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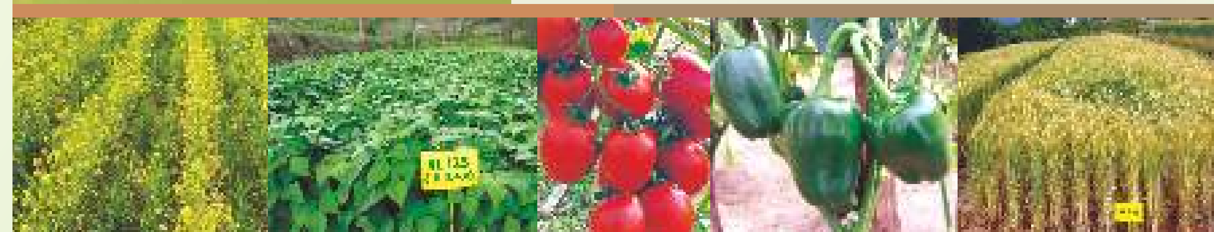

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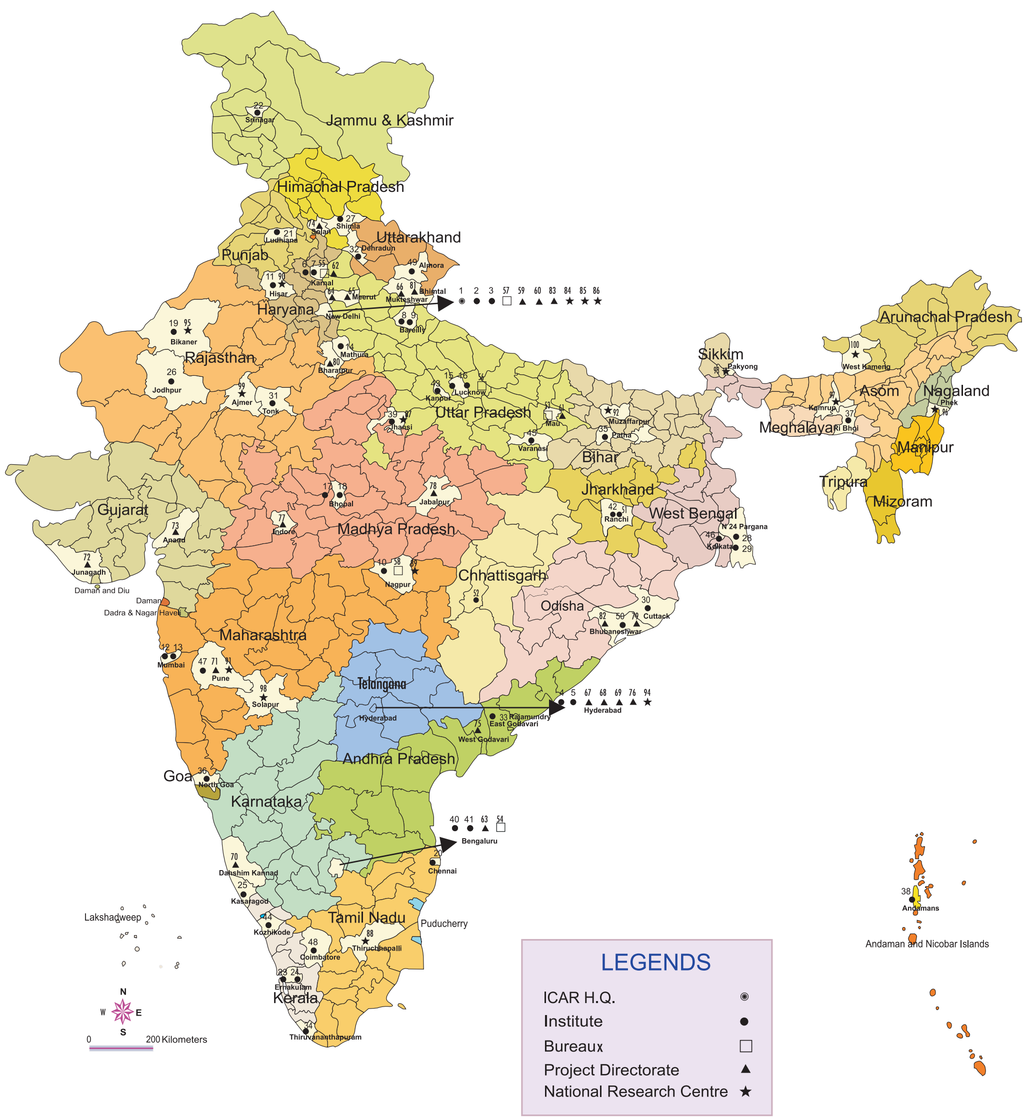

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Vision 2050

Vivekananda Parvatiya Krishi Anusandhan Sansthan
(Indian Council of Agricultural Research)
Almora 263 601
Uttarakhand

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संदेश

भारतीय सभ्यता कृषि विकास की एक आधार रही है और आज भी हमारे देश में एक सुदृढ़ कृषि व्यवस्था मौजूद है जिसका राष्ट्रीय सकल घरेलू उत्पाद और रोजगार में प्रमुख योगदान है। ग्रामीण युवाओं का बड़े पैमाने पर, विशेष रूप से शहरी क्षेत्रों में प्रवास होने के बावजूद, देश की लगभग दो-तिहाई आबादी के लिए आजीविका के साधन के रूप में, प्रत्यक्ष या अप्रत्यक्ष, कृषि की भूमिका में कोई बदलाव होने की उम्मीद नहीं की जाती है। अतः खाद्य, पोषण, पर्यावरण, आजीविका सुरक्षा के लिए तथा समावेशी विकास हासिल करने के लिए कृषि क्षेत्र में स्थायी विकास बहुत जरूरी है।

पिछले 50 वर्षों के दौरान हमारे कृषि अनुसंधान द्वारा सृजित की गई प्रौद्योगिकियों से भारतीय कृषि में बदलाव आया है। तथापि, भौतिक रूप से (मृदा, जल, जलवायु), बायोलोजिकल रूप से (जैव विविधता, हॉस्ट-परजीवी संबंध), अनुसंधान एवं शिक्षा में बदलाव के चलते तथा सूचना, ज्ञान और नीति एवं निवेश (जो कृषि उत्पादन को प्रभावित करने वाले कारक हैं) आज भी एक चुनौती बने हुए हैं। उत्पादन के परिवेश में बदलाव हमेशा ही होते आए हैं, परन्तु जिस गति से यह हो रहे हैं, वह एक चिंता का विषय है जो उपयुक्त प्रौद्योगिकी विकल्पों के आधार पर कृषि प्रणाली को और अधिक मजबूत करने की मांग करते हैं।

पिछली प्रवृत्तियों से सबक लेते हुए हम निश्चित रूप से भावी बेहतर कृषि परिदृश्य की कल्पना कर सकते हैं, जिसके लिए हमें विभिन्न तकनीकों और आकलनों के मॉडलों का उपयोग करना होगा तथा भविष्य के लिए एक ब्लूप्रिंट तैयार करना होगा। इसमें कोई संदेह नहीं है कि विज्ञान, प्रौद्योगिकी, सूचना, ज्ञान-जानकारी, सक्षम मानव संसाधन और निवेशों का बढ़ता प्रयोग भावी वृद्धि और विकास के प्रमुख निर्धारक होंगे।

इस संदर्भ में, भारतीय कृषि अनुसंधान परिषद के संस्थानों के लिए विजन-2050 की रूपरेखा तैयार की गई है। यह आशा की जाती है कि वर्तमान और उभरते परिदृश्य का बेहतर रूप से किया गया मूल्यांकन, मौजूदा नए अवसर और कृषि क्षेत्र की स्थायी वृद्धि और विकास के लिए आगामी दशकों हेतु प्रासंगिक अनुसंधान संबंधी मुद्दे तथा कार्यनीतिक फ्रेमवर्क काफी उपयोगी साबित होंगे।

(राधा मोहन सिंह)

केन्द्रीय कृषि मंत्री, भारत सरकार

Foreword

Indian Council of Agricultural Research, since inception in the year 1929, is spearheading national programmes on agricultural research, higher education and frontline extension through a network of Research Institutes, Agricultural Universities, All India Coordinated Research Projects and Krishi Vigyan Kendras to develop and demonstrate new technologies, as also to develop competent human resource for strengthening agriculture in all its dimensions, in the country. The science and technology-led development in agriculture has resulted in manifold enhancement in productivity and production of different crops and commodities to match the pace of growth in food demand.

