Climate Change Technical Note

P179357 - Uttarakhand Climate Responsive Rainfed Farming Project

Vulnerability Context

Uttarakhand is an Indian Himalayan state with 92 percent of hilly and mountainous territory and rugged topography, prone to climatic and seismic disasters. **Agriculture in Uttarakhand is the primary source of livelihoods for nearly half of its population, and much of it is in rainfed hilly areas.** The cultivated land in the state is divided between predominantly rainfed hilly areas and the more productive valley plain-land and typically known as irrigated plains. Agriculture productivity and profitability is impacted by the pressure of climate change. These include rising temperatures, changes in seasonal durations, alterations in precipitation patterns, and increased frequency and intensity of disasters such as flash floods and landslides. Climate change also affects the productivity of crops, leading to reduced yields, crop losses, and changes in the emergence of pests and crop diseases. Unsustainable development practices, such as deforestation, unscientific land use, and infrastructure development without consideration of geology, further exacerbate the vulnerability. The changing land use pattern and increase in settlement growth have adversely affected the geological environment, leading to soil erosion and depletion of soil moisture.

Approximately 80 percent (~11 million) of the farming population is dependent on rainfed hilly areas. Rainfed agriculture in the hills is inherently risky due to the linkages between temperature, rainfall, extreme events, and crop cycles, especially for rainfed hill areas. These are further intensified by climate change. For instance, annual rainfall in the State is high (1,523 mm) but more than 90 percent is received during the July-September monsoon months, which together with steep slopes, means rapid and large runoff, resulting in soil loss of 40 tons/ha/year. The 2013 cloudburst in the state resulted in 20,401 ha of cultivable land to be eroded due to the resultant flash floods and landslides (Salgotra 2019). At the same time, there has been an overall reduction in the discharge rate of stream and spring water sources, critical for year-round water supply both for agriculture and the domestic needs of villagers in the state. These stresses compound the constraints to enhancing rainfed agronomic practices and increasing agricultural productivity. Additionally, socio-economic vulnerabilities exacerbate the risks faced by the agriculture sector in Uttarakhand. These vulnerabilities include the dependence on agriculture for livelihood, especially in the hill regions where farmers practice subsistence farming and face limited access to irrigation, modern technologies, markets, and services. Consequently, household incomes are low and there is a trend of out-migration in the last few decades, highlighting the need for strong resilience measures in rainfed farming in the state. Further, for diversification towards more resistance crops, for example millets, a reliable seed supply system and appropriate varieties are needed.

The 'Revised Uttarakhand Action Plan on Climate Change'[1] (UAPCC) and the Draft Uttarakhand Agriculture Policy also reinforce the need for rainfed sector's transformation towards improved productivity, climate smart agriculture and diversification, ecosystem resilience and, agribusiness opportunities towards farmers' resilience and profitability.

Vulnerability to springsheds:

In Uttarakhand, Climate change has exacerbated water insecurity through erratic rainfall, drying of springs, reduced discharge, and diminished spring water quality. There has been a decline in the number of springs flowing through the year, with about 10 percent of spring sources having dried up over the last decade. It is in

[1] TERI. 2022 Revision of State Action Plan on Climate Change for Uttarakhand New Delhi: The Energy and Resources Institute.

this regard that spring-shed management, is critical for sustaining irrigation water supplies, also at critical times, for improving food security, and enhancing productivity from arable and non-arable areas.

Climate Trends and Projections

The last generation of regional climate models (RCMs) predict a warming of 1.3 – 1.6 degrees Celsius by the middle of the century and 2.3 – 5.9 degrees by the end of the century[2]. This may further contribute to the ongoing loss of glaciers (the ~1950 glaciers lost 16 Gt of water over the period 2000 – 2014, which is equal to ~3.5% of the total glacier volume) in the Uttarakhand Himalayas[3]. RCMs further predict a decrease in pre-monsoon precipitation and an increase in monsoon precipitation (6 – 16% by the end of the century), alongside an increasing interannual variability in annual precipitation. Together with the rising temperature and enhanced glacier melt (10 – 20% of yearly runoff), a significant increase in peak runoff during the monsoon months is expected[4], which can elevate the risk of flash floods, landslides, and glacial lake outburst floods. Climate change may therefore add to the unpredictability of climate-related disasters, which is further exacerbated by anthropogenic trends such as deforestation, soil erosion and irrigation water extraction. For instance, the region's hydrograph (i.e., distribution of streamflow over the months) is expected to shift due to a combination of factors, threatening food security, hydropower production, groundwater recharge, and rural water supplies.

