N)	Vegetation with distinct association colonies	Average biomass (kg/m^2)	Density (population /m^2)
Leh	Saboo (Spring sites), Undulating alluvial plain at the base of hills and uplands	77° 36' 58" E 34° 07' 38" N Elevation: 3488 m	*Kobresia, Astragalus, Glaux maritima, Taraxacum* spp., *Helepestussarmentosa, Potentilla* spp., *Lomatogonium carithiacum, Digitaria sanguinalis, Poa* sp., *Lentopodium* sp.	0.312	38-83
	Stakmo (Desiccated heave surface)	34° 02' 21" N 77° 43' 57" E Elevation: 3609 m	*Kobresia*sp and *Taraxacum* sp.	0.050	5-12
	Chushot (Indus river bank)	77° 37' 18" E 34° 03' 38" N Elevation: 3413 m	*Kobresia, Astragalus, Glaux maritima, Taraxacum* sp., *Helerpestussarmentosa, Potentilla* sp., *Lomatogonium carithiacum,* Poa sp., *Lentopodium* sp., *Hippophae rhamnoides* (sea buckthorn), Salix	0.423	51-63

Region	Village/surface type	Location (Longitude (E) and Latitude (N)	Vegetation with distinct association colonies	Average biomass (kg/m^2)	Density (population /m^2)
Tsokar	Gya, Rumtse (Salt Lake and its catchment)	77° 57' 19" E, 33° 19' 24"N Elevation: 4539 m	*Kobresia, Helerpestussarmentosa , Glaux maritima, Astragalus* sp., *Taraxacum* sp., *Cirsium arvense*	0.516	20-35
	Tanglang La	77°46' 11.59"E, 33° 30' 28.38"N Elevation: 5339 m	*Poa attenuata, Kobresia, Thylacospermum , Astragalus*	0.460	15-36
	Debring (8 Km north and upstream to Gya), grassland	33° 3' 024" N 77°°47' 774"E Elevation: 4679 m	*Poa attenuata, Poa alpina, Astragalus* sp, *Kobresia, Thylacospermum, Saussurea gnaphalodes, Lentopodium nanum, Knorringia pamirica, Stipa, Tenacetum* sp., *Elymus* sp., *Urtica* sp., *Arnebia, Artimisia, Geranium, Taraxacum, Lanceatibetica, Potentilla*	0.278	30-50
	Tso Kar: Wetland/a salt lake	33° 19' 31" N 77° 43' 57" E Elevation: 4607 m	*Kobresia* sp., *Helerpestus* sp., *Glaux, Astragalus, Taraxacum* sp., *Lomatogonium carithiacum, Caragana, Eurotia, Tanacetum, Alyssum* sp., *Carex, Artemisia. Chenopodium glaucum, Poa, Elymus, Stipa*	0.350	35-75
Changthang	Durbuk (River bed and flood plain) Grassland	34° 02.268' N 77° 12.826' E Elevation: 4016 m	*Kobrasia*sp (dominant), *Potentilla arneria, P. saundersiana, Glaux, Lanceatibetica, Helerpestus, Carex, Astragalus, Tenacetum* sp., *Pedicularis longiflora, Triglochin maritima, Oxytropis* sp.	0.620	42-84
	Tangtse-Site 1 (River bed and flood plain)	34° 02.065' N 78° 12.641' E Elevation: 4014 m	*Taraxacum* spp., *Lanceatibetica, Kobresia, Stephanomeria pauciflora, Agropyron repens, Cirsium arvesne, Carex* sp., *Astragalus* sp.	0.360	28-51
	Tangtse-Site 2 (River bed and flood plain)	34° 02.581' N 78° 12.618' E Elevation: 4014 m	*Kobresia, Glaux, Lanceatibetica, Helerpestus, Taraxacum* sp., *Carex* sp., *Astragalus* sp.	0.320	23-64
	Tangtse-Site 3 (River bed and flood plain)		*Kobresia, Glaux, Potentilla saundersiana, Taraxacum* sp., *Carex* sp., *Astragalus* sp.	0.360	58-68
Nubra	Hunder (Nubra) Riverbed, swampy grassland.	34° 33' 51" N 77° 31' 10" E Elevation: 3133 m	*Kobresia, Phragmites* sp., *Cirsium arvense, Berbaris* sp., *Carex* sp., *Poa* sp., *Glaux, Taraxacum, Stipa, Hippophae rhamnoide*	0.212	20-31

Spatial distribution of Salinity in the Indus valley

Detailed survey was carried out in the Indus flood plain from Ranbirpur (3270 m MSL) to Chushot Gongma village 3260 m MSL. Traverses were made on both side of Indus River encompassing Thiksey, Shey, Killibug, Choglamsar, Chuchot Yogma, Chushot Gongma, Yoma, Spituk villages of Leh block. Saline crusts were seen at various places. Soil samples were collected from riverbanks, agriculture lands, scrub lands, buried wetlands and frost heave affected grassland for laboratory analysis. Samples were collected from various altitudes and analysed. The details are given in Table 3.

Table 3. Analysis of soil samples collected from various altitudes

Village Sites	GPS locations		Altitude	pH	EC	TDS	Salt	Temp
	Longitude	Latitude	Feet		dS m^{-1}	ppm	ppm	°C
Ranbirpur	N34°00.850	E077°41.102	10796	9.23	0.22	156	104	13.2
Ranbirpur	N34°01.189	E077°40.632	10808	9.30	0.23	167	109	12.7
Ranbirpur	N34°02.504	E077°39.837	10770	9.04	0.24	175	114	12.4
Thiksey	N34°02.497	E077°39.787	10751	9.85	0.04	9.92	7.81	14.2
Thiksey	N34°02.576	E077°40.000	10740	9.92	0.09	6.37	4.82	13.4
Thiksey	N34°02.685	E077°40.220	10758	9.50	0.45	320	214	14.7
Thiksey	N34°03.411	E077°39.889	10731	8.76	1.96	1.39	972	13.8
Killibug	N34°03.541	E077°39.376	10716	9.70	0.08	6.00	4.52	14.1
Killibug	N34°03.541	E077°39.376	10716	9.70	0.26	6.00	4.52	14.1
Choglamsar	N34°06.569	E077°34.914	12742	9.12	0.01	187	123	14.2
Choglamsar	N34°06.639	E077°34.569	11728	8.76	0.49	7.55	5.77	14.1
Choglamsar boring water	N34°06.473	E077°34.831	11203	8.40	0.34	355	230	10.8
Choglamsar Indus water	N34°06.473	E077°34.831	11203	8.90	0.04	245	155	5.70
Shey (Sindhu Ghat)	N34°05.177	E077°37.056	11016	9.80	0.39	8.75	8.39	14.0
Shey	N34°04.301	E077°37.826	10876	9.48	0.05	280	186	14.3
Shey	N34°04.114	E077°38.146	10829	9.52	0.54	2.49	1.80	14.4
Shey (Stream Water)	N34°06.473	E077°34.831	11203	8.56	0.34	360	240	5.9
Chushot Shamma (Indus Shashi Bridge)	N34°03.572	E077°38.535	10782	9.00	0.34	239	150	5.8
Chushot Shamma (Marshy land)	N34°03.436	E077°38.436	10750	8.5	0.52	320	230	6.7
Chushot Gongma	N34°02.611	E077°38.792	10763	9.23	0.98	696	475	15.2
Chushot Gongma	N34°02.444	E077°38.772	10751	9.25	0.19	140	92.8	14.8
Chushod Yogma	N34°03.509	E077°37.614	10693	9.01	0.60	427	283	14.8
Chushod Yogma	N34°04.018	E077°37.012	10671	9.42	0.21	153	101	14.7
Chushot Yogma	N34°05.068	E077°35.987	10636	8.62	1.07	763	520	15.0
Spituk	N34°06.120	E077°34.391	10586	8.72	1.37	969	667	15.1
Spituk	N34°06.222	E077°34.274	10570	9.24	1.95	------	-----	15.6
Spituk	N34°06.222	E077°34.274	10570	9.24	1.96	------	-----	15.6
Spituk	N34°06.294	E077°34.296	10573	9.23	0.45	326	218	15.8

Productivity and energetic of agricultural production systems

A study was carried out on productivity and energetic of agricultural production systems in Leh with the objective to document geographical and physical features of landscape of six selected Tribal Sub-Plan (TSP) villages around Leh district. Village level information of land use, demography and livestock were collected to work out structure and production functions of farming systems and to work out energy budget of crops across the selected villages during 2012-2015. Results revealed that total absolute cultivated area in six selected villages (viz., Saboo, Stakmo, Nang, Umla, Phey and Stakna) was 375.2 ha. On an average across selected villages maximum area was covered by tuber crop i.e., potato (27.6%) followed by cereal crops i.e., wheat (24.2%) and barley (18.8%). Thus, in Leh region presently cereal crops are cultivated in 43% area, however, earlier information (around three decades back) indicated that cereal crops i.e., barley and wheat were sown in 60% area. Fodder crop alfalfa is sown in 14.5% area of the average total area across six villages. Other vegetable crops are grown in 6.2% of the total area which mainly include spinach, cauliflower, cabbage, tomato, French bean, brinjal, radish, carrot and chili.

In all the crops, manure was major input. Input of manure accounted to be 17.0×10^5 K cal ha^{-1} $year^{-1}$ for barley to 224.8×10^5 K cal ha^{-1} $year^{-1}$ for potato. Manure input was also very high in case of pea (213.3×10^5 K cal ha^{-1} $year^{-1}$) and Alfalfa (208.8×10^5 K cal ha^{-1} $year^{-1}$). Though, dung is often referred to as a byproduct, it may be a reason for maintaining better livestock population relative to land holding. Energy input values in case of fertilizer were negligible. Seeds are other important source of input, which accounted 0.1×10^5 Kcal ha^{-1} $year^{-1}$ in case of onion to 15.1×10^5 Kcal ha^{-1} $year^{-1}$ in case of pea. Total energy input was highest for potato followed by pea. The minimum energy input was observed in case of barley which was only 27.3×10^5 K cal ha^{-1} $year^{-1}$. Wheat had total energy input to the tune of 32.7×10^5 K cal ha^{-1} $year^{-1}$. It is interesting to note that farmers just sow the seeds of barley and wheat, and after that they do not carry out any weeding. They harvest the weeds along with the crops, and then separate the weeds and use that as an additional fodder in many cases. The input of human and animal energy was also low in case of wheat and barley.

Major constraint of the region

Depleting natural resources, highly rocky terrain, shallow soils, limited water resources, land degradation and receding of glaciers as indicators of climate change put serious limitations to agriculture activities at Leh region. Being a cold arid environment, climate change is a major concern in Himalayan belt. It causes a major metabolic response in crops, affecting their growing periods and consequently resulting in loss of agricultural production. The region is mostly prone to climatic vulnerability; cloud burst in year 2010 destroyed at least 90% of the irrigation channels in 34 villages and several villages lost their entire irrigation system. The livestock husbandry is in a general state of decline in whole Ladakh region. Socioeconomic constraints primarily include small land holdings, poor productivity, poor production management, labour shortages, poor post-harvest management, poor market networks (lack of market development) and lack of entrepreneurship. To address these issues, RRS Leh initiated surveys to collect baseline data to formulate research programs.