Agricultural production environment, being a dynamic entity, has kept evolving continuously. The present phase of changes being encountered by the agricultural sector, such as reducing availability of quality water, nutrient deficiency in soils, climate change, farm energy availability, loss of biodiversity, emergence of new pest and diseases, fragmentation of farms, rural-urban migration, coupled with new IPRs and trade regulations, are some of the new challenges.

These changes impacting agriculture call for a paradigm shift in our research approach. We have to harness the potential of modern science, encourage innovations in technology generation, and provide for an enabling policy and investment support. Some of the critical areas as genomics, molecular breeding, diagnostics and vaccines, nanotechnology, secondary agriculture, farm mechanization, energy, and technology dissemination need to be given priority. Multi-disciplinary and multi-institutional research will be of paramount importance, given the fact that technology generation is increasingly getting knowledge and capital intensive. Our institutions of agricultural research and education must attain highest levels of excellence in development of technologies and competent human resource to effectively deal with the changing scenario.

Vision-2050 document of ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan (VPKAS), Almora, Uttarakhand has been prepared, based on a comprehensive assessment of past and present trends in factors that impact agriculture, to visualise scenario 35 years hence, towards science-led sustainable development of agriculture.

We are hopeful that in the years ahead, Vision-2050 would prove to be valuable in guiding our efforts in agricultural R&D and also for the young scientists who would shoulder the responsibility to generate farm technologies in future for food, nutrition, livelihood and environmental security of the billion plus population of the country, for all times to come.

(S. AYYAPPAN)
Secretary, Department of Agricultural Research & Education (DARE)
and Director-General, Indian Council of Agricultural Research (ICAR)
Krishi Bhavan, Dr Rajendra Prasad Road,
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Preface

"We cannot increase production with the same model as in the past. We must increase productivity in a sustainable way, particularly in developing countries and among small-scale farmers." – Jose Graziano da Silva, DG, FAO.

ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora, shoulders the responsibility of agricultural research and development to cater the needs of farming community in North-Western Himalayan region of India comprising the states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand (the mandate area of the institute). In its quest, the institute has developed more than 135 varieties and hybrids of different crops with suitable package of practices. The institute has also been disseminating location-specific technologies to the farmers to achieve an increased and sustainable crop production.

Agriculture in hills is practiced against a plethora of odds. The recent problem of climate change makes the hill agriculture suffer the most by changing the whole spectrum of rainfall. Prolonged periods of drizzle during the monsoon, like *Satjhar* (local term for continual drizzle for seven days), which served the purpose of saturating hills for round the year water availability, is a thing of past now. Instead, droughts, flash floods and cloudbursts are a commonplace at present. The unprecedented emergence of new pests and diseases has also been observed, and the phenomenon seems to be alarming in the future. Thus, we must reorient our focus towards increasing productivity in a sustainable manner visualizing the future, including the distant future, opportunities and challenges.

The institute has prepared "Vision 2050" taking the agriculture scenario of Himalayan region (both North Eastern and North Western) into consideration for envisioning the future developments. Though the achievements of the institute have played a key role in changing the face of hill agriculture in many ways, the changes apprehended in the future are seemed to be considerably more challenging in the era of climate change, globalization and liberalization. The fragile ecosystem with frequent occurrence of natural calamities, migration of workforce to plains, threat posed by wildlife to agriculture and humans, make the situation much worse. However, even with all these challenges, the unique agro-climatic condition of the region provides a competitive edge over other areas for the cultivation of off season vegetables, temperate fruits, medicinal and aromatic plants etc. Traditional crops of the region offer an opportunity to get nutria-rich high-value products leading to economically viable farming. Organic agriculture, practiced by default in the hills, if properly encashed will be an additional advantage. The Himalayan hills are endowed with valuable natural resources and massive agro-biodiversity, which need to be conserved and utilised in a sustainable manner. Climate smart agriculture, precision farming, optimal utilisation of natural resources and input use efficiency are the areas to be focused upon. Nutrifarming, agro-processing, value addition along with mushroom cultivation, apiculture, quality milk and milk products, and fish farming are to be given importance in view of lucrative economic returns and small land holdings. Research in frontier areas such as nano biotechnology, bio-prospecting, allele mining, system biology, conservation agriculture, soil health management, market intelligence has to be envisioned. Topography-specific farm mechanization and light weight tools and equipment will play a major role in increasing productivity along with reducing drudgery. Effective extension strategies, use of high-tech devices for faster dissemination of agro technologies, precise market intelligences are needed to connect the farming communities residing in remotest hilly areas. Adhering to the strategies presented in the document will, humbly speaking, be a correct step towards the consummation of the famous quote of Swami Vivekananda (after whom the institute is named): "So far as a single dog is hungry in the country, my religion is find food for dog".

I place on record my sincere gratitude to Dr. S. Ayyappan, Secretary (DARE) and Director-General (ICAR) for his guidance in the conceptualization of the document. I am also grateful to DDG (CS) and ADG (FFC) for their suggestions and critical inputs for bringing out this document. I also thank all scientific staff of the institute, especially Drs. J. K. Bisht, Lakshmi Kant, J. Stanley, Dibakar Mahanta, Arun Kumar R, Anuradha Bhartiya, Ramesh P. Singh, Atheequlla GA, Anirban Mukherjee, Rajsekara H and V.S. Meena for their contribution in the development of the document.

A. Pattanayak
Director
ICAR-VPKAS, Almora

Contents

Context

Vivekananda Parvatiya Krishi Anusandhan Sansthan (ICAR–VPKAS), Almora, established by Professor Boshi Sen in 1924, became a constituent institute of ICAR in 1974. It is one of the multi-disciplinary multi-crop institutes of the ICAR. The institute is located at Almora (1600 m amsl, latitude 29°35' N, longitude 79°39' E) in Uttarakhand hills with its experimental farm at Hawalbagh (1250m amsl, latitude 29° 36' N, longitude 79° 40' E). The institute has two Krishi Vigyan Kendras (KVKs): one at Chinyalisaur (Dist. Uttarkashi), in Garhwal division and another at Kafligair (Dist. Bageshwar), in Kumaon division of Uttarakhand. It has networking with ICAR institutes, SAUs and KVKs spread across the North-Western Hills through All India Coordinated Research Projects and MoUs with different SAUs as well as NGOs working in the zone. The institute focuses on research in agriculture to enhance food, feed, nutritional and livelihood security in hills. ICAR-VPKAS is entrusted with catering the needs of agricultural research for development of North-Western Himalayan (NWH) states, *viz.*, Uttarakhand (UK), Himachal Pradesh (H.P.) and Jammu and Kashmir (J&K).