Projected Climate Impacts on Agriculture Sector

The increase in frequency of extreme events will impact productivity of most crops due to increase in temperature and decreased water availability. There will be spatial changes in the diversity of tropical / sub-tropical crops as well as that of temperate crops. Across the country, extreme climatic events have already impacted agriculture by causing fluctuation in production of major crops, creating pressure on the economy to counter the unexpected deficit in production. Further, National Innovations in Climate Resilient Agriculture (NICRA)[5], a project of Indian Council of Agricultural Research (ICAR), had predicted a marginal reduction (<2.5 percent) in upland rice yields in 2050 and irrigated rice yields by 7 percent in 2050 and 10 percent in 2080 scenarios. However, there has already been increasing fluctuation in rice production because of climate impacts, with the country recording an estimated deficit of 7-11 million tons during kharif 2022-23. While some new cropping opportunities may arise with higher temperatures in higher altitudes, these will also be facing new constraints in terms of soil suitability and water availability, and possible increased spread of pests. While varying by district, the climate vulnerability of many mountain areas both globally and in India is considered high[6]. Further, Spring-shed management needs to play a key role in rainfed upland agriculture and climate resilience. Water supply and management play an increasingly critical role with climate change. Historically, in the absence of assured irrigation supply in rainfed areas, comprehensive watershed treatment within a defined hydrological boundary has been the key assurance for moisture retention for rainfed crops, as done under the previous project. However, given the emerging temporal and spatial rainfall variability, watershed management has not been able to ensure full water security through the annual crop cycle. Spring-sheds and the springs they supply to are a critical year-round source of water for agriculture and domestic purposes for many

[2] Tyagi, N. *et al.* Evaluation of Observed and Future Climate Change Projection for Uttarakhand, India, Using CORDEX-SA. *Atmosphere.* **13**, 947 (2022).

[3] Bandyopadhyay, D., Singh, G. & Kulkarni, A. V. Spatial distribution of decadal ice thickness change and glacier stored water loss in the Upper Ganga basin, India during 2000–2014. *Sci. Rep.* **9**, 1–9 (2019).

[4] Lutz, A. F. *et al.* South Asian agriculture increasingly dependent on meltwater and groundwater. *Nat. Clim. Chang.* **12**, 566–573 (2022).

[5] ICAR initiated the network project NICRA in 2011 to address the impact of climate change on Indian agriculture.

[6] 'Climate Vulnerability Assessment for the Indian Himalayan Region' Dept. of Science and Technology, Govt. of India in collaboration with Swiss Agency for Development and Cooperation (2018)

communities in Uttarakhand. For more strategic watershed management, it is imperative to intervene at the spring-shed level to ensure water security in more focused areas of micro-watersheds.