Biodiversity Conservation of Annuals and Perennials

Collection, isolation and screening of microorganisms for phosphate solubilization

Studies were carried out to isolate and screen microorganisms for phosphate solubilization and further effect on crop growth and yields during 2015-16. Thirteen soil samples collected from different locations/crops were processed for enumeration, isolation and purification of bacteria (Table 4). The bacterial population in these samples ranged from 22×10^5 to 114×10^5. Following results were obtained:

- Number of bacterial isolates showing phosphate solubilization = 2
- Bacterial isolates showing phosphate solubilization at 15°C = 2
- Bacterial isolates showing phosphate solubilization at 5°C = 1
- Bacterial isolates showing production of ammonia = 2

Table 4 Number of colonies forming units (cfu) in various samples under different dilutions

Crops	Number of cfu in different dilutions		
	10^{-3}	10^{-4}	10^{-5}
Alfalfa	123	34	22
Sea buckthorn	>300	63	17
Wheat	136	58	31
Alfalfa (from block plantation of poplar)	112	32	5
Pea	152	65	23
Cucumber	86	30	20
Tomato	93	34	14
Cauliflower	132	75	28
Brinjal	134	104	9
Watermelon	146	114	18
Capsicum	167	55	30
French bean	122	31	17
Muskmelon	97	22	3

Collection of Germplasm and Indigenous Knowledge Appraisal

Germplasm collection has been carried out at various parts of Ladakh region i.e. at Dah [(Barley (Nus): Nagnus, Tukzoor, Yangma; Minor Millets (Cha): Marpo (red), Karpo (white), Karamat, Uun, Donacha; Buckwheat (Bro): Naqbro, Ragyambras; Wheat (Tho): Khongthuma]; Kukshaw (Oats (Nash); Lentil (Masoor): LT-Kerje; Wheat (To); Barley (Tswah); Black Pea

(Tsan Chung)]; Minji [Buckwheat (Bro): LT-Rygambrass; Minor Millets (Cha): LT-Marpocha; Foxtail Millet (Chachay); Local Pea (Gangbu); Barley (Sungmo); Black Pea (Naqstan)]; Poyen [Buckwheat (Bro): LT-Rygambrass; Minor Millets (Cha): LT-Marpocha; Foxtail Millet (Chachay); Local Pea (Gangbu); Barley (Sungmo); Black Pea (Naqstan)] and Poyen Shara [Buckwheat (Bro): LT-Rygambrass; Minor Millets (Cha): LT-Marpocha; Foxtail Millet (Chachay); Local Pea (Gangbu); Barley (Sungmo); Black Pea (Naqstan)] etc. and total 68 germplasm were collected (Table 5). The indigenous knowledge associated with germplasm was documented. The traditional way of apricot oil extraction was amongst one including the traditional way of seed conservation.

Agricultural biodiversity conservation and utilization

Baseline survey was conducted at four villages in Leh (Sakti, Umla, Nang and Stakmo) and three villages in Kargil (Sanko/Skilmartsay, Shargole and Mulbeak). The information was collected with respect to number of household, members of the household, farm land, irrigated crops, supports received (aid received from the government, non-religious or other organizations in the preceding year of the baseline survey such as food, training, fertilizers, seeds, animals, cash, etc.), farm inputs, livestock population and livestock product, important animal products, off farm income, climate vulnerability indicator and climate change experiences encountered and an overall change in the weather over the last twenty to thirty years. The collected database were anlysed for setting bench mark level for changes.

Table 5 Germplasm collection from Ladakh region

Sites	Location	Crops	Numbers
Dah	34.37.33°N 76.28.45°E	Barley (Nus): Nagnus, Tukzoor, Yangma; Minor Millets (Cha): Marpo (red), Karpo (white), Karamat, Uun, Donacha; Buckwheat (Bro): Naqbro, Ragyambras; Wheat (Tho): Khongthuma.	04
Kukshaw		Oats (Nash); Lentil (Masoor):LT-Kerje; Wheat (To); Barley (Tswah); Black Pea (Tsan Chung)	10
Minji	34° 28.38N 76° 04.23E Alt: 11482 ft	Buckwheat (Bro): LT-Rygambrass; Minor Millets (Cha): LT-Marpocha; Foxtail Millet (Chachay); Local Pea (Gangbu); Barley (Sungmo); Black Pea (Naqstan)	09
Minji Area	34° 33.38N 76° 08.14E Alt: 11482 ft	Buckwheat (Bro): LT-Rygambrass; Minor Millets (Cha): LT-Marpocha; Foxtail Millet (Chachay); Local Pea (Gangbu); Barley (Sungmo); Black Pea (Naqstan)	18
Minji Area	34° 28.10N 76° 04.25E Alt: 11482 ft	Buckwheat (Bro): LT-Rygambrass; Minor Millets (Cha): LT-Marpocha; Foxtail Millet (Chachay); Local Pea (Gangbu); Barley (Sungmo); Black Pea (Naqstan)	09
Poyen Shara	34° 33.41N 76° 08.21E Alt: 11482 ft	Buckwheat (Bro): LT-Rygambrass; Minor Millets (Cha): LT-Marpocha; Foxtail Millet (Chachay); Local Pea (Gangbu); Barley (Sungmo); Black Pea (Naqstan)	09
Poyen	34° 33.42N 76° 08.23E Alt: 11482 ft	Buckwheat (Bro): LT-Rygambrass; Minor Millets (Cha): LT-Marpocha; Foxtail Millet (Chachay); Local Pea (Gangbu); Barley (Sungmo); Black Pea (Naqstan)	09

Germplasm collections were made at Stakmo village of Leh district. Community Seed Bank (targeting barley, pea, black pea and mustard local variety of Leh, Ladakh) was also established at village Stakmo. Collections of buckwheat, local pea, local lentil, barley and minor millet were also made from two villages i.e., Poyen and Minji of Kargil region.

Fodder quality analysis: Two perennial fodder species Fescue and Sainfoin were analyzed for their fodder quality. Crude protein content of Fescue and Sainfoin was 3.74 and 15.87%, respectively. Sainfoin fodder had good palatability in Jersey cattle, local Ladakhi cattle, Zanskar pony and goat.

Degradation of native plant biodiversity

Studies on degradation of pastoral lands were carried out to understand the formation and impact of frost heaves weed invasion on native grasslands. Surveys on the occurrence, types and use of frost heaves and weed invasion on pastoral ecosystems at Leh, Nubra and Changthang region were conducted. The term 'heave' describes a displacement. It is because of freezing of water during winter months resulting in change in volume of frozen water. The common feature is their systematic growth under marshy, swampy or at places with abundant surface or subsurface water flow. Frost heave processes were examined in detail to explore and explain the further degradation of pastoral system in Ladakh region and the status of native vegetation where these stresses have effectively affected the pasture ecology in these regions. Continuous grazing pressure posed by nomadic livestock and other wild animals have impacted the plant mantle significantly by 30%. Accidentally invasive species like *C. arvense* has taken over the charge and affected the temperature differences between bare soils and covered ones. It has been observed in Tangtse, Durbuk block that *C. arvense* has replaced the native vegetation on frost heaves and on the other hand allowed *Carex* spp. which is considered to deplete and change the pasture ecology. Typical vegetation communities and their association were recorded at all the sites of observation. At Saboo, cluster of *Kobresia, Astragulus, Glaux*, *Taraxacum*, *Cirsium species* while at higher altitude at Hunder, species of *Kobresia, Phragmites*, *Cirsium* and *Carex* were recorded. In Tangtse of Changthang region, vegetation was mostly dominated by tiny rosette, sedges, and other cohesive group of vegetation such as species of *Kobresia*, *Leontopodium, Astragalus, Potentilla, Triglochin*, *Puccinellia*, *Lancea* and *Glaux*. In Tsokar area, species of *Kobresia, Glaux and Astragulus* were observed on frost heaves, being affected by species of *C. arvense* and *Carex* sp. While plant species viz., *Caragana, Artemisia, Eurotia* and above constitution also unified with each other on a community basis. The biomass on heaves ranged from 0.120 to 0.620 kg heave^{-1} in Saboo, Tangste, Tsokar areas (amounting on an average of 0.388 kg heave^{-1}). These heaves amount an area of 0.14 m ha (as recorded by ISRO for Desertification/ Land Degradation Status of India), ranging their sizes from small to compound structure with almost similar floristic constitution. Topography and elevation also showed impact on the morphological parameters of frost heaves and their habitat.

Kobresia pygmaea is one of the smallest alpine sedges, growing maximum upto 20 cm, but dominates the largest alpine pastoral ecosystems of Ladakh (over 3000 m altitude). Degradation of pasture occurs due to polygonal cracking of *Kobresia* lawn by frequent contraction and

expansion of the soil caused by frost heaving action, resulting into slow cracking of *Kobresia* pastured heaves because of the low sensitivity to low soil temperatures. Regular grazing pressure/stress imposed by livestock in alpine ecosystems, also weaken *Kobresia* prairie. This gradual degradation initiates a die-off of the above- and below ground plant compartments and the decay of the root litter expands the surface cracks. Frost heaving accompanied with invasion of *C. arvense,* soil salinity and grazing pressure by livestock are the three major reasons identified for pasture degradation followed by erosion processes in Changthang pastoral system.

Integrated Arid Land Farming System Research

Traditional agroforestry systems and their effect on soil quality

Survey was carried for prevailing agroforestry systems in Ladakh region during 2016-17 and 2017-18. In the region, poplar (*Populus*) and willow (*Salix*) were the main timber trees grown under silviculture-agroforestry system. There were about 20 species of local willows and 10 of poplar growing at different altitudes of Ladakh. Out of them, some worth mentioning were: *Populus nigra, P. alba, P. ciliata, P. balsamifera, Salix alba, S. angustifolia, S. excelsa, S. sclerophyla, S. tetrasperma.* In agri-silviculture agroforestry system, alfalfa is grown in the dense plantation of poplar locally called *yulat*. This system of agroforestry is very popular in Ladakh. In silviculture-pastoral system, plantations are managed for producing fuel wood as well as rearing of animals. This agroforestry system is practised in high altitude pastures like Changthang of Ladakh. The species of *Caragana, Hippophae* and *Salix*can be grown in pastures. Agri-silvi-pastoral agroforesty system is designed for the concurrent production of agricultural crops, forest trees and rearing of domestic animals. Sometimes along with poplar and willow trees, *Robinia* species is also grown. Thus, this system of agroforestry provides food, fodder, fuel wood and timber. Horti–pastoral system consists of growing of fruit orchard and raising of animals. As for instance, in the fields of alfalfa, fruit trees like apricot or apple are grown. In lower agricultural zone of Ladakh, the plantation of poplar and grape is practiced and between the spaces of poplar and grape, alfalfa is grown.