The mandate of the institute covers:

- Basic and strategic research on: (i) improving productivity and quality of important hill crops and (ii) conservation and efficient utilization of natural resources.
- Development of ecologically sound and economically viable agro-production, protection and post-harvest technologies for different growing conditions of hills.
- Transfer of technology, research on extension methodology, organization of specialized training programmes and consultancy on hill agriculture.

The research efforts of the institute have led to the development of high yielding, disease resistant varieties suited for rainfed and irrigated conditions; development of suitable crop production and protection technologies; conservation and management of rain water and nutrients; fodder production and dissemination of improved technology to the farmers of the region. The collection, evaluation and maintenance of germplasm from unexplored areas; breeding through conventional methods and biotechnology for biotic and abiotic stresses; monitoring of pests and soil health hazards, integrated pest management; development of appropriate eco-friendly crop production technologies; more remunerative cropping systems; organic farming; protected cultivation; designing suitable farm implements for farm mechanization and reduction of drudgery and cost of cultivation; enhancing the availability of fodder and effective dissemination of crop production technologies have been the major research programmes during the last decade to achieve the higher levels of food and fodder production and ensuring the nutritional security.

Significant Contributions

The institute has made significant contributions in the improvement of hill crops as well as resource and pest management. The most notable contribution of the institute is the development and release of 135 improved varieties and hybrids in 25 hill crops. These varieties possess a high-yield potential under different hill conditions and are endowed with resistance/tolerance to biotic and abiotic stresses. Their crop production and pest management technologies have also been worked out.

Genetic wealth of the institute consists of more than 11,000 native and exotic accessions of wheat, rice, maize, small millets, pulses, oilseeds and vegetables, which are maintained, documented and utilized for crop improvement. Development and release of QPM version of Vivek Maize Hybrid 9, having 30 and 40% more lysine and tryptophan, respectively, coupled with 10% higher yield compared to its non-QPM counterpart, is one of the successful examples of using marker aided selection (MAS) for crop improvement.

Other significant contributions of the institute include in the development of remunerative intensive sequential cropping, intercropping, relay intercropping systems as well as integrated cropping system modules for better management of resources to optimize yield from different production conditions (organic as well as inorganic) of hills. Though hills are known as the water tower of the world still water has been a scarce commodity in hills as most of the water runs away to plains. The institute has designed, developed and standardized low cost water storage MLCL (multi layered cross laminated) film-lined tanks for water harvesting and enhancing the water use efficiency through integration of the micro-irrigation system. The large-scale demonstration of these technologies in adopted villages has resulted in increasing the water use efficiency by about 70% over the flood irrigation.

In the light of ongoing climate changes, green houses can play a key role to boost the economy of hill farmers, if managed suitably.

The institute has standardized the structural design of green houses and suitable off-season vegetable sequences for green house cultivation. Successful demonstration of greenhouse technology for vegetable production in Bhagartola village of District Almora has resulted in doubling the vegetable production in the village.

Hill agriculture is predominantly drudgery prone, as mechanization is difficult due to peculiar topography of hills. The institute has made significant contributions in design, development and commercialization of small farm implements and tools suitable for mechanization of agriculture in hills. Vivek Millet Thresher, VL Paddy Thresher, VL Seed-cum-Ferti drill, VL Syahi *Hal* and other small farm implements have helped tremendously to reduce the drudgery in the related operations.

Management of white grub and beetle (a menace to hill agriculture) has been developed and successfully demonstrated. A low-cost insect trap has been designed for trapping beetles of white grub (species of *Anomala*, *Holotrichia*, *etc.*), whereas a talc-based bacterial formulation of *Bacillus cereus* WGPSB-2 has been developed for managing the grubs. Management of beetles as well as grubs through insect trap and bacterial formulation has shown a reduction of 70-90% grub population in two years in 18 adopted villages spread across Uttarakhand.

Button and oyster mushroom cultivation, a profitable venture, particularly for landless farmers, has been standardized and popularized. Daulaghat, a village near Almora has been evolved as a mushroom village. Some of the farmers have entered in value addition of mushroom and have benefitted a lot by this intervention.

Fodder is one of the most important components of hill agriculture. The institute has identified suitable species of fodder grasses, legumes and trees. Hand in hand, agro-techniques for production of fodders on terrace risers, degraded sloping lands, forest floor and wetland sites as well as dual-purpose wheat varieties, viz., VL *Gehun* 616 and VL *Gehun* 829, have been developed.

Present Scenerio

Hills and mountains are fragile ecosystems yet globally important in terms of being water towers of the earth and repository of rich bio-diversity, occupying 20% of world's land and providing life-support to 10% of humankind and about 40% people occupying adjacent medium and lower areas (Spehn *et al.*, 2005). The hilly and mountainous areas in India vastly distributed all over the country with a larger area located in the Himalayas, extending up to 2500 km in length and 250 to 400 km in breadth, Longitudinally; Himalayas are also classified as Shivalik's flat summits (600-1200m msl altitude), Middle Himalayas (65-75km width, average height 3000 m), Greater Himalayas (average altitude 5,200m),), and Trans Himalayas (average width 60km, average altitude 4500 m). In addition to the mighty Himalayas, the areas categorized as Hill and Mountain Zones, are distributed in 23 states, *viz.*, Andhra Pradesh, Assam, Bihar, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Mizoram, Nagaland, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and West Bengal. The majority of these areas has slope above 15%, which covers 35% of the total geographical area of the country (Barah, 2010).

i. The Himalayan region is further classified in three major categories comprising, (i) North Western Himalayas (NWH): Jammu and Kashmir, Uttarakhand and Himachal Pradesh; (ii) North Eastern Himalayas (NEH): Sikkim, Manipur, Meghalaya, Nagaland, Tripura, Arunachal Pradesh, Mizoram, hilly areas of Assam and Darjeeling district of West Bengal; (iii) Trans-Himalayas (TH): Tibet and Central Himalayas as well as Nepal, which is outside the territory of India.

There are four distinct agricultural production zones in Himalayan region of which zone I (low hills), and zone II (mid hills) are strategically important for agriculture. Himalayas are capable of supporting production of a variety of crops because of varied agro-climatic conditions. However, in recent times the environmental degradation due to faster deforestation, unrestricted grazing and destruction of vegetation pose a threat to hill agriculture. Unprecedented extreme events of climate like cloud bursts, flash floods, hailstorms, drought, *etc.* have worsened the situation. Hill agriculture is sustainable but degradation of water resources, erratic rainfall pattern, non-availability of inputs and soil fertility depletion at a high rate hinder the sustainability of crop productivity in hills. However, the diverse agro-climatic conditions impart unique advantage and competitive edge over other states (of plain region) for cultivation of off-season vegetables, temperate fruits, production of organic fruits and vegetables, aromatic rice as well as medicinal and aromatic plants, fisheries, quality milk and milk products. However, poor marketing infrastructure as well as transport facilities for high value perishable cash crops reduce net return and diminish farmers' interest in these crops.

The document '**Vision 2050**' compiles the key challenges and opportunities in hill agriculture that are anticipated in the next four decades to develop multi pronged strategies for sustainable growth of hill agriculture in future to contribute significantly at national as well as international scenario.

Future Prospects

The research achievements of the institute have been playing a significant role in changing the face of hill agriculture from sustenance to sustainable. The example of model villages developed by the institute has proven that hill agriculture can be a profitable venture and has attracted the migrated youths back to the villages. However, the changes which are expected in future hill agriculture are going to be much more challenging. The climate changes, experienced in the recent past and predicted in the future, pose new challenges like shift in crop seasons. Therefore, the search for suitable varieties and management techniques, alternative crops to respond better to the climate change situation to feed the ever increasing population, threats of new diseases and pests or new races of already existing diseases and pests and their management strategies, changed socio-economic scenario due to globalization and strategies for their management, etc., are the major tasks ahead to be tackled.