Need for climate resilient market infrastructure

Addressing gaps in supply chain and inadequate marketing infrastructure for income resilience is critical to sustaining climate-responsive rainfed production systems. Maximizing the value of rainfed hill agriculture due to its distinct quality and off-season availability is critical to sustain its potential value, and to deliver more sustainable sources of income is also key to resilience. Mountain ecosystems enable the cultivation of crops, including high-value vegetable crops, during the off-season (when plain states are busy producing cereal crops) for most of the country, thereby providing an opportunity for farmers to benefit from relatively higher prices during that season. Commodities from the hills and mountains are also recognized for high quality varieties, and low use of pesticides. The state is close to major urban markets and population centers including the National Capital Region thereby providing a ready market for high value produce. However, the state is unable to realize its potential and incurs substantial post-harvest losses due to inadequate processing facilities, storage infrastructure, and logistical issues in the mountainous terrain. A cluster approach with aggregating products and upgraded processing, marketing has been demonstrated under the Gramya II, but was only supporting a relatively small number of farmers and the enterprise was only just established at the end of the project. Connecting climate-smart precision farming protocol with an effective marketing chain can provide backwards-forward linkages towards a paradigm shift. Agricultural enterprises in the hills will be critical for delivering quality inputs such as seeds. This needs further specialized support for niche markets, geographic indication, targeted markets, and recognizing and branding quality products. There is also currently a lack of entrepreneurship among upland smallholders.

Objective and intend of Project to address climate change impacts

Through targeted climate change adaptation and mitigation actions, the Project will help the state achieve its vision of enhancing food security, climate resilience, and farmer income. Based on India's commitment to "Paris Agreement", COP26 and COP27 in supporting agriculture adaptation to the changing climate, and the World Bank's global focus on promoting climate resilience at the farm level, the project is built around a comprehensive, multi-sector approach. In support of the state government's shift towards climate adaptation and sustained and green agricultural growth, **the proposed project supports the agriculture sector's adaptation and transformation towards production system resilience while reducing emissions from farming practices, leading to increased farmers' profitability.** With water as a critical resource, the project focuses on springshed development to enhance availability of perennial water supply and help farmers harness this for agriculture (and domestic use). The project promotes transition to production systems that are climate adaptive, use water, soil and other inputs more efficiently, result in optimum volume and stability in outputs, and are resilient to short and long-term climate variability. With productivity improvement, input-cost reductions, and crop diversification, together with a systematic agribusiness approach to add value to products from the hilly areas, an increase in farmers' incomes and broader household resilience are expected. Specialized climate smart land and water practices will also aim to reduce GHG emissions per unit of land while enhancing the capacity of terrestrial ecosystems to act as carbon sinks, thereby contributing to climate change mitigation and adaptation. The project will bring in consortia for the co-creation of Climate Smart Agriculture (CSA) knowledge and developing protocols for technologies and localised advisories. An agricultural digital platform will be developed to underpin the science base and delivering of services to farmers.

Furthermore, in the context of India's Energy Conservation (Amendment) Bill, 2022, and the emergence of voluntary carbon markets, the project will also contribute towards mitigation of methane emissions from paddy rice cultivation, particularly in the lowlands that are integral to the broader agricultural landscape of Uttarakhand. This may have potential This endeavor holds the potential to harness carbon credits through participation in voluntary carbon markets, providing an income-enhancing incentive to farmers. This aligns with the Government of Uttarakhand's aim to reduce greenhouse gas emissions through agricultural practices.

The specific adaptation and mitigation activities that are considered and discussed with the client under the operation are tabulated below:

Table 1: Component-wise Adaptation and Mitigation Actions

Component	Adaptation actions	Mitigation actions
Component A: Developing Resilient and GHG- efficient Production Systems *(38.12 US$ million)*		
Sub-Component A1: Supporting Climate Smart and Diversified Production Protocols	*Vulnerability Context: refer above* *Intent to address identified vulnerabilities:* This sub-component boost productivity, enable and scale the widespread adoption of climate-smart agriculture (CSA) among farmers through a participatory approach. It aims to improve farm planning, engage farmer interest groups, and promote practices that enhance farm productivity and resilience. Supported by a landscape approach based on land-use capability, the project will provide quality inputs and deploy early warning advisory systems to ensure adoption of ecologically sensitive and diversified production system. *Explicit link between identified climate change risks and specific project activities:* a) The sub-component will be bringing more areas under controlled irrigation, promote protected cultivation, converting abandoned agricultural fallows, promote diversification of agriculture, and supplement incomes of farmers through diversified livelihoods (including small ruminants). It will include optimization of inputs and practices for different typologies of farms while appreciating various trade-offs for farmers. The sub-component will also deploy weather forecasting to enable farmers to identify, access, and implement most suited CSA activities. b) The sub-component will promote water use efficiency (WUE) through i.) improving cropping intensity by adoption of practices that reduce the soil water evaporation component and divert more water into transpiration by affecting crop residue management, mulching, row spacing, and irrigation, and ii.) crop diversification through multiplication of climate-resilient crop varieties such as millets (seeds) for kharif and rabi	The project will have dedicated land parcels to showcase the methane emission reduction in lowland paddy rice. Such pilots will be managed by a technical partner highlighting various options for reducing Methane (CH4) and maintaining Carbon dioxide (CO2) emissions. This will take place in highland and lowland areas of Uttarakhand, which will also provide lessons for wider adoption. Further the project will help farmers invest in small farm equipment, such as solar energy for water lifting and crop drying, and fuel-efficient agro-logistics, to reduce waste and to help offset emissions. Overall, there will also be monitoring of carbon assimilated as biomass (including grain) produced per unit of water used. In addition, with greater WUE the