Livelihood options from agroforestry systems:

Indian Himalayan cold desert region is situated on the rain-shadow region of mountain and is not influenced by monsoon. Out of total geographical area of 45,100 sq. km, forest occupies an area of 5.57 sq. km only which is very less than the required space for forest. Farmers have developed their own unique traditional agroforestry systems in the region in the form of agri-silvi system which is a combination of agricultural crops with boundary/block plantations of willow and Poplar mainly meant for livelihood options such as *Salix* cuttings (locally known as *Talu*) for roofing and sale, fuel wood and fodder needs which are under high demand especially for warming the houses during harsh winter months when this unsustainable practice poses a huge pressure on wild stocks and livelihood security of people in the region. All the woody species are utilised for fuel purposes. Wild seabuckthorn is another multipurpose thorny shrub which is also in high demand due to its value for fuel, fodder, fertility (fixing nitrogen), fencing, and other medicinal/cosmetic purposes etc. The caloric value of dry sea buckthorn is 4,785.5 calories per day, the shrub is fast growing and can be stumped after every 3-5 years. Six-years-old sea buckthorn plantation can produce 18 t ha^{-1} firewood which is equal to nearly 12.6 t of standard coal. Twigs and stems from *Salix*, poplar and sea-buckthorn are used as firewood. The utilization of firewood and cow dung cakes varies as per the accessibility of these resources. Main source of energy at the household level in Ladakh region is biomass, majority of which is provided from fuelwood obtained from pruning of trees at house level and forests. Shortage of fuel wood and the high price

of imported conventional fuels result in a situation of high energy vulnerability and ecosystem-based approach for energy security.

Nutritional status of sea buckthorn berry of Leh valley

Sea buckthorn (*Hippophae rhamnoides*) is a very important shrub of this region. Besides protecting soil from erosion, it improves soil fertility status and can be used as vegetative barrier for protecting the pasture lands. Use of sea buckthorn as nutritional supplement can help to maintain a normal balance of most of the ions at high altitude like cold desert. The study on biochemical composition of sea buckthorn growing in different land use systems (river-side, wetland, slopy and barren) of Leh valley of Trans-Himalaya were carried out. The study revealed the presence of high amounts of vitamins, protein, total sugar (%), calcium, magnesium and zinc in the plants from river-side followed by plants from wetland and barren lands. Plants from barren lands had higher amount of vitamin A, E and C, sodium, manganese, phosphorous and potassium (Table 6).

Table 6 Nutritional value of sea-buckthorn pulp from different sites

Contents	Sampling sites			
	River-side	Slopy	Wetland	Barren
Total protein (g kg^{-1})	3.7	2.8	3.2	3.4
Fibre (g kg^{-1})	12.8	11.4	12.5	13.5
Carbohydrate (g kg^{-1})	27.4	28.5	26.5	27.5
Total sugar (%)	55.1	50.6	52.78	54.13
Total organic acids (g kg^{-1})	10.2	16.5	10.3	7.0
Xylitol (mg g^{-1})	41.5	36.2	46.0	45.0
Mannitol (mg g^{-1})	15.0	15.0	18.0	19.0
Sorbitol (mg g^{-1})	310	310	317	317
Calcium (mg kg^{-1})	168.5	160.5	166.7	167.4
Magnesium (mg kg^{-1})	100.6	98.5	101.5	102.2
Manganese (mg kg^{-1})	3.3	3.2	3.9	3.6
Phosphorous (mg kg^{-1})	68.2	60.5	66.5	90.0
Potassium (mg kg^{-1})	187.5	185.5	201.2	192.4
Zinc (mg kg^{-1})	4.17	3.10	3.67	3.83
Iron (mg kg^{-1})	8.8	7.8	9.5	9.6
Sodium (mg kg^{-1})	40.5	30.8	45.5	42.2
Copper (mg kg^{-1})	0.10	0.08	0.11	, 0.10
Selenium (mg kg^{-1})	7.0	5.9	7.8	8.2
Vitamin-A (mg 100 g^{-1})	98.9	90.5	101	104
Vitamin-E (mg 100 g^{-1})	215	202	210	216
Vitamin-C (mg 100 g^{-1})	615	602	620	622

Pastoral systems and chemical composition of fodder resources of Ladakh region

Survey was carried out jointly by ICAR-CAZRI RRS, Leh and ICAR-NRC-Camel, Bikaner during 2015-18 for understanding the possible and potential fodder resources and their composition. The flora of this region belongs to alpine and high alpine zones, followed by few stunted shrubs and bushes. Rearing of livestock, particularly cattle, goat, sheep and yak, which play a key role in the development of the socio-economic condition of the inhabitants as they get milk, meat, wool etc. in cold arid region. In view of livestock rearing, fodder trees and shrubs have also become important as a good source of protein and energy to keep the animal healthy and to obtain better milk, meat and wool production which are the critical food and income sources in this region. During the field survey and from published literature, 29 potential fodder species including grasses, legumes, trees and shrubs were identified and samples were collected for their chemical composition. It further revealed that a large number of species belonged to the family of Poaceae, Cyperaceae, followed by Leguminosae and Salicaceae.

Amongst the pastoral fodder resources, alfalfa (*Medicago* spp.) is a highly demanded unique and potential resource and is stall-fed in addition to cereal straw, willow leaves. Three *Medicago* species i.e. *M. falcata, M. media,* and *M. sativa* are mostly grown. Alfalfa, being a highly cross-pollinated crop, show wide variation in colours. But mostly found is violet and yellow flowered with a good production potential. Farmers generally harvest the fodder rather collecting seeds while few farmers from Nubra region who make good business by selling its seeds at the rate from Rs. 800 to 1600 per kg. Changthang region (includes Durbuk, Tangste, Dibring, Tsokar, Khardong and Digger valley) is the major belt where there are large population of livestock (cow, sheep, goat, horse, yak, etc.). The species of *Astragulus*, *Carex*, *Stipa*, *Kobresia*, *Agropyron, Poa*, *Phragmites*, *Potentilla*, *Galux*, *Taraxacum*, *Plantago*, *Lancea* etc. are predominant. All these fodders have 92-98 and 82-96% dry matter and organic matter content, respectively (Table 7).

Weed endemics and weed seed bank in cropped and non-cropped areas

Bio-geographical survey was carried out at different Tribal Sub-Plan (TSP) identified villages of Leh valley such as Saboo, Stakmo, Nang, Umla, Phey and Stakna for identifying weedy species in different crop production systems and to assess the volume of weed seed accumulation in different crop rotations under existing situation of farmer's field. Study indicated the dominance of conventional method of farming system where weeding is not carried out in field crops and crop faced severe weed pressure resulting in build-up of weed seed bank. On the other hand, higher seeding (2.84 times of recommended seed rate) with initial starter dose of manure due to default organic farming for many decades also encouraged weed prevalence. The survey revealed that major weeds of the crop fields belonged to the families Amaranthaceae, Asteraceae, Poaceae and Fabaceae. The species viz., *Amaranthus* spp., *Avena sativa*, *Bidens biternata, Chenopodium album, C. botrys, C. carinatum, Convolvulus arvensis, Datura stramonium, Digitaria ischaemum, Hordeum vulgare, Medicago lupulina, M. sativa, Melilotus officinalis, Polypogon monspeliensis, Setariaviridis, Stellaria media, Trifolium repens, Polygonum convolvulus*, *Malva neglecta*,

Table 7 Chemical composition of fodder species of pastoral systems

Plant species	Plant Forms	Plant part	DM (%)	Ash	OM (%)	AIA (%)
Agropyron repens	Perennial grass	Whole plant	95.1	10.0	90.0	3.1
Elaeganus species	Herb	Whole plant	96.0	13.7	86.3	2.2
Festuca species	Grass	Whole plant	96.9	6.8	93.2	3.9
Cirsium arvense	Shrub	Leaf	98.1	19.6	80.4	3.2
Glaux maritima	Herb	Whole plant	96.0	17.4	82.6	4.6
Hippopha erhamnoides	Shrub	Twig	98.0	5.1	94.9	0.6
Irislactea	Perennial Herb	Leaf	95.9	10.4	89.6	0.3
Kobresia species	Perennial sedge	Whole plant	97.0	15.3	84.7	3.5
Lancia tibetica	Herb	Whole plant	93.9	20.3	79.7	2.9
Medicago falcata	Herb	Whole plant	95.8	11.5	88.5	0.8
Medicago sativa	Herb	Whole plant	97.3	7.4	92.6	1.0
Phragmites australis	Grass	Leaf	98.1	12.9	87.1	4.1
	Grass	Stem	97.5	4.1	95.9	1.5
	Grass	Panicle	95.1	10.5	89.5	3.3
Phragmites species *(Dambu)*	Grass	Whole plant	96.6	10.8	89.2	3.2
Plantago depressa	Annual Herb	Whole plant	92.8	37.8	62.2	3.7
Poa pratensis	Perennial grass	Whole plant	87.6	12.8	87.2	2.3
Populus species	Tree	Leaf	95.3	12.8	87.2	2.0
Potentilla species	Herb	Whole plant	93.2	19.6	80.4	3.4
Robinia pseudoacacia	Tree	Leaf & pods	95.3	12.6	87.4	1.1
Rosa webbiana	Shrub	Bulb	96.7	4.0	96.0	0.6
		Leaf/Twig	95.5	9.4	90.6	1.9
Lolium perenne	Grass	Whole plant	98.4	11.4	88.6	4.7
Salix alba	Tree	Bark/Dry/Green	97.5	6.2	93.8	0.1
Salix species	Tree	Leaf	95.7	13.9	86.1	1.7
Setariaviridis	Grass	Whole plant	95.4	7.8	92.2	3.0
Stephanomeria pauciflora	Herb	Whole plant	96.0	51.3	48.7	2.3
Taraxacum species	Herb	Whole plant	96.3	20.3	79.7	3.1

DM-Dry matter, OM-Organic matter, AIA-Acid insoluble ash

Agropyron repens, Phragmites australis, *Plantago minor, Elymus* sp. and *Lolium*sp are the dominant and common weeds in the crop fields. While in non-cropped situation, *Cirsium arvense* and *P. australis* are the two most problematic weeds. In pastoral systems at Changthang and Nubra, *C. arvense,* and *Carex* species are the most problematic and unpalatable weedy species, which seriously affect the native species such as *Kobresia* spp., *Leontopodium pusillum,*

Astragalus strictus, Glaux maritima, Potentilla spp., *Aster flaccidus, Pedicularis* spp., *Lancea tibetica*, *and Persicaria glacialis*.

In villages like Saboo, Umla, Stakmo, and Nang at an altitude of 3200 m from mean sea level, weeds like *Chenopodium album, C. carinatum, Agropyron repens, Convolvulus arvensis, Polygonum convolvulus, Amaranthus* spp., *Melilotus officinalis, Setariaviridis, Stellaria media, Avena sativa, Bidens biternata, Digitaria ischaemum, Hordeum vulgare, Medicago* spp. and *Lolium* spp. dominated in wheat, barley, pea and potato crops. While in Phey, Spituk and Thiksey at an altitude of 2900 msl on river side, weeds like *Phragmites australis*, *Chenopodium album*, *Malva neglecta*, *Convolvulus arvensis*, *Setariaviridis*, *Cirsium arvense*, and *Festuca* spp. were recorded. In case of non-cultivated land, vegetation along the river belt around seabuckthorn was dominated by *Phragmites australis* followed by *Cirsium arvense, Festuca* spp., along with *Ambrosia artemisiifolia* and *Clematis* spp.

Weed seed bank study revealed that species such as *Chenopodium album, C. carinatum, Agropyron repens*, *Convolvulus arvensis, Avena sativa* and *Fagopyrum esculentum* were common to crop rotation like potato-potato, pea-potato, and barley-barley. Moreover, *A. repens* which is an aggressive perennial grass, was not identified in seed bank as it spreads by a shallow mass of long, slender, branching rhizomes.