Research on physiological mechanism of crop growth in major hill crops under organic and inorganic conditions and evaluation of effects of multiple stresses, elevated CO_2 levels and low light intensities on grain yield **for "CLIMATE SMART AGRICULTURE"** and contingency crop planning to mitigate the aberrations of the climate change in which studies on root architecture and rhizosphere engineering for higher abiotic stress tolerance and resource use efficiency would be important. Molecular profiling and allele mining in major hill crops for in-depth understanding of the molecular mechanism and their exploitation for higher grain yield, bio-fortification of crops for micronutrients, QTL mapping for agronomic traits, disease resistance and quality traits in major hill crops will help in MAS.

GIS-based digital evaluation models and other tools would help in precise measurement of resource base. Conservation agriculture, zero tillage, water harvesting and micro-irrigation have a great potential in the future, particularly in view of climate change and these need to be perfected for different future production conditions of hills. Efficient farming systems, incorporating integrated crop, nutrient, pest and water management, need to be further fine-tuned for wider adaptability. In future, natural resource management will have to play a pivotal role. Therefore, conservation and optimal utilization of natural resources and enhancement in water and nutrient use efficiency would have to be researched upon. To create job opportunities and attract youth to agriculture and allied industries, concerted research efforts would be made to refine value addition and other post-harvest technologies to make them more user-friendly and affordable to small farmers. Mechanization in hill farming is required to extenuate drudgery with the simultaneous increase in productivity through use of integrated farming system approach. Focus will continue to be on developing light-weight, affordable and efficient tools and equipment required for farm operations and post-harvest handling. Information will hold the key in future, thus, efficient utilization of ICT and futuristic information technology tools for dissemination of agricultural information will also be investigated. ❑

Challenges

Farming in mountains is as diverse as the myriad mountain landscapes of the world. The NE and NW hills of India even experience a vast difference in climatic conditions and thus the pattern of agriculture itself. However, the challenges of hill farmers are almost common. The challenges to hill agriculture in the future are going to be enormous with fast depleting resources, unpredictable weather and changing climate, migration of youths due to unprofitable agriculture and feeding the ever increasing population. Some of the most important challenges are given as under:

1. Productivity Requirements for 2050 vis-à-vis Present Productivity for Different Agricultural Commodities

There is a wide gap between the projected productivity of crops in 2050 and current yield levels in both NE and NW Himalayas (Tables 1). Among all major hill crops, the disparities for oilseeds and pulses are far wider, which need a quantum jump in productivity to realize the projected requirement. In NW Himalayas, current productivity levels of vegetables is almost comparable to the projected yield levels but dismal in NE Hills and to fulfill the future requirement focused efforts are needed.

Table 1 Productivity requirement for 2050 vis-à-vis 20011-12 productivity of major hill crops

Crops	Region	Require-ment ('000 t)	Present area (000ha)	Required productivity (kg/ha) *	Present productivity (kg/ha)	Productivity surplus/ deficit (%)
Cereal & millets	NEH	3426.9	1216.4	2817	1986.29	-29.49
	NWH	6178.9	2568.1	2406	1894.67	-21.25
Pulses	NEH	395.8	92.9	4260	1003.28	-76.45
	NWH	713.7	113.3	6299	784.33	-87.55
Oilseeds	NEH	791.6	158.8	13107	881.57	-93.27
	NWH	1427.4	109.5	13036	829	-93.64
Vegetables	NEH	2364.1	196.2	15798	9500	-39.87
	NWH	4262.6	238.1	17903	17400	-2.81

Projected population in 2050('000)- North Eastern Hill (NEH)-21689; North Western Hill (NWH)-39106.695

- Requirement (Cereal & millets @ 158 kg/capita/annum; Pulses @ 18.25 kg/capita/annum; Oilseeds @ 36.5 kg/capita/annum; Vegetables @ 109 kg/capita/annum)

* - On the basis of 2011-12 area Source - (Fertilizer Statistics 2012-13)

2. Low Productivity of Crops

In general, the productivity of the crops is low in hills as compared to that of the country. For food grains, H.P., Nagaland, Uttarakhand, Arunachal Pradesh, Tripura and Sikkim are self-reliant whereas J&K, Meghalaya, Mizoram and Manipur suffer a deficit, however, as a whole, NWH is self-sufficient whereas NEH suffers deficient. The surplus in food grains is chiefly due to cereals and millets, and all the states are way behind in pulses except Sikkim. All the states suffer a substantial deficit for oilseeds. Vegetables in the region mimic the food grains situation. This self-reliance of the region in terms of food grains is chiefly due to the lion's share contributed by plains of the region.

3. Impact of Climate Change

During the period 1901 – 2003, an increasing trend was observed in annual minimum temperature (Sonali and Kumar, 2013). In western Himalayas during December, January, February months (1975 to 2013) the number of cold nights is decreasing and number of warm nights increasing. The changes in the day and night time temperatures are not symmetrical and warming is more pronounced in the day time. Annual rainfall data (1964 to 2010) of Hawalbagh, revealed an increasing trend until 1986 thereafter, decreasing. Only 16 drought (5 severe) years were observed during 1964-2000 whereas, 7 drought (3 severe) years in next ten years. In recent years, drought stress has been observed in initial stage and cold stress at the grain filling stage of *kharif* crops, and low rainfall has caused significant reduction in *rabi* crop yields.

The climate change has facilitated the appearance of some new diseases, insects and new races of pathogens resulting greater degree of damage. In addition to drought and temperature stresses, the effect of elevated CO_2, UV rays, ozone, light intensity (low/high) and weather extreme events on crop plants have posed a serious threat, therefore, tolerant genotypes suitable for changing climatic/weather conditions. Various components of agriculture, *i.e.,* crops, fruits, fisheries, livestock, *etc.*, are affected adversely due to climate change/variability.

4. Poor Marketing Facility and Inadequate Infrastructure

A sharp increase in production of vegetables and fruits is realized in the hills in the recent past but could not be translated into better economic returns to the farmers. The marketing network is almost non-existent in the hills; therefore, farmers are forced to sell their produce at very less or nominal prices either to big traders in the plains (who are the source of assured credit for the farmers) or the middlemen. In addition, the poor network of road, in-turn poor transport as well as topography of the hill states is also not favorable for the quick movement of the produce. No major industry exists in the hills, and about 5,000 villages (58%) in Uttarakhand remain cut off from proper roads (Planning Commission report, 2011). Besides, the present procurement practices, marketing approaches, poor storage and processing facilities are also constraints in the rural marketing.

5. Problem of Migration

Agriculture, once the backbone of village economy has no longer remained a holding force to stop migration. The migration of youth has increased manifold because of easy and lucrative jobs available in the industries set up in adjacent foot hill/plains. Unemployment, wild animal menace, frequent occurrence of unprecedented extreme natural calamities (Kedarnath and Kashmir flood) *etc.* has further aggravated the situation. The problem of migration is crucial from the strategic and national security point too as out of the 7581 km long international border in the Himalayas; 3488 km is shared with China. The Uttarakhand state's statistics department claims that 1,065 villages have permanently turned into 'ghost villages' because of migration (Chopra, 2014).

6. Wild Life Menace

Crop and livestock depredation by wildlife such as wild boars, monkeys, deer species, bear, porcupine and wolves are increasingly viewed as agricultural pests. The total estimated value of crop yield losses due to wildlife damage in buffer zone villages located near Nanda Devi Biosphere Reserve, Uttarakhand during 1996-97 is about Rs. 5.38 lakhs; monkey and wild boar alone accounted for about 50-60% of total crop damage (Rao *et al.*, 2002). Even in a protected farm like ICAR–VPKAS, Hawalbagh, increasing damage by vertebrate pests in crops and fruit trees sometimes leads to total failure of the crop.