	seasons under upland and lowland conditions. For millets and other important climate resilience crops and varieties, the ready supply of high-quality seeds will be critical, and the project will support the development of seed systems with farmers groups.	project will also identify and monitor those practices which also help to reduce the amount of GHG emissions.
Sub-Component A2: Building Consortia and Digital Platform for Evidence-based Decision Support	*Vulnerability Context:* refer above *Intent to address identified vulnerabilities:* In this sub-component, the project will establish an evidence-based decision support system for Climate-Smart Agriculture (CSA) through valuable science partnerships, both State and national levels. The consortia approach will showcase interdisciplinary science's importance in leveraging edaphic and climate factors for resilient agriculture, considering the livelihoods challenges in hilly areas.. This approach will help the project evolve into a knowledge hub, enhancing staff capabilities to promote climate-resilient practices at the local level. The project will employ strong extension protocols, informed by pilot project insights, to drive systemic change in rainfed farming at the block/district level. *Explicit link between identified climate change risks and specific project activities:* These consortia partnerships will develop knowledge products through co-creation, mostly with pilot communities, and establish a digital data source that includes advisory tools, analytics, and data management to support on-field implementation, bridging the gap between the lab and the field. This digital resource will be linked to spatial and farm data systems, providing state-specific analytics. Further, the consortia will engage researchers and scientists from leading institutions to enhance project implementation and technology diffusion. Since the project has multiple dimensions, no single institution possesses the expertise to meet all the technical requirements to achieve its objectives. The proposed 'consortia' will pool subject-specific expertise to: i) Develop resilience protocols to promote improved agricultural production systems. ii) Create a precision farming package suitable for local rainfed conditions. iii) Implement irrigation methods and scheduling to enhance agriculture productivity while reducing greenhouse gas emissions. iv) Define water use efficiency criteria for crops and cropping patterns to increase soil organic carbon and biomass. v) Develop technology to reduce post-harvest losses and	

	establish district-wise agribusiness growth centers. The project will leverage existing data systems and Geographic Information Systems (GIS), building a robust digital agriculture ecosystem accessible across the state. This aligns with the Government of India's vision for a comprehensive core digital agriculture ecosystem under the India Digital Ecosystem of Agriculture (IDEA) framework. Data from partners involved in hydrology, water resources, crop water budgeting, and Climate-Smart Agriculture (CSA) will be integrated into the platform. Additionally, the project will tap into existing knowledge and datasets from its partners. Key elements of the data platform will include (i) building an Agri Stack of farmer beneficiaries, (ii) asset geocoding, and (iii) service delivery tracking to support program implementation. This platform will serve as the foundation for user applications developed by third parties, tailored to specific needs and demands.	
Component B: Science-based development of Resilient Springsheds (43.19 *US$ million)*		
Sub-Component B1: Participatory Planning for Spring-shed Development	*Vulnerability Context:* refer above *Intent to address identified vulnerabilities:* This sub-component will focus on enhancing participatory micro-watershed planning to enhance water supply and reliability, ensuring more timely input with water budgeting for each crop, for improved farm productivity under Component A. Under this sub-component, a plan will be developed for each of the selected vulnerable spring-sheds, considering climate trends, during early stages of implementation that will provide a roadmap for the implementation of project activities and investment priorities. *Explicit link between identified climate change risks and specific project activities:* In this sub-component, the project will: i) Build the capacity of watershed committees to understand science-based spring-shed hydrology and identify key project intervention sites, particularly around critical springs. ii) Analyze relevant data layers, including hydrology and climate risks, to define spring-sheds and target specific land types for planning and interventions. iii) Engage local communities in analyzing water demand and supply trends for optimization in farming and livelihoods. The spring-shed plans will integrate data from participatory micro-planning led by the Village Spring-shed Development Committee, involving local stakeholders. These plans will then be aggregated at the cluster level to create mini spring-shed plans, offering detailed resource maps that consider social, economic, hydrological, and climatic factors.	The project will assess the potential for carbon sequestration through soil and vegetative cover.