Integrated weed management: Studies on organic and chemical weed management in major crops carried out during 2015-2017 revealed that weed management measures in crops had significant influence on weedy population. In Leh district, earlier farmers did not carry out weed management practices beside hand weeding by few farmers in Kargil district. It was also noted that three times more seed rate had less impact on seed yield (0.8 t ha^{-1}) under subsistence farming. Now the farmers are aware of weeds and their impact on crop yield with small scale interventions and trainings imparted by ICAR-CAZRI, RRS, Leh. Some interventions such as organic and chemical weed management practices, changes in varieties of crops, and field demonstrations created the awareness in farming community with respect to yield enhancement in crops.

Organic weed management in potato: The experiments were carried out in potato crop during 2016-17 and 2017-18 at Stakna and Stakmo, respectively to find out the suitable organic weed management practices for resource poor farmers. It has been noted that presence of weeds caused 50-72% yield loss in potato. *Chenopodium album, C. carinatum*, *Agropyron repens, Cardaria* spp., *Agropyron repens*, *Melilotus sativa,* etc. were the major weed species. Maximum tuber yield was recorded under black polythene mulch (21.65 and 23 t ha^{-1} respectively at Stakna and Stakmo) followed by hand hoeing 30 DAS (19.13 and 11.78 t ha^{-1} respectively at Stakna and Stakmo) and earthing up at 30 DAS (18.89 and 23.204 t ha^{-1} respectively at Stakna and Stakmo) as compared to control (5.70 and 6.40 t ha^{-1} respectively at Stakna and Stakmo).

Organic weed management in onion: An experiment was carried out during 2015-16 and 2017-18 in Gopuk and Stakmo villages to find out suitable non-chemical approach for resource poor farmers. *Chenopodium album, C. carinatum*, *Malva neglecta, Artemisia* spp. in Gopuk and *C. album, C. carinatum*, *Agropyron repens*, *C. arvensis* etc. in Stakmo village were the major

weed species. Presence of weeds in onion crop caused yield loss to the tune of 50 to 84%. Use of hand hoeing (once or twice), black polythene mulch and saw dust have performed significantly in controlling weeds. In Gopuk, hand hoeing once (16.5 t ha^{-1}) or twice (17.82 t ha^{-1}) were at par to each other in terms of yield and preventing weeds to cause loss of black polythene mulch (12.64 t ha^{-1}) as compared to control (6.10 t ha^{-1}). While in case of Stakmo village, maximum tuber yield was recorded under black polythene mulch (9.77 t ha^{-1}) as compared to saw dust (6.50 t ha^{-1}); one hoeing at 30 DAS (6.42 t ha^{-1}); two hoeing at 30 and 45 DAS (6.04 t ha^{-1}), white polythene (6.09 t ha^{-1}) and control (1.87 t ha^{-1}).

Improved agronomic intervention for enhancing crop production in Leh region

Field trial was conducted to evaluate the performance of wheat, barley, buckwheat and mustard crops and their varieties in cold arid conditions. Maximum wheat yield (1093 kg ha^{-1}), barley (1413 kg ha^{-1}), buckwheat (425 kg ha^{-1}) and mustard yield (1050 kg ha^{-1}) was recorded in Turtuk Local, BHS 352, Himpriya and RH 749 varieties, respectively (Table 8).

Table 8 Grain and straw yield (kg ha^{-1}) in different crop varieties

Crop/variety	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Crop/variety	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
Wheat			**Barley**		
HS-562	325	1125	BHS-400	963	1213
Kailash	913	2347	BHS-352	1413	1500
Turtuk Local	1093	2267	Khardong Local	1313	1900
HS-542	451	1125	PL-751	675	1700
Buckwheat			**Mustard**		
Local Kargil	213	1047	Shang white	238	713
BRO Turtuk	163	1250	Local Likir	338	625
Himpriya	425	1000	Toria TL-17	400	725
Giyas Turtuk	188	1025	RH-749	1050	1188

Socio-economic Investigation and Evaluation

Farming Systems and Indigenous Traditional Knowledge

The Indigenous Traditional Knowledge (ITK) among farming community in the Union Territory of Ladakh was documented and validated based on the primary data collected from 400 farm households across 25 villages in Leh district from 2015 to 2020. The primary data were aided and validated by Focused Group Discussions with key informants, experts and secondary data. Union territory of Leh-Ladakh consists of 8 tehsils with 113 villages.

Only 22% of the geographical area was under cultivation. Net area sown was 9963 ha (2017-18), with a cropping intensity of 106%. Up to 81% of the land holdings were either marginal (<1 ha) or small (1-2 ha). The average size of land holdings in Leh district was 0.46 ha (2015-16). The land holdings were fragmented (average of 3 per household) and were located at different altitudes with the implication that sowing of crops at different altitudes was undertaken at different time intervals.

The subsistence farming was practised on terraces over high mountains with limited scope for intensive agriculture and large-scale mechanization. The annual precipitation (snowfall and rainfall) is too low that agriculture is practiced only on those lands having access to irrigation. The major source of irrigation was streams fed by glacier melt and rivers (Indus, Shayok and other tributaries).

Barley, wheat and alfalfa were the major crops cultivated in the region and occupied 42, 26 and 20% area under cultivation respectively. Millets, vegetables, pulses and fruit crops (apple and apricot) were the other crops cultivated in the region. Between 1996-97 and 2016-17, area under wheat has decreased drastically and this area was replaced by barley. Composition of livestock population (2016-17) indicated that Pashmina goat and sheep constituted 52 and 26% respectively, whereas Dzo/Dzomoes and yak/demos constituted 9 and 5% respectively. Cattle constituted 3% of the livestock population.

Traditional knowledge on 63 themes were documented from the region including database of traditional cultivars in different crops and plants of medicinal significance, agro-forestry systems, livestock management, storage of grains and vegetables, agricultural engineering/ renewable energy (Rantak: traditional watermill), weather forecasting using biological, environmental indicators and *Lotho* (Tibetan almanac), institutional mechanisms for management of natural resources (Zing: water reservoir), traditional occupations (weaving) and traditional foods and beverages. The detailed inventory of ITKs pertaining to agriculture, animal husbandry, soil and water conservation, agro-forestry and culture and tradition of Leh-Ladakh region were made. These ITKs, after scientific validation, could be integrated with scientific knowledge generated from research and development organizations for efficient management of fragile natural resources for sustainable development of the region.

Outreach

CAZRI-RRS Leh is facilitating the farmers in adoption of improved technologies including high yielding crop varieties in cold arid region of Ladakh through awareness programs, on-farm demonstrations and capacity building programs.

Awareness and interaction program organized

Farmers' Awareness Program on "Protection of Plant Varieties and Farmers' Rights Act" on September 06, 2018 at Igoo, Leh

ICAR-Indian Institute of Wheat and Barley Research (IIWBR), Karnal and ICAR-CAZRI, RRS, Leh jointly organized one day farmers' Awareness Program at Igoo village, Leh on Protection of Plant Varieties and Farmers' Rights Act on September 06, 2018. A total of 70 farmers from Igoo and surrounding villages attended the program. This program was funded by Protection of Plant Varieties and Farmers' Rights Authority (PPVFRA), New Delhi.

One day farmers' Awareness Program at Igoo village, Leh

Mrs. Zenab Praveen from Leh Ladakh recognized as CAZRI Kisan Mitra

ICAR-CAZRI, Jodhpur has selected Mrs. Zenab Praveen as CAZRI Kisan Mitra for adopting and disseminating CAZRI technology in cold arid region of Ladakh. She was facilitated on September 13, 2018 as CAZRI Kisan Mitra during State Level Kisan Mela at Jodhpur. The Honourable Union Minister of State for Agriculture and Farmers' Welfare, GOI, Shri G.S. Shekhawat ji presented her the memento and shawl for her achievements, and hoped that her efforts would help the other farmers to replicate her model of enhanced productivity through organic farming in cold arid region of Ladakh. Mrs Praveen resident of Saboo village (approx. 10 Km from Leh city) is a hardworking progressive farm lady. She has been following CAZRI technologies from last four years and sowing only the suggested high yielding varieties of different vegetable crops. CAZRI-RRS Leh is supporting the farmers in adopting improved technologies including high yielding crop varieties in cold arid region of Ladakh through awareness programs and on farm demonstrations.

Training of farmers from village Sumur, Nubra

Twenty-six farmers from Sumur, Nubra visited CAZRI-RRS Stakna Farm on September 17, 2018. The exposure visit of the farmers was facilitated by the KVK, SKUAST (K), Leh and sponsored by NABARD to demonstrate improved technologies. Farmers were apprised about the small implements being used for line sowing and weeding, CAZRI Kassi, feed block to store and enrich forage for winter months, etc. Farmers were demonstrated about the performance of improved varieties of different crops *i.e.*, maize, sunflower, Chenopodium, grasses, potato, wheat/barley, gladiolus, etc. Farmers were happy to observe the performance of new crops/varieties being grown for the first time at the farm. Lawn grass raised at the farm was source of attraction for the farmers.

Exposure visit of the farmers sponsored by NABARD at RRS-Leh

Farmers' Training Program on "Propagation of Juniper and Management" at Sumur, Nubra Village

A farmers' training program was organised at Sumur on juniper seed management and nursery raising in collaboration with Himalayan Forest Research Institute (HFRI), Shimla on August 22, 2018. Juniper (shukpa) is a sacred tree in the region and at present there are very few trees remaining. Issues regarding seed dormancy, quality seeds and management techniques were discussed.

Training Program on Propagation of Juniper and Management at Sumur-Nubra

Farmers' exposure visits cum training

Farmers visited Stakna, Leh farm on September 08, 2021 and were apprised of the ongoing Tribal Sub Plan (TSP) activities. Discussions were held on improved agriculture practices viz., line sowing, tools for weeding, improved potato cultivation, natural resources management, PGR conservation in cold arid region of Ladakh and role of indigenous people as custodian of agro-biodiversity of the region.

Exposure visit of the farmers sponsored by LAHDC Kargil at RRS-Leh

Kisan Mela cum Exhibition at Chemday Village (Kharu-Block) of Leh Ladakh (UT)

ICAR-CAZRI, RRS Leh participated in Kisan Mela cum Exhibition on September 06, 2021 attended by around 350 farmers from different villages of Kharu block. Various technologies of ICAR-CAZRI, RRS were displayed in the exhibition.

Participation in Kisan Mela organised by state agricultural department at Chemday

Farmers'- Scientist's interaction

Farmers'-Scientist's interaction was organized at Stakna campus on July 19, 2021 in which 30 farmers from different villages of Zanskar region participated. Interactive sessions on Value addition of horticulture and agriculture produce, Potato cultivation practices and Agroforestry systems of Ladakh were conducted. Farmers also visited the farm of RRS Leh.

Exposure visit of the farmers from Zanskar sponsored by KVK at RRS-Leh

TSP Baseline Survey

Interaction with farmers for TSP Baseline Survey was done on February 12, 2022 at LAHDC Office Campus, Leh. Hon'ble Executive Councillor (Agriculture), Sh. Stanzin Chosphel requested the farmers of Matho village to take the benefits of the scheme.