7. Animal Husbandry and Fishery

Livestock is an integral part of hill farming. It is one of the major sources of protein in the form of milk and meat, manure and draught power. More than 90% of the animals in these areas belong to local breeds of low productivity. The high population of these stocks is causing a substantial feed deficit as well as imbalance for the ecosystem by overgrazing of the pasture and hill slopes. The situation is further aggravated by unscientific nutrition and stock management, limited housing space, poor veterinary services leading to higher morbidity and mortality, low purchasing power and risk bearing ability of farmers.

Fishes are the source of high quality and inexpensive animal protein, crucial for marginal food secure communities. Huge availability of lakes, streams, rivers and reservoirs has potential but remains invariably untapped due to lack of proper market, non-availability of quality fish seed and feed, policy support as well as unawareness of farmers for intensive fish farming.

Backyard poultry farming is a traditional and age-old practice of rural communities to provide small but regular source of income. However, low productive native germplasm, predators and health disorders, inappropriate institutional credit and policy support, lack of feed industry are the major bottlenecks in large-scale promotion of poultry industry.

8. Untapped Potential of Horticulture and Post-harvest Technology

Himalayan hills are most suitable for a large variety of horticultural crops, including temperate fruits, vegetables, flowers, spices, condiments, medicinal and aromatic plants, *etc*. Among the fruits, apple, peach, pear, plum, apricot, walnut, guava and citrus spp. are the major ones. The horticultural crops have the huge potential for bringing economic prosperity, but this could not be realized at present due to poor production and quality of senile orchards, long gestation period fruit varieties, highly perishable nature of produce, lack of adequate transport, communication, market channels and intelligences, etc. Climate change has further adversely affected the horticultural crops. The post-harvest industries are meager in these areas owing to which almost 20 to 25% of fruits go as a waste every year.

9. Insufficient Fodder Production and Availability

The fodder requirement of NWH states is 135 million tonnes to feed 26 million cattle population. However, the availability of fodder in the region is inadequate and, therefore, faces 54% deficit in green fodder and 34% deficit in dry fodder. With the changing scenario where the resources are shrinking and demand for dry and green fodder is expected to increase, meeting the fodder demand will be one of the major challenges in the future.

10. Dissemination of Agriculture Information/Knowledge to the Clientele

A lot of information on hill agriculture has been generated during the past to enhance the productivity of hill crops in NWH as is evident from the frontline demonstrations and other outreach programmes.

However, in the absence of an effective extension system, a lot of technological information is yet to be transferred to the farmers. This creates a huge gap in terms of difference in potential and realized productivity levels at farmers' fields.

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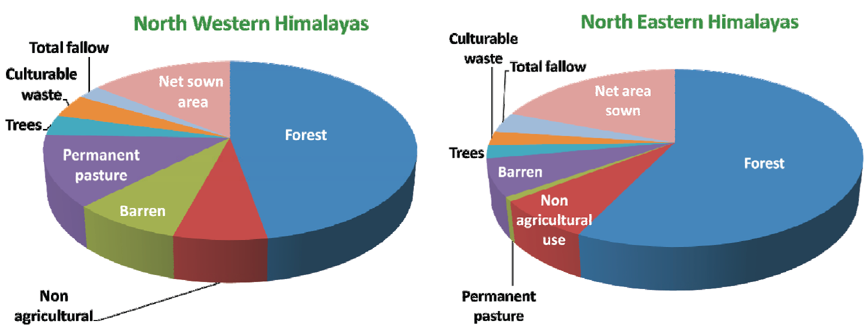
Operating Environment

The institute's mandate covers the NWH region spread over 33.1 million ha area. Agriculture is the keystone to this region as 78.6% population resides in rural areas. The contribution of agriculture and allied sectors to the state GDP is around 20%.

Agricultural Scenario in Himalayan Region

The land utilization pattern has been presented in Fig.1. Forests cover the largest land area, being more than double to that of national percentage. A low level of developmental activities is pointed by a relatively less area put to non-agricultural use. Around 7-8 per cent of barren area, in NWH and NEH, indicates the need for developing alternative land use. NWH has a sizeable area under permanent pastures and other grazing lands, which is a great support to livestock. Culturable waste, almost equal in both regions, is probably due to migration from rural areas and calls for creating more opportunities for employment in rural areas to check migration and culturable waste. Total fallow in both the regions is less than the All India level. The net area sown (NWH-19 and NEH-14 per cent) in the region is far below the national average, which is due to high forest cover. The cropping intensity in NWH states is quite high compared to that of NEH as well as All India, which can be further enhanced by introducing crops and/or crop varieties suitable for the areas where keeping land fallow or mono-cropping is practiced.

The crop production systems in NWH region are based on agriculture (field crops), olericulture, horticulture or agri-horticulture, and



Source : *Fertilizer Statistics 2012-13*

Fig. 1 Land utilization (% of total reported area) pattern in Indian Himalayas agroforestry/agri-horti-silvi-pastoral system whereas, in NE Himalayas, sericulture is embedded with the agriculture and horticulture-cum-plantation crops based production system such as agri-seri-horticulture or agri-horti-sericulture system. Livestock is inseparable part of the system in the region. However, fishery and floriculture are also the parts of the production system in certain areas. Wheat, rice, maize, finger millet and barnyard millet are the major cereals and millets of the region and black gram, horse gram, ricebean, *rajma* (a pulse version of French bean, which is a highly remunerative crop) and bhat (a variant of soybean, which is used as a pulse and has better quality fats and proteins to make it tastier and more digestible than the common soybean, which is primarily used as an oilseed) are the major pulse crops. Mustard and soybean constitute the major oilseed crops. Among vegetables, cole crops, cucurbits, capsicum, tomato, radish, pea, french bean, potato and onions are the major crops.

The region is riddled with a number of problems. From agriculture point of view, these can be categorized as regional and agriculture-related problems. Among regional problems, the major ones are - hill physiography makes places difficult to access and sparsely inhabitable, seismic sensitivity, water tower to plains yet a very little of water it generates is utilized locally, large magnitude of soil loss, sloping terrain and thin soil cover leads to slow recovery of the ecosystem from natural and human disturbances, high temporal variations in climate and uncertain weather, relatively low temperature throughout and high rate of migration of youths to greener pastures.

The agriculture related problems are - small and fragmented land holdings; low risk bearing capacity due to poor economic condition; largely rainfed agriculture, for example, the net irrigated area in hills of Uttarakhand is only 40,822 ha compared to 2,96,874 ha area in plains, *i.e.,* hills enjoy only 12.1% of the total net irrigated area in the state; modest soil fertility; age-old farming practices; low input use, *viz*., the fertilizer consumption in hill districts ranges from 65 to 666 thousand tonnes against 31,851 and 73,768 thousand tonnes in Haridwar and Udham Singh Nagar, respectively, which are plain districts (Mittal, *et al.*, 2008); negligible farm mechanization; a certain degree of reluctance to agriculture as the preferred occupation due to low returns; unawareness of improved technologies; extremely insignificant extension infrastructure and inadequate extension efforts; huge gap in research farm and farmer's field yields; women dominant agriculture with scrimpy male contribution; inefficient and insufficient marketing base; wide weather and climatic variation presents a multitude of problems to agricultural researchers and planners to cope with; livestock are one of the main components of hill farming, but there is a great paucity of green and dry fodder; the majority of livestock are of local breed and there is an acute shortage of livestock improvement facilities and poultry hatcheries; and sizeable post-harvest loss to fruits and vegetables on account of lack of storage facility, poor transport facilities and processing units.