Sub-Component B2: Enhancing Springshed Hydrology and Water Storage	*Vulnerability Context:* refer above *Intent to address identified vulnerabilities:* This sub-component will incorporate spring-shed treatment; rehabilitation of degraded common land; and water harvesting/storage from improved spring flows to (ii) improve quantity and stability of spring flows through drainage management; and (iii) increase volume of water stored for farm use in farm ponds. These measures will contribute to the development of climate-resilient spring-sheds, which are the primary source of water supply for agriculture and domestic use in Uttarakhand. *Explicit link between identified climate change risks and specific project activities:* In this sub-component, the project will invest in improving biotic cover in critical stream and spring catchment areas to replenish aquifers. The project will choose treatment methods and regeneration solutions based on proven best practices and science-based location analysis. Participation in implementation and monitoring will enable evidence-based learning for potential project scaling. The project will also support the installation of water harvesting and storage structures, along with gravity-based farm-level distribution systems, including field channels and farm ponds as needed. The volume of stored water and distribution patterns will be monitored through community participation. A comprehensive water budgeting exercise will complement spring-shed plans, encompassing hydrological analysis and evapotranspiration related to prevailing cropping patterns. To ensure sustainability and promote water use efficiency, the sub-component will assess both demand-side and supply-side hydrology, quantifying water use in relation to dependable spring flows within each spring-shed. In-flow hydrology management will be reinforced through institutional strengthening and stakeholder capacity building.	The project will monitor the benefits of increased biotic cover, evaluating its contribution to carbon sequestration through measurements of above-ground and soil carbon levels.
Component C: Enhancing Income Resilience through Agribusiness and Entrepreneurship (12.77 *US$ million)*		
Sub-Component C1: Supporting Agribusiness Promotion Centers	*Vulnerability Context:* refer above *Intent to address identified vulnerabilities:* This subcomponent will promote investments in agribusiness to increase the stability and diversity and thus income resilience of rural and agricultural households in project area (designated micro-watersheds). This will be through value addition of farm-based produce and enterprise development, tapping into the State's rainfed areas' opportunities and relative strengths, also for the most vulnerable households, and tapping the surpluses from productivity gains and agriculture expansion arising resulting from Component A and B. To meet this objective, the project will engage dedicated Agribusiness Support Agencies at the district level to help in planning entrepreneurship activities at the GP level, providing	