Interaction with farmers for TSP Baseline Survey

Awareness program on "Natural Farming"

ICAR-CAZRI, RRS, Leh, Union Territory of Ladakh organized Awareness Program on "Natural Farming", which is being promoted as Bharatiya Prakritik Krishi Paddhati Program (BPKP) under Paramparagat Krishi Vikas Yojana (PKVY) at Nang Village Leh on February 25, 2022. The program was attended by 37 farm women and farmers of Nang village. Er. Changchuk Lamo, Scientist, made a detailed presentation on "Natural Farming" which is a chemical free, traditional farming method. An overview of the website launched by NITI Aayog highlighting the traditional indigenous practices which reduces externally purchased inputs and also improves the environment, soil and human health simultaneously and local formulations of seed treatment and plant protection methods were

presented. Mr. Jigmet Stanzin briefed about the "Importance of conservation of our traditional seeds" and emphasized on practicing traditional indigenous farming methods suitable for the arid region. Ms. Stanzin Landol presented a lecture on "Agroforestry practices in Cold Arid Ladakh" and its benefits to improve livelihoods of the farming community. Mr. Mohd Raza explained the seed storage methods and their importance.

One day training Program on natural farming at Nang village

Need Assessment meeting with Hemis farmers at CAZRI, RRS, Leh

A meeting was held with the farming community of Hemis village under Martselang Panchayat halka of Leh, under TSP scheme on July 2, 2022, in which 20 farmers attended. The team conducted a need assessment-based interaction with the farmers to identify the various issues related to the agricultural practices and better utilization of available water resources. Farmers were keen about new short-duration crop varieties and other fodder crops.

Need Assessment meeting with Hemis farmers under TSP

Tribal Sub Plan (TSP) activities

The scheme is being implemented in two districts of Ladakh. The demonstration of improved varieties of vegetables, pulses, oilseeds, horticultural crops, crop protection chemicals, soil nutrition and harvesting implements were organized. Scientists-farmers interaction meetings and field days were conducted on improved production technologies of *agriculture* and horticultural crops for enhancing crop productivity and income of farmers.

The vegetables seeds and strawberry (Chander variety) were distributed in 19 villages during 2014. During 2015, Strawberry (var. Karteen sweet and Dilpasand), vegetable seeds, peas, Apricot seedlings, Oats seeds (JHO-992), Solar based lantern, were distributed and demonstrated to the 1163 beneficiaries. Vegetable seeds, horticulture tool kits, foot spray pump, UVS Film, Solar dryer, Cotton tarpal seed bins, scissor pashmina and globe axe were distributed and demonstrated during the period 2016 and 2017. The number of beneficiaries was 466 farmers. During 2018 and 2019, drying trays, horticulture tool kits, fruit and vegetable seeds, spray pump, waste decomposer, feed and fodder shed (repairing), vegetable cellar, irrigation channel (repairing), broiler chicks, animal shed, shepherd transit shed, sewing machine, underground cellar and animal shed were distributed and demonstrated to 395 farmers. In 2020, garden tools viz., hand saw, apple harvester, secateur, green net, small axe, pruning knife, falcon khurpa and hand sickle were distributed in five villages viz., Tsogstii, Chilling, Khardong, Sumar Naubra and Kukshow and number of beneficiaries was 76 in districts of Leh and Kargil.

Farmers were trained on package of practices of cereal and fodder crops, weed management, crop diversification, quality fruit production and plant protection measures by scientist farmers interface meetings and field days conducted by RRS, Leh. Awareness camps were organized for orchard management, sanitation, animal health, community seed bank, etc. More than 2000 farmers were benefitted in Leh and Kargil districts.

Crop Cafeteria demonstration

Crop cafeteria of cold arid region was demonstrated at RRS Leh farm during **2018-19 and 2019-20.** The improved varieties of nine main cold arid region crops viz., lentil (PL-6, Local Kargil, Local Turtuk, Almora VL-129, Masoor VL-514 and LL-931), rajmah (Shalimar Bheej, Pantnagar, Cotender, Kargil KVK,WB-956, BR-39 and WB-1492), peas (Lincoln, PB-189, Local Shang, Black pea (Nubra), Local Kargil, Pea azad, Local Zanskar), buck wheat (PRB-1, IC-107981, IC-329199, IC-107153, IC-341674, IC-329197, Local Kargil, IC-107983, HIMGIRI, IC-37294, IC-328190, Local Turtuk BRO and IC-107116), local Nubra millets (Cha), barley (EC-578444, IC-393973, IC-335811, IC-138120, IC-542209, IC-445568, Local kargil, IC-542194, EC-0667420, IC-138119, IC-138121, EC-0667493, IC-113060, EC-0578856), chenapodium (EC-507741, EC-507742, EC-507743, EC-507744, EC-507746, EC-507748, EC-507739 and EC-507740), wheat (Local Thiksey, PBW-725, PBW-677, Shalimar-1, HS-365 and HS-562) and mustard (DRMR NRCHB-101, RH-749, Likir red, Shang white, PB-357, P-J-KISAN, IC-317528, IC-355410, IC-481007, Varuna, EC-481008, Rajat, EC-399301, Toria, PM-30, IC-491349, EC-182923, Laxmi, EC-657071, IC-73134 and RH-30) were demonstrated for the benefit of the farming community.

Crop Cafeteria

Farmers Trainings Organized

Duration	Title of training	Number of farmers	Sponsoring agency
August 28, 2013	Interactive meet with Ladakhi farmers at Saboo Model village	15	CAZRI-RRS, Leh
September 09, 2013	Interactive meet with Ladakhi Farmers at Nimoo village	28	CAZRI-RRS, Leh
September 29, 2013	Interactive meet with Ladakhi farmers on Barley at Stakmo village	30	CAZRI-RRS, Leh
March 21-22, 2014	Potato production techniques under cold arid regions of Leh at Nang, Stakmo, Egoo, Shara, Sharmos and Phuksey villages	230	CAZRI-RRS, Leh and CPRI, Shimla
June 27, 2014	Modern techniques on potato seed production at high altitude at Nang, Shara and Phuksey villages	160	CAZRI-RRS, Leh, KVK, Leh and CPRI, Shimla
July 27, 2014	Composting: A step towards organic farming in cold arid region at Chushot village	32	CAZRI-RRS, Leh
December 05, 2014	Composting: A step towards organic farming in cold arid region at Egoo, Langkor Village	23	CAZRI-RRS, Leh
December 26, 2014	Recent advances in crop production and weed control in crops in cold arid region at Phey village	44	CAZRI-RRS, Leh
January 20, 2015	Crop production techniques at Ney village	40	CAZRI-RRS, Leh
February 16, 2015	Advances in crop production and technical Know-how at Umla village	24	CAZRI-RRS, Leh
August 18, 2015	Rodent pest management in cold arid region at Stakna village	18	CAZRI-RRS, Leh
August 23, 2015	Livestock health and management in cold arid region at Ranbirpur (Thiksey) village	20	CAZRI-RRS, Leh

Duration	Title of training	Number of farmers	Sponsoring agency
October 06, 2015	Health camps for yak rearers of Ladakh at Khardong village	30	CAZRI-RRS, Leh and NRC Yak, Dhirang
December 18, 2015	Advances in sustainable crop production at Chushot village	35	CAZRI- RRS, Leh
January 30, 2016	Weed management in crops and advances in sustainable crop production at Umla village	21	CAZRI-RRS, Leh
February 05, 2016	Weed management in crops and advances in sustainable crop production-Stakmo village	45	CAZRI-RRS, Leh
June 07, 2016	One-day stakeholder meet at Thiksey village	55	CAZRI-RRS, Leh
June 29, 2016	Rodent pest management in cold arid region at Ranbirpur village, Leh	29	CAZRI-RRS, Leh
September 05, 2016	Mushroom cultivation at Ranbirpur village	23	CAZRI-RRS, Leh
September 21-22, 2016	Mushroom cultivation at ITBF 16 Battalion Choglamsar in Leh	25	CAZRI-RRS, Leh and KVK, Leh
October 01, 2016	Interactive meet on vulnerability assessment with farmers of Ranbirpur village	15	CAZRI-RRS, Leh
October 05, 2016	Interactive meet on vulnerability assessment with farmers of Phey village	24	CAZRI-RRS, Leh
October 07, 2016	Interactive meet on vulnerability assessment with farmers of Stok village	20	CAZRI-RRS, Leh
December 13, 2016	International Mountain Day at CAZRI RRS Leh office campus	30	CAZRI-RRS, Leh
December 18, 2016	Orchard sanitation camp at Nimoo village	50	CAZRI-RRS, Leh
December 23, 2016	Basics of orchard establishment and management at Chushot village	35	CAZRI-RRS, Leh and CITH, Srinagar
December 24, 2016	Training on vegetable production at Phey village	11	CAZRI-RRS, Leh and CITH, Srinagar
December 25, 2016	Basics of orchard establishment and management at Ranbirpur village	11	CAZRI-RRS, Leh and CITH, Srinagar
December 26, 2016	Basics of orchard establishment and management at Nimoo village	13	CAZRI-RRS, Leh and CITH, Srinagar
January 15, 2017	Orchard sanitation at Nimoo and Basgo villages	110	CAZRI-RRS, Leh and Department of Horticulture, LAHDC Leh
November 22, 2017	Workshop on Protected Cultivation Technologies for Cold Desert collaboration program held at Stakna SKUAST Leh campus	160	SKUAST-Leh HAAMARI and ICAR-CAZRI-RRS, Leh
December 06, 2017	Training on Package of Practices in wheat and barley cultivation at Stakmo village	49	CAZRI-RRS, Leh
December 06, 2017	Training on "Community Seed Bank" at Stakmo village	52	CAZRI-RRS, Leh under NMSHE-TF-5 Project

Duration	Title of training	Number of farmers	Sponsoring agency
December 23, 2017	Protection of Plant Varieties and Farmers' Rights at Muth village, Nyoma	85	CAZRI-RRS, Leh and KVK, Nyoma
January 03, 2017	Interaction meet with farmers of Angkung village in Nyoma	16	CAZRI-RRS, Leh
February 28, 2018	Science day cum training on potato planting techniques at Igoo village	56	CAZRI-RRS, Leh
March 09, 2018	Training Program cum Awareness Camp on Swachhata under TSP and Celebrated "Women's Day" at Khardong village in Nubra	44	CAZRI-RRS, Leh
March 10, 2018	One day Training Program and Field visit for farmers of Takmachik village	50	CAZRI-RRS, Leh
March 22, 2018	Awareness Camp cum Celebration of 'Sparrow Day, World Water & Forestry Day' at BVN School Choglamsar, Leh	100	CAZRI-RRS, Leh
May 25, 2018	Awareness camp on improved techniques of crop cultivation & demonstrated seed drill for line sowing at Khardong village, Nubra	30	CAZRI-RRS, Leh
June 05, 2018	World Environment Day at Govt. Primary School at Stakna village.	50	CAZRI-RRS, Leh
June 21, 2018	Interactive meet of farmers with CAZRI Scientists and Audit team at Thiksey village	10	CAZRI-RRS, Leh
July 15, 2018	Scientist Farmer Interaction Meet at Dargoh and Kukshow villages	42	CAZRI-RRS, Leh
August 09, 2018	Scientist Farmer Interaction Meet at TSP village Kukshoo in Kargil District	95	CAZRI-RRS, Leh
August 22, 2018	Training on Juniper Propagation & Management at Sumoor village in Nubra	50	CAZRI-RRS, Leh and HFRI, Shimla
September 03, 2018	Package of practices of potato cultivation at Pibting village in Zanskar	36	CAZRI-RRS, Leh
September 05, 2018	Rodent pest management and their control in cold arid region at Stakmo village	35	CAZRI-RRS, Leh
September 06, 2018	Training on Protection of Plant Varieties and Farmers' Rights Act at Igoo village	70	CAZRI-RRS, Leh and NBPGR, New Delhi
September 07, 2018	Rodents Pest Management and their control in cold arid region and awareness on Swachhata Abhiyaan at Shang village	42	CAZRI-RRS, Leh
October 4, 2018	Training on "Availability, use and performance of quality seed used for sowing in different crops by farmers in Leh region" at Saboo village	16	CAZRI, Jodhpur and RRS, Leh under NMSHE-TF-5 Project
October 4, 2018	Training on "Availability, use and performance of quality seed used for sowing in different crops by farmers in Leh region" at Stakmo village	22	CAZRI, Jodhpur and RRS, Leh under NMSHE-TF-5 Project