The climate change has put forth an entirely different scenario of biotic and abiotic stresses, *e.g.,* (i) heavy incidence of brown plant hopper (*Nilaparvata lugens*) was noticed for the first time in some rice-growing areas of Uttarakhand during 2010 (ii) high severity of yellow rust was observed during late-February to mid-March in wheat in 2011, and (iii) a very low winter rainfall had resulted in a dismal wheat crop in many rainfed areas during past four years (iv) adverse effect of increasing maximum temperature and sunshine hours of February months on wheat yield (v) reduction in crop productivity due to agricultural pest and plant pathogens in cold arid trans-Himalayan Ladakh region (Vaish et al., 2011) (vi) The damage caused by wild animals, like monkeys and boars, has assumed menacing proportions in recent years.

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Opportunities

Himalayan hills harbour rich genetic diversity in the form of landraces, farmers' varieties, ecotypes, weedy and wild relatives, which offers opportunities for discovery of novel genes, expanding the gene pools for further improvement in crops, fruits, trees, livestock, *etc*. and exploring the potential geographical indications (GI). Further the development of specialty crop varieties like QPM, sweet corn and popcorn in maize, product-specific wheat, finger millet, rajmash (pulse french bean), horsegram (as a remedy for kidney stones) and *bhat* (a variant of soybean with high level of protein and healthy fats) generate great opportunities. As there is a wide gap between demand and production of pulses and oilseeds in the region, a lot of scope exists to improve pulse and oilseed production to bridge this gap. Bio-fortification to extenuate malnutrition also presents a key area to ensure nutritional security in hilly areas. Popularization of profitable crop rotations, utilization of fallow land with a short-duration crop like *toria* for increasing cropping intensity, adoption of watershed approach for holistic development and high-value crop production in assured input areas put forth a suitable strategy for enhancing crop production in hills.

Organic farming is increasingly becoming popular because of the perceived health and environment benefits. The traditional knowledge and practices of organic farming have almost sustained in Himalayan regions, although, it is eroded from many parts of India due to the influx of modern "green revolution" technologies. For many (especially small and marginal) farmers in Himalayas, the purchase of manufactured fertilizers and pesticides is and will continue to be constrained by their high costs and unavailability. This may be a profitable venture as the organic produce can be marketed within and outside the country with premium price. In addition, organic agriculture will emit less green house gases than intensive modern agriculture that will be helpful in mitigating climate change.

Comparatively cooler climate in hills provides congenial environment for cultivation of high value off-season and European vegetables, medicinal, aromatic plants and flowers. With the development of IT based marketing infrastructure, market intelligence, intensive agriculture, storage capacities, secondary agriculture interventions, these enterprises may attract the youth workforce, check migration and bring prosperity in hills. Niche specific potential of hills can be exploited by setting up seed industry in hills for export of high-value low volume crops like temperate vegetables. This will generate huge employment opportunities; engage the local workforce and higher economic returns. Protected cultivation has a great scope being ideal for small and marginal farmers of hills due to lower running cost as compared to plains. In higher hills, this is one of the viable solutions during extreme winter months. The institute has demonstrated this technology in some of the villages and can be extended further in future with newer technologies, crop rotations and better water use efficient devices.

Himalayan ecosystem is enriched with a large number of Apis (honey bees) and non-Apis (bumble, little, orchid, blue, carpenter bees *etc.*) pollinators, which has a great role in pollinating the crops and fruits. Presently, a great scope exists for other bees and non-Apis pollinators to be exploited commercially after exploring the suitable techniques for their domestication. Promoting apiculture for a two-pronged advantage of procuring honey along with an increased level of pollination in crops is also a viable proposition to the groups of farmers.

Mushroom production and its value addition are profitable ventures for farmers having small land holdings. This enterprise has comparative advantages in hills due to lesser cost of production, longer supply duration as compared to plains owing to favourable climatic conditions in hills. In addition, some entrepreneurs may indulge in mushroom compost production at block or district level and provide employment to others too.

Due to non-suitability to the large-scale mechanization, hill agriculture is drudgery prone. Therefore, there is huge scope for the design and development of small and light-weight farm implements for farm mechanization in hills and consequent, drudgery reduction. Devising equipment to drive away the rogue wild animals will attract a lot of farmers back to agriculture who has left it just because of devastating wild animal damage to the crops.

In future, management of natural resources for sustainable crop production is going to play a very important role. Therefore, developing strategies for resource conservation, their efficient management for sustainability and remuneration has to be given due importance. Exploring and tapping the potential of locally available bio-agents and botanicals to combat pests will also be an important area to reduce the pesticide load and will be a boon to organic farming. As an example, a *Bacillus thuringiensis* strain VL Bt6 is found effective against many of the lepidopteran pests and seed powder of *Melia azedarach* was found effective to repel cutworms in capsicum. Besides, integrated plant nutrient and pest management modules have also to be devised for optimizing the production.

Livestock is one of the most important components and practiced as a profitable venture in rocky mountain ranges of the world. In NW hills, there is a huge gap between demand and supply of fodder. This gap is going to be wider in the future, particularly in view of shrinking land and other resources. The technologies like production of Hybrid Napier on terrace risers, wasteland and forest floor to elevate fodder availability, development of dual (grain-cum-fodder) crop varieties will help to bridge this gap.

Water use efficiency in hills is a matter of concern. Though endowed with plenty of water resources and ample rainfall but most of it goes unutilized for several reasons. In such situation, water harvesting and use of the micro-irrigation system (MIS) become crucial to enhance water use efficiency and production. The institute's technology of MLCL film lined tank is an attractive alternative to the concrete tank to store irrigation water at a lower cost with the added advantage of being far more crack tolerant. This technology, coupled with polyhouse and MIS can greatly enhance water use efficiency. Further, refinement of these technologies to suit the local needs and utilization of locally available materials will help in faster adoption of this technology.

Value addition will be an instrumental area of operation to make hill agriculture a viable profitable venture and generate employment. There is a huge scope for design and development of small processing units for value addition and reduction of post-harvest losses and packaging units to extend shelf life and make goods more presentable. Successful operation of agro-processing centres established by the institute in three villages of Uttarakhand has shown the potential of this enterprise.

Application of information and communication technology (ICT) for extension of agricultural technology and farmer's help is going to play a pivotal role in times to come. Therefore, development of suitable models for technology dissemination opens a new vista. Replication of successful models, like integrated village development program in Bhagartola (District Almora, Uttrarakhand), to the greatest possible extent in the region and creation of an efficient cooperative system for marketing of vegetables, flowers and specialty goods such as organic produce and locality specific commodities like Munsyari *rajma* and Dunagiri *mooli* will also help to convert hill agriculture into a lucrative venture.

Under changing climate scenario, IPCC has predicted elevated temperature and carbon-di-oxide in Himalayan ecosystem. This would be playing a major role in increasing productivity of most hill crops. However, the chilling requirement of apple will not be fulfilled in the mid Himalayas. These areas may be occupied by the sub-tropical fruits. These changed climatic conditions will further provide opportunities for enhancing cultivation of vegetable, medicinal, aromatic, spices, flowers, *etc.* as new crops to these areas along with more productivity. Further, the elevated temperature would be more congenial in rearing of goats and poultry farming in hills, which is being hampered by low temperatures, especially in winter seasons, at present. Improved soil quality would be the snowball effect of this, leading to climate resilient organic agriculture.

Plausible and implementable hill specific policies for land consolidation, crop insurance and micro-credit need to be devised for hill agriculture. Evolving pathways to tap the potential of public-private-partnership, involvement of line departments, NGOs, SHGs and farmer groups for effective and wider diffusion of research output will contribute immensely to the growth of hill agriculture.