	facilitation, aggregation and value-addition to access markets. It will also support the inclusion of the marginal landless households in the watershed development process and benefits. *Explicit link between identified climate change risks and specific project activities:* To promote the competitiveness of smallholder farmers, the project will facilitate demand-driven value chains through a participatory approach. The sub-component will assist farmer clusters in establishing Agribusiness Promotion Centers (ABPCs). These centers will empower smallholder farmers by addressing input supply and post-harvest management issues, ensuring timely availability of seeds and other inputs, aggregating produce, performing sorting, grading, packaging, and secondary processing activities (such as oil milling and spice powders), and establishing market linkages. ABPC products will be marketed locally or under the existing 'Gramyashree' brand. While professionally managed, ABPCs will be owned by smallholder farmers or collectives, like cooperatives or Farmer Producer Companies (FPCs) from the project area. Where needed, the project will support the development of farmer collectives. Additionally, this sub-component will conduct value chain studies to identify market gaps and invest in capacity building for relevant stakeholders (farmers, project staff, etc.) through training, workshops, exposure visits, and other agribusiness activities. The project aims to establish 10 ABPCs and will provide funding for (i) ABPC infrastructure and equipment, (ii) mobilization and capacity building of farmers or farmer collectives in ABPC management, (iii) professional management support for ABPCs, (iv) value chain and market assessment studies, and (v) brand development activities, including standardization and quality control.	
Sub-Component C2: Micro- Enterprise Development	*Vulnerability Context:* refer above *Intent to address identified vulnerabilities:* This sub-component will focus on value addition of farm produce that will be facilitated further through micro-enterprises in the project areas. The subcomponent will enable individuals and collectives to develop new or expand existing micro-enterprises with the aim of maximizing returns for farmers supported under the project, and hence enhancing climate resilience for the farmers. *Explicit link between identified climate change risks and specific project activities:* The project will identify and train entrepreneurs, providing technical guidance and financial	

	assistance. Emphasis will be on green enterprises and those supporting higher-value organic produce. Technical Support Agencies (TSAs) will assist in developing bankable business plans, implementation, and market connections. These TSAs will help secure commercial finance for these plans, either through existing state MSME schemes or a Matching Grant Program (MGP). The project will leverage government cost-sharing norms to create a financial instrument that encourages rural entrepreneurs to establish or expand micro-enterprises typically perceived as risky by commercial banks. The project's goal is to support 100 farm-based micro-enterprises in project areas. Specifically, the project will fund (i) identification and training of entrepreneurs from project areas; (ii) cost of TSAs for preparing bankable business plans, facilitating MGP with commercial banks, providing sector-based technical advisory services, and market linkages; (iii) matching grants; and (iv) capacity building and technical assistance to project staff and commercial banks in micro-enterprise financing.	
Sub-Component C3: Income Generation Support for Vulnerable Groups	*Vulnerability Context:* refer above *Intent to address identified vulnerabilities:* In this sub-component, the project will support marginalized households, including women-headed and landless families, who may not directly benefit from the primary farm-related investments in Component B. These vulnerable groups often bear a disproportionate burden of climate change impacts. The aim is to narrow the economic gap, enhance the overall climate resilience and prosperity of the community in the project areas. Additionally, the project will provide beneficiaries with green skill development and business management training. *Explicit link between identified climate change risks and specific project activities:* The project will support 7,000 vulnerable households. The project will fund small-scale income-generating initiatives for these vulnerable groups based on basic business proposals developed with the assistance of field-level staff or local consultants. Grants will be directly awarded by district offices to the accounts of vulnerable households after evaluation by the state office. Specifically, the project will finance (i) individual grants of up to 50 percent of the financing need up to INR 30,000; (ii) capacity building of beneficiaries from vulnerable households in business management and trade-based skill training; and (iii) market linkage support through locally based consultants or TSAs.	
Component 4: *Project monitoring and*	*Vulnerability Context:* refer above	

***evaluation and learning* (7.93 US$ million)**	*Intent to address identified vulnerabilities:* Lack of resilience to climate change at time stems for lack of capacity. Thus, this component addresses the need for desired skill-set to manage and implement the project on-time and achieve the underline objective of attaining resilience to climate change. *Explicit link between identified climate change risks and specific project activities:* This component will support project management, including key staff and operational costs to deliver on project objectives by hiring talent from the market. This will further cover the overall project Monitoring and Impact Evaluation (M&IE) and reporting activities, including the project impact evaluation; the implementation of the project's Information and Communications Technology (ICT) activities; and the coordination with a human resources agency to be hired for filling the project's technical positions in the field.	