Duration	Title of training	Number of farmers	Sponsoring agency
November 11, 2018	Training program on Natural farming and Swachhta at Khardong village in Nubra	70	CAZRI-RRS, Leh
December 08, 2018	Interaction meets with traditional brass and silver handicraft artisans at Chillingvillage	16	CAZRI-RRS, Leh
August 11, 2019	Interaction meets with Nomadic families at Angkung village in Changthang	10	CAZRI-RRS, Leh
August 29, 2019	Training on "Agro-forestry systems in Leh region and their role in traditional and modern farming systems" at Nang village	10	CAZRI, Jodhpur and RRS, Leh under NMSHE-TF-5 Project
August 30, 2019	Training on "Agro-forestry systems in Leh region and their role in traditional and modern farming systems" at Likir village	8	CAZRI, Jodhpur and RRS, Leh under NMSHE-TF-5 Project
August 31, 2019	Training on "Agro-forestry systems in Leh region and their role in traditional and modern farming systems" at Changa village	8	CAZRI, Jodhpur and RRS, Leh under NMSHE-TF-5 Project
September 2, 2019	Training on "Agro-forestry systems in Leh region and their role in traditional and modern farming systems" at Sakti village	9	CAZRI, Jodhpur and RRS, Leh under NMSHE-TF-5 Project
September 3, 2019	Training on "Agro-forestry systems in Leh region and their role in traditional and modern farming systems" at Basgo village	6	CAZRI, Jodhpur and RRS, Leh under NMSHE-TF-5 Project
September 4, 2019	Training on "Agro-forestry systems in Leh region and their role in traditional and modern farming systems" at Matho village	8	CAZRI, Jodhpur and RRS, Leh under NMSHE-TF-5 Project
September 10, 2019	Training Program on protected cultivation	340	CAZRI, RRS, Leh
September 29, 2019	Training on "Traditional cultivars *vis-a-vis* improved varieties in crops cultivated in Leh region" at Basgo village	12	CAZRI, Jodhpur and RRS, Leh under NMSHE-TF-5 Project
September 30, 2019	Training on "Traditional cultivars *vis-a-vis* improved varieties in crops cultivated in Leh region" at Martselang village	10	CAZRI, Jodhpur and RRS, Leh under NMSHE-TF-5 Project
October 01, 2019	Training on "Traditional cultivars *vis-a-vis* improved varieties in crops cultivated in Leh region" at Matho village	9	CAZRI, Jodhpur and RRS, Leh under NMSHE-TF-5 Project
October 02, 2019	Training on "Traditional cultivars *vis-a-vis* improved varieties in crops cultivated in Leh region" at Stok village	9	CAZRI, Jodhpur and RRS, Leh under NMSHE-TF-5 Project
October 03, 2019	Training on "Traditional cultivars *vis-a-vis* improved varieties in crops cultivated in Leh region" at Changa and Stakna villages	14	CAZRI, Jodhpur and RRS, Leh under NMSHE-TF-5 Project
October 04, 2019	Training on "Scientific cultivation of annual crops in Leh region" at Taru village	10	CAZRI, Jodhpur and RRS, Leh under NMSHE-TF-5 Project
October 05, 2019	Training on "Scientific cultivation of annual crops in Leh region" at Saboo village	12	CAZRI, Jodhpur and RRS, Leh under NMSHE-TF-5 Project

Duration	Title of training	Number of farmers	Sponsoring agency
October 06, 2019	Training on "Scientific cultivation of annual crops in Leh region" at Shyang village	8	CAZRI, Jodhpur and RRS, Leh under NMSHE-TF-5 Project
October 16, 2019	Training Program on Organic Farming	300	CAZRI-RRS, Leh
February 10, 2020	Interactive meet with farmers of KVK Nyoma	40	CAZRI-RRS, Leh and KVK, Nyoma
February 25, 2020	Interactive meet with farmers and scientists at Kukshoo village in Kargil	35	CAZRI-RRS, Leh
September 11, 2020	Training program on "Water management" at Tsogsti village	05	CAZRI-RRS, Leh
September 11, 2020	Training program on "Importance of Agroforestry" at Chilling village	07	CAZRI-RRS, Leh
February 25, 2022	Awareness program on "Natural Farming"	37	CAZRI-RRS, Leh
June 24, 2022	Interact with villagers for need assessment at Takmar-Khardong village Nubra under TSP	18	ICAR-CAZRI, RRS Leh
July 01,.2022	Interact with villagers for need assessment at Shang Village under TSP	37	ICAR-CAZRI, RRS Leh
July 02, 2022	Interact with villagers for need assessment at Hemis village under TSP	14	ICAR-CAZRI, RRS Leh
July 05, 2022	Interact with villagers for need assessment at Sumdo Changthang under TSP	12	ICAR-CAZRI, RRS Leh
August 29, 2022	Interaction meet with ICAR General Body Member and Team GOI Sh. Bikram Jit Singh Ji	08	ICAR-CAZRI, RRS Leh
September 28, 2022	One day training Program on "Fodder Production and Feed Management" at Hunder Village Nubra	15	RRS Leh and NDRI Karnal
October 17, 2022	Interaction Meet with Journalist from Rajasthan, Madhya Pradesh, and Ladakh Union Territory	15	ICAR-CAZRI, RRS Leh
October 26-31, 2022	One Weeks Training-Cum-Awareness Program on Cultivation, Processing and Value Addition of Medicinal and aromatic plants under CSIR-Aroma Mission Phase-II IN Collaboration with CSIR-IIIM Srinagar	25	ICAR-CAZRI, RRS Leh and CSIR IIIM Srinagar
November 09, 2022	"Training on Technological Intervention for livelihood security and income Enhancement" at Hemis TSP Village	30	ICAR-CAZRI, RRS Leh
November 10, 2022	"Training on Technological Intervention for livelihood security and income Enhancement" at Shang TSP Village	41	ICAR-CAZRI, RRS Leh

Officers' training programs organized

Date	Title and venue	No. of participants	Sponsoring agency
February 17, 2017	Plant protection measures in cold arid region at State AgricultureDepartment, LAHDC Leh	40	CAZRI-RRS, Leh

National Symposium/workshop organized

Date	National Symposium/Workshop	Organizers
August 19-22, 2015	National Symposium on Sustaining Agricultural Productivity in Arid Ecosystems: Challenges & Opportunities (SAPECO-2015) at Leh, Ladakh	AZRAI, ICAR-CAZRI, DST& NABARD
July 30, 2016	First Stakeholder Workshop on Importance of Documentation of Traditional Knowledge Systems in Indian Himalayan Region for Climate Change Adaptation and Mitigation at Leh-Ladakh	ICAR-CAZRI, JNU, New Delhi and DST, New Delhi under NMSHE-TF-5 Project

Exposure visit of farmers sponsored by TATA Trust

Participation in Farmers' Fair, Field days, Exhibition etc.

Date	Event	Place
August 11, 2014	Kisan Jawan Vigyan Mela	DRDO-DIHAR, Leh
August 29, 2014	Kisan Mela and Kisan Gosthi	Shenam hall Leh, organised by RRS, Leh
August 08, 2015	KisanJawan Vigyan Mela	DRDO-DIHAR, Leh
September 07, 2015	Horticulture Mela	State Department of Horticulture, Leh at Khaltsi
September 10, 2015	Kisan Mela	State Department of Agriculture and Horticulture, Leh
August 29, 2018	State Agriculture and Horticulture Exhibition Mela	Agriculture and Horticulture Department, LAHDC, Leh
August 12-13, 2017	Kisan Mela	State Agriculture and Horticulture Department, LAHDC, Leh
August 22, 2017	Fruit Exhibition Mela	State Horticulture Department, LAHDC, Leh
August 29, 2017	Kisan Mela Cum Exhibition	State Agriculture and Horticulture Department, Leh
June 22, 2019	One Day Plantation Drive	HMAARI, SKUAST-Leh Campus

Date	Event	Place
August 29-30, 2019	Kisan Jawan Vigyan Mela	DRDO-DIHAR, Leh
September 05, 2019	Kisan Mela	State Agriculture Department, Leh
September 17, 2019	Kisan Mela	KVK, Nyoma
August 30, 2021	Kisan Mela cum Exhibition	Department of Horticulture, LAHDC Ladakh (UT) at Saspol village
September 06, 2021	Kisan Mela cum Exhibition	State Department of Agriculture, LAHDC Ladakh (UT) at Chemday village in Kharu block
August 10-11, 2022	Agritech Mela	Science Technology and Innovation Hub (STI), CSIR-NIELIT and DST at Leh
August 29-30, 2022	Ladakhi Kisan-Jawan-Vigyan Mela	DRDO-DIHAR, Leh
September 07, 2022	Ladakh Agri Tech Expo	ICAR, SKUAST HMAARI Leh Stakna at Leh

Participation in Ladakh Agritech Mela (10-11 August, 2022)

Participation in 29th Ladakhi Kisan-Jawan-Vigyan Mela (29-30 August 2022)

Meetings and Events Organized

Two days workshop organized by ICAR-CAZRI, Regional Research Station Leh

Workshop on Development of horticulture under cold arid region of Ladakh for enhancing quality production and improving livelihood" was organised at SKUAST-K Campus Leh during August 23-24, 2017 by ICAR-CAZRI RRS Leh and HMAARI, SKUAST-K, Leh in collaboration with ICAR-Central Institute of Temperate Horticulture, Srinagar, ICAR-CPRI, Shimla, ICAR-IIVR, Varanasi and ICAR-IIHR, Bengaluru. During the technical sessions various issues related to horticulture were discussed. Farmers showed a lot of enthusiasm in learning new technologies during the workshop. Various technologies of ICAR-CAZRI, RRS Leh were also exhibited.

Two days workshop organized by ICAR-CAZRI, Regional Research Station Leh

Workshop on Traditional Knowledge Systems in Leh-Ladakh region organized at Leh

First Stakeholder Workshop on "Importance of Documentation of Traditional Knowledge Systems in Indian Himalayan Region for Climate Change Adaptation and Mitigation" was organized jointly by ICAR-CAZRI and JNU, New Delhi under the DST funded project "National Mission on Sustaining Himalayan Ecosystem (NMSHE)-TF-5 (Traditional Knowledge Systems)" at CAZRI RRS, Leh. Forty-five delegates from ICAR-CAZRI, JNU, New Delhi, DST, New Delhi and various research organizations

Workshop on Traditional Knowledge Systems

from Leh participated. The workshop focused on the broad approach and methods of knowledge documentation, protection and management with the active participation of stakeholders. A framework for protection and management of the documented traditional knowledge of Leh-Ladakh as per Biological Diversity Act (2002) & Rules (2004) and internationally laid down procedures was developed.

Swachhata day at Chamday village, Leh

CAZRI-RRS Leh organised Swachhata day at Chamdey village on September 22, 2018. Thirty-eight farm women participated in the program.