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Goals and Targets

The institute aims at enhancing crop productivity and ecological sustainability of hill agriculture through technology dissemination with the following targets for the accomplishment:

Genetic Enhancement of Crops

- Varietal development for higher productivity under changing climatic conditions, multiple stress tolerance (drought/heat/cold and low light intensity stresses), better photosynthetic and input use efficiency and quality.
- Basic and strategic research related to physiology, biochemistry, genomics, phenomics, metabolomics and nanotechnology for yield and agronomic trait enhancement.

Resource Management for Hill Farming System

- Improvement of soil health and resilience; resource use efficiency; root architecture and rhizosphere engineering to combat abiotic stress, bio-prospecting of microorganisms; renewable energy management, non arable land management (integrated resource conservation and fodder, fuel and multipurpose tree farming) *etc.*
- Models for site specific integrated farming system on the basis of carbon leaching, sustainable resource conservation technology and water harvesting; space intensified protected cultivation, terrain specific farm mechanization and drudgery reduction, development of energy efficient cropping system and agronomic practices.
- Risk minimization by developing suitable agronomic practices which are climate resilient; produce less green house gas emission and enhance carbon sequestration; monitoring pesticides load, particularly in fruits and vegetables for export; and post-harvest management.
- Development/identification of microbial stimulant and enzymes for accelerated and improved degradation of pine needles for mushroom compost preparation. Cataloguing and conservation of wild edible mushrooms and bringing them under cultivation.

Management of Diseases and Pests of Crops

- Deciphering deviant disease and insect-pest scenario and host-pathogen interaction in hill crops under changing climate.

- Serological and molecular detection of phytopathogens, bioprotectants and immuno-localisation of pathogens through plant defensive proteins.
- Sensor based early detection of plant pathogens and insect pests of different hill crops and automated plant health management.
- Location-specific, bio-intensive pest and disease management with the integration of bio-pesticides (preferably, using locally available materials), cultural practices and safer pesticides.

Transfer of Technology

Tapping the potential of high-tech devices, virtual learning models, internet, public-private partnership, involvement of line departments, NGOs, SHGs and farmer groups for effective and wider diffusion of research output, devising marketing strategies for farm produces, determination of gender-specific resource use pattern and farmer especially women health status.

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Way Forward

In order to achieve above goals/target the following strategies will be deployed:

Varietal Development Using Conventional and Molecular Approaches

- Synergy between conventional and molecular breeding for developing varieties in major hill crops to combat biotic and abiotic stresses and quality traits. Molecular profiling and allele mining, in-depth understanding of the molecular mechanism, their exploitation for higher grain yield, biofortification of crops for micronutrients, QTL mapping for agronomic traits, root architecture, disease resistance and quality traits in major hill crops to help in MAS.
- Transgenics maize having Bt gene for insect resistance, herbicide-tolerant maize, transgenic rice for resistance against biotic like stem borer, sheath blight *etc.*, tolerance to abiotic stresses like drought and cold, basic studies to better understand the drought, cold, biotic stresses and quality components.
- Varietal development for speciality uses of different hill crops including traditional and underutilized crops (like vegetable soybean/ *bhat*, low glycemic index rice and nutraceutical rich millets and buck wheat, dual purpose wheat, barley etc.) and specific conditions (like organic agriculture, super intensive protected cultivation *etc.*) and their suitable seed production models.
- Precision pre-breeding for enhanced exploitation of rare alleles from land races, wild relatives *etc*. using high throughput molecular and bioinformatics techniques, system biology; and breaking yield ceiling of traditional crops like horsegram, *bhat* etc. by redesigning the plant type to determinate, photo & thermo insensitive, high harvest index *etc*.

Basic and Strategic Research for Crop Improvement

- Systematic explorations of the diversity-rich inaccessible areas to collect valuable germplasm, wild relatives of crops and related ITK, their characterization, evaluation, documentation, utilization and conservation using modern techniques.
- Research on physiological and biochemical mechanisms for abiotic stress tolerance like drought, cold, terminal heat, drought, elevated

CO_2 levels *etc.* and other traits like grain quality and nutrition. Advanced genomics, proteomics, metabolomics and phenomics for understanding major abiotic/biotic stress tolerance mechanism and sensor based detection and management. Enhancement of photosynthetic efficiency of selected crops for Rubisco specificity factor genes from red algae (*Galdieria partita*) through genetic engineering approaches.

- Cross-talk in metabolic pathway programming for regulating the metabolites for better nutrition, therapeutic and abiotic including heat production for inducing cold tolerance in major hill crops under high altitude zones. Protein engineering/protein characterization to cope up with climate change condition.
- Pharmacogenetics of valuable chemical compounds from local medicinal plants leading to development of improved technologies for large scale bio-prospecting.
- Use of Nanotechnology like nanobased multiplexed diagnostic kit for understanding the disease stage and protein release to increase the speed of detection and power of detection.

Resource Management

- Development of resilience indices for the soils, land capability classification surveys to optimize the land use for arable (agriculture, horticulture) and non-arable (agro-forestry systems, multi-purpose tree systems for meeting the fodder and fuel requirement) land for sustainable production.
- Exploring possibilities of pine needle for non-conventional uses like biogas generation and briquettes making, carbon sequestration potential of agro-forestry as an adaptation to climate change.
- Rhizosphere engineering for abiotic stress tolerance and resource use efficiency. Bio-prospecting of microorganisms through exploration of the culturable/unculturable psychrophilic and psychrotolerant microorganisms for the presence of novel genes for creating an indigenous pool of expression systems to be used for alleviating cold stress/control of plant diseases and decomposition of agro-wastes.
- Revolutionizing organic agriculture in Himalayan region, through science and technology based sustainable production modules, linking with national and international markets with IT based intelligence, leading to lucrative economic returns to inhabitant small and marginal farmers; as compared to inorganic agriculture of plain areas.
- Evolving suitable models for utilization of wasteland for fruit, fodder and grasses, fuel, bio-fuel crops *etc.*

Precision Farming

- Measurement of resource-base through advance technologies like GIS-based digital and other tools for precision farming.
- Development of location-specific and need-based diversified integrated farming systems modules on the basis of topography, cropping systems, livestock production, fisheries, carbon leaching and other allied enterprises to achieve soil quality index upto 0.9 for small and marginal farm holdings as an inbuilt risk management strategy for enhancing production, productivity and profitability.

Water Resource Management

- Refinement of water harvesting, storage and recycling techniques to reduce the risk to the crop against rainfall aberrations, particularly in off-season vegetables and high value crops.
- Enhancing water use efficiency in hill agriculture through rhizoplane/ ultra micro-irrigation especially for vegetable production.

Farm Mechanization and Post-harvest Management

- Developing topography-specific mechanization (tractor/power tiller, animal or manually operated) systems and light weight equipment for hills and their ergonomic evaluation.
- Development of post-harvest technology and equipments for rural level processing, value addition and production for various products in production catchments, particularly of millets and underutilized crops, horticultural and fodder crops and wild fruits to enhanced income of farmers/growers.

Adaptation Strategies to Climate Change

- Contingency crop planning to adapt the aberrations of the climate change.
- Grid based agri-hortisystem and agro-forestry modeling for carbon trading, enhance productivity and abiotic stress tolerance.
- Studies on pesticide load, particularly in fruits and vegetables grown in different parts, standardization/development of analytical methods for estimation of pesticide residues and assessment/persistence studies on pesticide residues in farm produce and soil, effect of pesticides on non-target organisms (soil microbes, earthworms, honey bee, etc.) and effect of climate change on the efficacy of pesticides and also on its remediation/decontamination.