Swachhata day at Chamday village, Leh

Union Minister of Agriculture and Farmers' Welfare inaugurates the Research facility at CAZRI-RRS, Leh

The Regional Research Station of ICAR-CAZRI, Leh (UT of Ladakh) was inaugurated by Sh. Narendra Singh Tomar, Hon'ble Union Minister of Agriculture and Farmers' Welfare on December 21, 2020. He appreciated the institute for addressing various R&D issues related to cold desert. Mr. Parshottam Rupala, Minister of State for Agriculture and Farmers' Welfare expressed that the new facility would help in developing technologies for sustainable development of agriculture and animal husbandry in one of the climatically most challenged regions. Mr. Jamyang Tsering Namgyal, Member of Parliament from Ladakh highlighted that the cold desert area has a very fragile ecosystem and vulnerable to climate change. He appreciated the institute efforts for making its' presence felt in remote villages of the region through various outreach programs.

Virtual inaugration of RRS-Leh office building at Stakna

Dr. T. Mohapatra, Secretary DARE and DG ICAR mentioned the genesis for establishing RRS of CAZRI, Jodhpur, which has enormous accomplishments in the development of arid regions. He underlined the role of CAZRI in initiating focused R&D activities for cold arid regions and in reaching a large number of Ladakhi farmers. Dr. S.K. Chaudhari, DDG (NRM), ICAR mentioned that issues of cold arid regions would be addressed in comprehensive manner in a sustainable way.

Union MoS, Agriculture and Farmers & Welfare visits ICAR-CAZRI RRS, Leh

ICAR-CAZRI-RRS, Leh organized a Kisan Mela and an interactive meet with the farming community of Trans-Himalayan Mountain region of Ladakh on July 4, 2021. Shri Kailash Choudhary, Hon'ble Union Minister of State expressed his priority for strengthening linkages between research and farming communities. He underlined the need of Integrated Farming System (IFS) and FPOs for bringing in a radical change in agrarian community of the country including cold arid region. Shri Jamyang Tsering Namgyal, MP of Ladakh, stressed upon the schemes and programs targeting exclusively for the holistic development of Ladakh region. He spoke in detail about how Ladakh is organic by default and is moving towards becoming a certified organic region through the Mission Organic Development Initiative (MODI). Farmers from all the valleys of the UT of Ladakh viz, (Leh, Nubra, and Changthang and Kargil) were present on this occasion.

Visit of Union MoS, Agriculture and Farmers & Welfare visits

International Day of Forest and World Water Day

International Day of Forest and World Water Day was organised by RRS, Leh at KV school at Leh. The program included lectures on water and forest resources and their conservation followed by interaction and a quiz competition for the students.

World Environment Day

World Environment Day was celebrated by the RRS at Tsogsti village on June 05, 2022. Issues related to exploitation and pollution of natural resources and protection of the environment were discussed with the farmers.

Celebration of World Environment Day at Tsogsti village

International Yoga Day 2022 celebrated at CAZRI, Leh Research Station

International Yoga Day 2022 was observed on June 21, 2022 at the campus of Regional Research Station, Leh. Head and staff of the station practised various yoga asanas and pledged to make yoga as an integral part of their life.

International Yoga Day celebration at RRS-Leh

Institute Development

Construction of office building and office premises

Office building was constructed along with farm building, security hut, laboratory, and one meeting hall during the year 2020.

Development of new area for crop cultivation

Approximately 19-hectare new area was developed at main research farm of RRS Stakna at Leh. This area is being utilized to carry out the research and cultivation of seasonal crops. The area is very slopy in nature. Hence, terraces were built along the contour to establish the plantations and to cultivate the agriculture crops. Total 69 terraces were constructed in three rows. Irrigation channel was developed along the road to irrigate the canal water in the field. Three ponds are there to store water in the farm of RRS, Leh.

Foundation stone

Terrace development

ICAR-CAZRI-RRS-Leh office building

Linkages and Collaborations

- High Mountain Arid Agriculture Research Institute (HMAARI), SKUAST-K, Leh
- KVK-Leh, SKUAST-K, Leh
- Defence Institute of High-Altitude Research (DIHAR), DRDO, Leh
- GB Pant National Institute of Himalayan Environment (NIHE), RC, Ladakh
- State Department of Agriculture and other line departments
- Himalayan Institute of Alternatives (HIAL) and Student's Education and Cultural Movement of Ladakh (SECMOL)
- Ladakh Environment and Health Organization (LEHO)
- Leh Nutritional Project (LNP)

Capacity Building

Participation in Trainings, Summer/Winter Schools

Date	Training course, organizers and venue	Name of the participants
September 22-24, 2014	3rd Interface Meeting on Improvement of Yak Husbandry and Upliftment of Socio-economic Status of Yak Rearers in the Country held at Leh	M.S. Raghuvanshi Jigmat Stanzin Stanzin Landol Digambar Singh
July 25-29, 2015	17th International Conference of International Association for Ladakh Studies at Kargil	M.S. Raghuvanshi Stanzin Landol Mohd. Raza Digambar Singh
August 19-22, 2015	National Symposium on Sustaining Agricultural Productivity in Arid Ecosystems: Challenges & Opportunities (SAPECO-2015) at Leh, Ladakh	M.S. Raghuvanshi Jigmat Stanzin Stanzin Landol Rigzin Dorje Mohd. Raza Lakhan Singh Heera Lal Koodi Digambar Singh
September 11, 2015	Ecology Orientation Workshop for Officers of Military/Paramilitary Forces & Wildlife Conservation in Ladakh	Jigmat Stanzin Stanzin Landol
October 04-5, 2015	National Seminar on Precision Farming Technologies for High Himalayas	M.S. Raghuvanshi Jigmat Stanzin Stanzin Landol Mohd. Raza Rigzin Dorje Lakhan Singh
November 16-19, 2015	"Off-Campus Specialized Program for Enhancing Human Relations and Performance of People at Work for Administrative and Technical Personnel", organized by the faculty of NAARM, Hyderabad at CAZRI, Jodhpur.	Jigmet Stanzin Stanzin Landol
January 01, 2016	NMSHE –Task Force-6 (Himalayan Agriculture) Review meeting during the DST expert meeting organized by the Department of Science and Technology, New Delhi	M.S. Raghuvanshi
March 22, 2016	Consultation Workshop of NMSHE-TF-6 (Himalayan Agriculture) held at CAZRI, Jodhpur	M.S. Raghuvanshi
June 30, 2016	Traditional Knowledge Systems (TKS) in collaboration with JNU, New Delhi at Leh	M.S. Raghuvanshi Jigmat Stanzin Stanzin Landol Rigzin Dorje Heera Lal Koodi Mohd. Raza Lakhan Singh Digambar Singh

Date	Training course, organizers and venue	Name of the participants
August 03-23, 2016	Summer School on Livelihood and climate change mitigation and adaptation through Agroforestry, organized at ICAR-CAZRI Jodhpur.	Jigmat Stanzin
January 30 to February 08, 2017	Short courseon "Engineering intervention in fodder production including management of fodder/crop-residue and their value addition" sponsored by ICAR-IGFRI, Jhansi (UP)	Mohd. Raza
August 01-10, 2017	Training on Selection, Adjustment, Operation and Maintenance of Agricultural Implements for field and Horticultural Crops organized by ICAR-CIAE, Bhopal (MP)	Rigzin Dorje
November 28, 2017	Farmers' Awareness Program under GraminKrishiMausam Sewa (GKMS) organised by Agro-Meteorological Field Unit, SKUAST-K, Leh	S.K. Chauhan Jigmat Stanzin Stanzin Landol Rigzin Dorje Lakhan Singh Mohd. Raza
April 25-26, 2018	"Field Training for baseline survey" mainstreaming agricultural biodiversity conservation and utilization in agricultural sector to ensure ecosystem services and reduce vulnerability sponsored by GEF held at Deendayal Research Institute, Chitrakoot	Mohd. Raza
January 11-23, 2019	10 days of training on "Layout and maintenance of field experiments and records observations" at Division of Agronomy, ICAR-IARI New Delhi	Stanzin Landol

Participation in Conference/Seminar/Symposia/ Workshop/Meetings

Date	Title, name of organizers and venue	Name of participants
February 15-17, 2014	Biennial Conference of Indian Society of Weed Science on Emerging challenges in Weed management at DWSR, Jabalpur	M.S. Raghuvanshi
October 13-16, 2015	Asian-Pacific Weed Science Society Conference on "Weed Science for Sustainable Agriculture, Environment and Biodiversity", Hyderabad, India	M.S. Raghuvanshi
November 20-24, 2015	XXIII International Grassland Congress (IGC-2015)	M.S. Raghuvanshi
December 3-5, 2016	National Symposiumon Agroforestry for Environmental challenges, sustainable landuse, biodiversity conservation and rural livelihood options at ICAR-CAFRI, Jhansi	M.S. Raghuvanshi
March 01-03, 2017	Biennial Conference of the Indian Society of Weed Science on "Doubling Farmers' Income by 2022: The Role of Weed Science"at MPUAT, Udaipur	M.S. Raghuvanshi
September 22-24, 2017	National Conference on Sea buckthorn: Improving Health and Sustainable Development of Himalayan region held at DRDO-DIHAR, Leh	M.S. Raghuvanshi Jigmat Stanzin Stanzin Landol Rigzin Dorje Mohd. Raza
July 17, 2019	SAC Meet held at SKUAST-K HMAARI Leh Stakna	S.K. Chauhan Stanzin Landol Rigzin Dorje
September 22-23, 2017	State level Workshop on Protected Cultivation technologies for Cold arid region at HMAARI, SKUAST-K Leh	S.K. Chauhan Stanzin Landol Rigzin Dorje Lakhan Singh Mohd. Raza
February 11-14, 2019	13th International Conference on Development of Drylands: Converting Dryland Areas from Grey into Green, at ICAR-CAZRI, Jodhpur	M.S. Raghuvanshi
September 30, 2019	Meeting on "Mission Organic Development Initiatives of Ladakh" held at LAHDC Leh	Stanzin Landol
June 22, 2019	Seminar on "Christianity and the Environment in Ladakh" at Moravian Mission School, Leh Hosted by Snow Leopard Conservancy India Trust & Moravian Mission School.	Stanzin Landol Mohd. Raza
June 18, 2022	हिंदी की विविध विधाओं में विज्ञान–लेखन organized Central Institute of Buddhist Studies (Deemed University), Leh	Dr. Mahesh Kumar Gaur
September28-30, 2022	International Conference on Advances in agricultural, veterinary and allied sciences for improving livelihood and environmental security (AAVASILES-2022) organised by ICAR-IGFRI, RRS, Srinagar, ICAR-NAHEP, BAU, Ranchi and NADCL, Baramulla, J&K at Gandhi Bhawan, University of Kashmir, Hazratbal, Srinagar, Kashmir	Dr. M.B. Noor mohamed
November 07, 2022	IP Awareness/Training program under National Intellectual Property Awareness Mission of Intellectual Property Office, Government of India at Leh	Dr. R.K. Goyal Dr. Mahesh Kumar Gaur

Publications

Research Papers

Meena, H.M., Tewari, J.C., Raghuvanshi, M.S., Pandey, C.B. and Ahmad, L. 2015. Influence of weather variation on cropping pattern of Leh district of Ladakh region. *Current World Environment* 10(2): 489.

Raghuvanshi, M.S., Tewari, J.C., Pareek, Kamlesh, Stanzin Landol, Mohd. Raza and Jigmet Stanzin 2018. Energy Budget of Crops and Weed Management to Enhance Crop Productivity in Cold Arid Ladakh Region. *Defence Life Science Journal* 3(2): 157-161.

Gaur, M.K., Goyal, R.K., Raghuvanshi, M.S., Bhatt, R.K., Pandian, M., Mishra, A. and Sheikh, S.I. 2020. Geospatially extracting snow and ice cover distribution in the cold arid zone of India. *International Journal of System Assurance Engineering and Management* 11(1): 84-99.

Raghuvanshi, M.S., Maharna, P., Spalbar, E., Dorjay, N., Singh, R.K., Saxena, A., Gaur, M.K. and Arunachalam, A. 2020. Spatial distribution of nutrients in soil profile under different land use systems of cold arid region of Ladakh. *Indian Journal of Hill Farming* 22(2): 394-399.

Gaur, M.K., Goyal, R.K., Saha, D., Singh, N., Shekhar, S. and Chauhan, J.S. 2022. The Estimation of Snow Cover Distribution Using Satellite Data in the Cold Arid Leh Region of Indian Himalaya. *Polish Journal of Environmental Studies* 31(1): 63-73.

Sharma, S., Singh, P., Chauhan, S. and Choudhary, O.P. 2022. Landscape position and slope aspects impacts on soil organic carbon pool and biological indicators of a fragile ecosystem in high-altitude cold arid region. *Journal of Soil Science and Plant Nutrition*, 1-21.

Compendiums

Raghuvanshi, M.S., Vikas Gupta, J.C. Tewari, S. Landol, J. Stanzin, Rigzin Dorje and Mohd. Raza Onion: Maggot management in cold arid region of India published by ICAR-CAZRI, RRS, Leh.

Book Chapters

Raghuvanshi, M.S., Gaur, M.K. and Goyal, R.K. 2020. Vulnerability of resource-poor farmers to climate change and traditional adaptation pattern at high-altitude cold arid region. In: *Food Security and Land Use Change under Conditions of Climatic Variability* (Eds. R. Victor Squires and M.K. Gaur) Springer. pp. 311-329.

Chapters in Conference Proceedings/ Compendium

Raghuvanshi, M.S., Tewari, J.C., Gupta, V., Stanzin, L., Enoch, S., Dorjay, N., Raza, Mohd and Dorje, R. 2017. Weeds and their management in crops of cold arid region. In: *Training Manual on Plant Protection*. Deptt. of Agri., Leh on 21 Feb. 2017. pp. 5

Dorje, R., Raza, Mohd, Raghuvanshi, M.S. and Stanzin, L. 2017. *Mechanical Tools for Effective Management of Weeds in Training Manual on Plant Protection*. Deptt. of Agri. Leh on 21 Feb. 2017. pp. 54.

Stanzin, L., Raghuvanshi, M.S., Gupta, V., Dorjay, N., Enoch, S., Dorje, R. and Raza, Mohd 2017. *Precautions during Plant Protection Measures in Training Manual on Plant Protection*. State Deptt of Agri. Leh on 21 Feb. 2017. pp. 59.

Popular Articles

Mohd. Raza, Rigzin Dorje, Stanzin Landol, Raghuvanshi, M.S. and Tewari, J.C. 2016. Firewood options in Ladakh region. *Voice of Ladakh* 4(23): 5.

Rigzin Dorje, Raza, Mohd, Raghuvanshi, M.S., Landol, Stanzin, and Tewari, J.C. 2016. Scope of Farm Mechanization in Ladakh. *Reach Ladakh Bulletin* 4(16): 6-9.

Raghuvanshi, M.S, Stanzin Landol, Mohd Raza, R. Dorje, Jigmet Stanzin, Tewari, J.C and Bhatt R.K. 2015. Organic approach for managing Onion Maggots in Cold Arid. Rangyul.

Raghuvanshi, M.S., Tewari, J.C., Bhatt, R.K., Landol Stanzin, Spalbar, Enoch Dorje, Ngawang and Raza Mohd 2018. Importance of weedy endemic in unique subsistence agriculture and their traditional management in Ladakh Region. *Indian Farming* 68(11): 53-57.

Mohd Raza and Ngawang Dorje 2018. The Sab Sucking Pest in Kargil Ladakh-Black Willow Aphid, Published at Voice of Ladakh.

Raghuvanshi, M.S., Stanzin Landol, Ngawang Dorje, Enoch Spalbar and Mohd Raza 2019. Article on Dambu: A Potential threat to biodiversity published at *Stawa Magazine* vol.6 issue 3 March 2019.

Raghuvanshi, M.S., Tewari, J.C., Bhatt, R.K., Landol, Stanzin, Spalbar, Enoch, Dorje, Ngawang, Raza, Mohd. 2018. Importance of weedy endemic in unique subsistence agriculture and their traditional management in Ladakh Region. *Indian Farming* 68(11):53-57.

Saxena, A., Raghuvanshi, M.S., Lamo, C., Raza. M. and Landol, S. 2021. Buckwheat in high altitude temperate zone of trans Himalayan region. *Agro India* 24-27.

Saxena, A., Raghuvanshi, M.S., Landol, S. and Lamo, C. 2021. Apricot Cultivation in High Altitude Temperate Zone of Ladakh. *Agri Journal World* 1(2): 1-6.

Saxena, A., Suna, T., Ram, H., Lamo, C. and Kumar, M. 2021. Artificial Intelligence: A New dimension in Agriculture. *Agriculture Today*. XXIV (10): 74-75.

Awards and Recognitions

- Drs. Anurag Saxena, Sanjeev Chauhan and Mahendra Singh Raghuvanshi conferred with "ICAR-Fakhruddin Ali Ahmed Award for Outstanding Research in Tribal Farming Systems 2019" by ICAR, New Delhi.
- Mrs. Stanzin Landol was awarded for her outstanding contribution for the work done at RRS, Leh, UT of Ladakh during the 62nd Foundation Day of ICAR-CAZRI on October 1, 2020.
- Dr. M.B. Noor Mohamed received "The Emerging Scientist Award 2022" from Vigyan varta Excellence awards by an international E-magazine for science enthusiast on 2022.
- Dr. M. Noor Mohamed received "Best Paper presentation Award" on paper "Ber based horti-agri production system for livelihood security of farmers in hot semi-arid region of western Rajasthan" in International Conference on "Advances in agricultural, veterinary and allied sciences for improving livelihood and environmental security (AAVASILES-2022)" organised by ICAR-IGFRI, RRS, Srinagar, ICAR-NAHEP, BAU, Ranchi and NADCL, Baramulla, J&K at Gandhi Bhawan, University of Kashmir, Hazratbal, Srinagar, Kashmir on 28-30, September, 2022.
- Dr. M. Noor Mohamed received "Best Poster presentation Award (Third place)" for paper on "Agro-forestry trees of hot arid and semi-arid regions"in International Conference on "Advances in agricultural, veterinary and allied sciences for improving livelihood and environmental security (AAVASILES-2022)" organised by ICAR-IGFRI, RRS, Srinagar, ICAR-NAHEP, BAU, Ranchi and NADCL, Baramulla, J&K at Gandhi Bhawan, University of Kashmir, Hazratbal, Srinagar, Kashmir on 28-30, September, 2022.

Distinguished Visitors

- Dr. S. Ayyappan, Secretary (DARE) and DG (ICAR) on September 13, 2013
- Dr. Bir Pal Singh, Director, ICAR-Central Potato Research Institute (CPRI), Shimla on September 16, 2013
- Dr. P.N. Mathur, Biodiversity International on September 30, 2013
- Shri. Sonam Dorjey, Executive Councillor (Agriculture), Ladakh Autonomous Hill Development Council (LAHDC), Leh on November 14, 2013
- Shri. Sat Paul, IFS, District Forest Officer (DFO) Leh on November 14, 2013
- Dr. A.K. Sikka, Deputy Director General (NRM) on August 29, 2014
- Dr. K.M.L. Pathak, Deputy Director General (Animal Sciences) on September 21, 2014
- Dr. Anupam Anand, Consultant, World Bank, GLCF, University of Maryland, Maryland, USA on November 20, 2014
- Dr. Pushpinder Singh, Head, World Wide Fund-India (WWF) on November 20, 2014
- Dr. R.C. Bassi, Former Under-Secretary, ICAR HQs, New Delhi on April 07, 2015
- Dr. Pankaj Chandan, World Wide Fund-India (WWF), India on May 19, 2015
- Shri. M.L. Mantoo, Former Advisor, MORD, GoI on June 24, 2015
- Dr. Gyanendra Mani, Deputy General Manager, Department of Economic Analysis and Research, NABARD, Head Office, Bandra, Mumbai on August 23, 2015
- Dr. A.R. Sharma, Director, ICAR-Directorate of Weed Research (DWR), Jabalpur, Madhya Pradesh on June 15, 2016
- Sh. Chhabiliendra Roul, IAS, Additional Secretary, ICAR, GoI, New Delhi on June 21, 2016
- Dr. Gurbachan Singh, Chairman, Agricultural Scientists Recruitment Board (ASRB) on September 13, 2016
- Dr. Desh Beer Singh, Director, ICAR-Central Institute of Temperate Horticulture (CITH), Srinagar on August 21, 2017
- Dr. O.P. Chaturvedi, Director, ICAR-Central Agroforestry Research Institute (CAFRI), Jhansi on September 09, 2017
- Dr. A.K. Singh, Director, ICAR-Directorate of Coldwater Fisheries Research (DCFR) on September 10, 2017
- Shri Anand Zambre, Executive Director, NCPAH, MoA & FW, New Delhi on November 23, 2017
- Shri Sierra Glagfelter and EbenYonnetti from University of Colorado Boulder, Colorado, USA Fulbright Nehru Research Fellows on April 04, 2018
- Shri Soman Wangchuk, SECMOL on November 13, 2018
- Shri Sonam Gechen Agola Addl. Private Secretary to Union Minister of State for Home Affairs, Govt. of India on April 24, 2019
- Shri Jamyang Tsering Namgyal, Hon'ble Member of Parliament, Union Territory of Ladakh on December 21, 2020

- Dr. Desh Beer Singh, Director, ICAR-Central Institute of Temperate Horticulture (CITH) on April 09, 2021
- Shri Stanzin Chospel, Executive Councillor (Agriculture), Ladakh Autonomous Hill Development Council (LAHDC), Leh on June 17, 2021
- Shri Kailash Choudhry, Hon'ble MoS, Agriculture and Farmers Welfare, GoI on July 04, 2021
- Dr. Sustana Kumar Jena (Principal Scientist & Project Coordinator, CRP on water ICAR-IIWM Bhuvneshwar on June 23, 2022
- Dr. Dheer Singh NRDI Joint Director ICAR-Karnal on June 25, 2022
- Shri Bikramjit Singh Cheema, ICAR-GB Member on July 29, 2022.
- Dr. A.K. Singh, DDG (Agricultural Extension) ICAR on September 03, 2022
- Dr. Rameshwar Singh, Vice Chancellor Bihar Veterinary University Patna on September 12, 2022
- Shri Jai C. Rana Country Rep. Alliance of Bioversity & CIAT New Delhi on November 28, 2022

CAZRI®

Enhancing resilience of arid lands