Biotic Stress Management for Enhancing Crop Production

- Research on dynamics of disease and insect-pest scenario in relation to crop preference, e-pest surveillance, pathogen/pest correlation, compatibility, virulence, aggressiveness and evolution pattern both under open as well as protected conditions in hill crops due to perceived changes in the climate.
- Studies on host-pathogen interactions to broaden the genetic base of resistance by incorporating effective genes like QTLs, minor genes for pyramiding and multiple disease resistance, identification of the resistance effective at different temperatures and other weather variables.
- Understanding the mechanism of non host resistance in major hill crops for plant health management. Underpinning the mechanism of 'R gene' mediated resistance through allele mining, gene annotation and pyramiding for major diseases of hill crops.
- Bio-intensive pest management using native parasitoids and predators of crop pests. Use of efficient and safer pesticides compatible with bio-control agents, antagonists, pheromones and semio-chemicals to form IPM modules. Use of botanicals (e.g. *Melia, Urtica, Lantana, Parthenium etc.*), composts, organic substrate *etc.*, possessing suppressive activity against pathogens and enhancing microbial activity.
- Management of vertebrate pests (animals and birds) through evolving frightening methods and devices for a short term management and integrated vertebrate pest management (IVPM) for sustainable damage prevention.

Remunerative Agricultural Options

- Nutrifarming of traditional Himalayan crops for secondary agriculture *viz.*, *bhat* (vegetable, tofu, chocolate, namkeen, baby foods *etc.*), *ragi* (popped, namkeen, baby food, liquor, diabetic food *etc.*), horsegram (probiotics, baby food *etc.*).
- Exploring traditional crops for exporting organic bakery products, Himalayan health mix, medicinal food *etc.*
- Inventing new generation, eco-friendly and bio-safe technologies for developing premium export quality canned products of niche specific *rajmash, kakdi, mooli, pahadi aalu*, Himalayan raspberry (*Rubus elipticus*), *kafal* (*Myrica esculenta*), *buransh* (*Rhododendron* sp.).
- Exploration of the microbial world for the efficient degradation of pine needles and conversion into compost for mushroom production.

Identification and conservation of edible and medicinal mushroom species, development/standardization of cultivation technology for identified mushrooms.

- Developing advanced technologies for '**Himalayan brand'** premium export quality honey production with specific colour (white: sage to dark brown: chest nut) and flavour from crops plants (monofloral), medicinal and wild flora as alternative livelihood options.
- Domestication of stingless bees (meliponiculture), bumble bees (bombiculture), modernising traditional wall hives for enhancing pollination as well as economic returns.
- Himalayan food security through reducing post-harvest losses, improving storage hygiene and management, enhancing shelf life of the perishable agro produce (like fruits, vegetables *etc*.) for long distance transport/export.
- Artificial trees for higher photosynthesis and CO_2 absorption for effective carbon sequestration enabling profitable carbon trading and enhanced oxygen availability and thereby promoting tourism in very high hills.

Information Communication Technology

- Use of high-tech devices for faster agricultural information dissemination, formulation of effective extension strategies, socio-economic and psychological studies in respect of high tech communication devices, technological knowhow, associated change in the behavioural components of stakeholders through training and demonstration.
- Tapping the maximum potential of SMART ICT's to reach around 80-85% stakeholder residing in difficult and inaccessible areas than present day (5-10%).
- Research on market transformation, precision based market intelligence and advisory; smart supply chain management, impact of policies on hill agricultural growth and equity.
- Modelling of human socio-psychological parameters for better prediction of hill farmers' behaviour in rate of adoption of technologies.
- Site specific extension models will be developed based on accumulated GIS database, human behavioural database, ICT devices *etc*. for effective transfer of technology.
- Training of stake holders including the ones residing in remotest hilly areas through ICT mediated techniques like distance FLD, OFT *etc*.

Participatory Approaches

- Strengthening of public-private partnership involving farmers' groups, SHGs, NGOs at village level, contract farming, educating farmers in the field of agribusiness, development of remunerative marketing strategies and capacity building through need based training of the clients.

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Probable Scenarios

The institute envisages the following probable scenarios in hill agriculture:

Scenario 1: Realization of Himalayan hill agriculture potential at state/national/international level and faster development of hill agriculture on priority basis through macro and micro levels of research and policy support. Organic agriculture, agro-tourism, eco-tourism, biodiversity conservation, utilization and trading, export of specialty products from traditional hill crops, livestock, fisheries, poultry, apiary, sericulture, agro-forestry etc., carbon trading may lead to rainbow revolution in hills. The institute mandate should be broadened including livestock, fisheries *etc* (Please see Annexure I).

Scenario 2: Growth of hill agriculture may continue to be at snail speed as compared to plains at that time, due to dismal policy support, unwillingness from farming community to continue due to better and easy livelihood options in industries coming up in the hills, wild life menace, climate change, natural calamities, change in land use pattern. Further, due to the impact of globalization, liberalization and impact of WTO, policy to promote hill tourism as industry, research and development at macro and micro levels of hill agriculture may finally decline and extinct. Institute's priorities may be reoriented to meet the upcoming challenges.

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ANNEXURE

Probable Scenario of hill agriculture in 2050

Parameter	2014	2030	2050
Population (NWH)	285.5 million	345.5 million	410.0 million
Climate			
Temperature	0.2 ⁰ C (IPCC, 2010)	0.9±0.6 ⁰C to 2.6±0.7 ⁰C (INCCA, 2010)	0.8-2.3 ⁰ C (IPCC, 2010)
CO_2	400 ppm (IPCC, 2010)	450 -500 ppm	463-623 ppm (IPCC, 2010)
Seasonal drift	Low - Medium	Medium - High	Medium- High
Rainfall	Erratic rainfall and extreme events in the form of flash floods etc	More extreme events (INCCA, 2010)	More rains
Technology			
Nanotechnology	Nil	Application	Full-fledged application
Distance Farming (robotics and sensor based detection of crop stress)		initiation	Application
Cross-talk in metabolic pathways	Initiated	application	Full-fledged application
Ready reckoner of soil quality and fertilizer recommendation	To be initiated	Application in R & D	Farmer field application
Internet penetration	<5%	15-30%	80-90%
Tele density	15.7% (Uttarakhand), 48% (J&K), 107.9% (HP) over all 49%	Over all 90%	Over all 150%
Mobile based Agri. Apps	Initiated R &D	Farmer field application	Extinct (Substituted by advanced technology)
Farming	Subsistence farming	Commercial and precision farming	Automated distance farming
Agriculture revolution	Organic farming (crop)	Organic green revolution	Rainbow organic revolution
Input application	Area based	Need based	Single Plant based
Resources			
Prevalent Farmer types	Marginal and small	Small and medium (due to migration)	Medium to large (commercial farming)
Farm mechanization	Minimal	Optimal	Full
Labour availability	Less due to migration	lesser	Least
Irrigation	Surface irrigation, Micro-irrigation intiated	Micro-irrigation	Rhizoplane based irrigation

Parameter	2014	2030	2050
Energy	Hydro and thermal based	Hydro and solar	Solar, bio-fuel, nuclear & other unconventional sources
Microbes	N-fixing, P-Solublizing Microorganisms	N-fixing, P and K Solublizing Microorganisms	SMART-Microbes
Fertilizer	FYM	FYM + NP	Judicious application
Water conservation	Tank	Rain water harvesting	Cloud harvesting and dew harvesting
Economy	Public dominated	Mixed	Private dominated
Policy			
Hill development policies	Ecotourism,	Agrotourism, Promotion of SEZ Organic farming	Export of organic quality products through brand name
Industry	Small entrepreneurship	Small and medium entrepreneurship	Large scale industrial development
MOU	Business organization state and inter state	Business organizations all over India	With Nepal, Bhutan and other Hill countries

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