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CHANGING CLIMATE, FOOD SECURITY AND SUSTAINABILITY IN THE WESTERN HIMALAYAN REGION: A CRITICAL ASSESSMENT

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Abstract

The Western Himalayan Region (WHR) with gigantic mountains and extraordinary landscapes covering more than 10% of geographical area of the country, sustain diversity of flora and fauna and human population. The region is being under threat by climate change, food insecurity, and insatiable human pursuit of development. This paper examines the complex interplay of these issues, concentrating on the differential impacts of climate change on agricultural systems and nature dependent vulnerable communities inhabiting the region. Rising temperatures, fluctuating rainfall patterns, and accelerated glacial melt pose significant risks to the ecologically and biologically delicate ecosystems, escalating existing pressures on agriculture and food production along with rising population. By analysing of available research literature on the region, this study highlights the cascading consequences on cryosphere dynamics, biodiversity, and availability of water - critical for both rain-fed agriculture and downstream populations. It explores vulnerability of agricultural systems, high-altitude pastoralism and irrigated farming, increased exposure to climate-induced disasters (droughts, flash floods, avalanches) etc., and new types of pests attack and diseases. In-situ with ecological concerns, the research looks into the socio-economic aspects of food insecurity, assessing its impact on livelihoods, food availability, and nutritional well-being, particularly for the marginalized groups. The paper highlights the role of climate smart agricultural practices, diversification strategies, and community-led adaptation measures based on traditional knowledge systems and supported by technology, in enhancing resilience. To promote sustainable livelihoods, the paper recommends for community based land use and water resource management, fostering cooperation, and developing ecosystem services based robust institutional frameworks. It highlights the need for region based targeted interventions that address the WHR's specific vulnerabilities and secure long-term food security through bridging critical knowledge gaps and support evidence-based policymaking towards building long term sustainability.

Keywords: Climate Change, Food Security, Sustainability, Adaptation, Natural Resources, Resilience

1. Introduction

The Western Himalayan Region (WHR) in India broadly consisting of Jammu & Kashmir, Ladakh, Himachal Pradesh and Uttarakhand, has a complex tapestry of rugged mountains, varied microclimatic zones, and vivid elevation changes, from the lower slopes to the high-altitude glacial zones. It is largely inhabited by nature dependent communities having distinct

cultural features, food choices and subsistence livelihood practices. It is identified as one of the biological hotspots of the world due to its socio-cultural and biological diversity (Gautam et al., 2013). WHR is the source of major rivers that are very crucial for agriculture and livelihoods far downstream to the densely populated plains of northern India. The rich cultural heritage of the WHR reflects generations of human adaptation to its challenging topography. Its geopolitical location has significant transboundary challenges such as water sharing clashes and war situations on borders creating sense of uncertain fear of loss and damage of available natural resources and structures. The fragility of the region is a probable ground for disasters like floods and landslides (Cruz et al. 2007) aggravated by climate change and may lead food insecurity and loss of its rich habitat (Xu et al. 2009). The climate crisis will force people to migrate, adjust, invent, cross boundaries and find ways to survive and transform their lives (Gonzalez, 2021) and may create a ground of conflict among nations. The WHR due to exponential population growth, intense deforestation and unplanned development has changed the land use and land cover patterns which has affected the forest distribution and led to loss of ecological systems (Mondal et al., 2018) and will affect livelihood patterns and food production.

Climate change, food security and sustainability are criss-crossing to the challenges posed by anthropogenic factors. In the recent two decades unusual temperatures rise, erratic rainfall patterns, and recurring extreme weather events are disturbing the ecological equilibrium at an alarming rate in the WHR (GOI, 2010). Further, glaciers are losing ice, water availability has become increasingly inconsistent, and droughts are occurring frequently, threatening agricultural and allied sector output; and human sustenance. Additionally, these climatic disruptions are placing immense pressure on livelihoods of local communities and increasing their vulnerability, reducing resilience. In the 1996 world food summit, the concept of food security was introduced referring to the physical, social and economic access to adequately, safe and nutritious food, available to meet the food requirements and choices for a healthy life (Galie, 2019). Further, it is completely conceptualised on five parameter of availability, accessibility, utilization, stability and sustainability (Peng et al., 2019). Climate change is affecting the food security and its various dimensions as agricultural production are decreasing, reducing livestock rearing spaces and livelihood options in the WHR. Sustainability, an important dimension, which requires preserving ecological equilibrium while fostering economic and social well-being of communities, has become a critical concern for the WHR. The region's forests, wetlands, and grasslands providing essential sustenance amenities, like regular water flow, protecting soil health, and supporting biodiversity. The implications of climate-induced food insecurity extend beyond agriculture. Many communities are already experiencing rising malnutrition, economic instability, and increased migration as people seek better opportunities elsewhere leading to issues of climate justice. The unsustainable and unplanned land-use practices and human-induced pressures are draining these ecosystems. Protecting and reinstating them is essential for reducing food insecurity, sustaining livelihoods, and ensuring long-term resilience for local communities and preservation of their traditional ways of life.

1.1 Climate Change Impacts

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The macro and macro level impacts are disrupting the agricultural sustenance of local communities and endangering their livelihoods with change in local ecosystem. As highlighted by Mondal & Zhang (2018) the rising temperatures are altering plant phenology, crop maturation and pollination cycles. These alarming shifts will fasten the glacial melting, depleting water supply due to fast drainage downstream making water scarcity a crisis phenomenon for agricultural as well as human consumption (Tewari, Verma, & von Gadow, 2017). Further, Variability in rainfall patterns resulting in extreme weather events like flash floods, landslides, droughts have added to the agony of small land holding vulnerable communities in the WHR because of declining agricultural productivity and damages to assets (Meiyappan et al., 2016; Rasul, 2014). The mountain glaciers are retreating and snow melting happening at faster rates affecting water availably during agricultural season for irrigation and disrupting livelihood and increased food insecurity (Prasad & Sohoni, 2020).

1.2 Food Security Implications

Changing climate has disrupted agricultural practices and threatened crop yield and availability in the WHR, due to extreme weather events triggering shortage of food and food inflation further reducing accessibility and availability dimension of food security (Mondal & Zhang, 2018; Meiyappan et al., 2016). The shifting of seasons has forced subsistence farmers to adapt to new patterns of climate thus altering traditional sowing and harvesting time which further reduces productivity and bring about economic instability in forms of spending on farm supplements like fertilizers etc., (Tewari, Verma, & von Gadow, 2017). Due to this non availability of fodder and grazing areas for livestock's resulted in losses (Rasul, 2014) and has led to conflicts among pastoral communities for grazing lands, affecting their traditions and cultural harmony. Prasad & Sohoni (2020) have highlighted that due to decrease in crop yield and limited access to all, particularly vulnerable communities malnutrition and other health risk have drastically increase leading to economic losses. The dependence on agriculture, livestock, forestry; which are highly climate sensitive sectors, by these communities for livelihood and food security makes them more vulnerable in terms of food and nutritional security with high chances of livelihood support system getting ruptured (Negi et al., 2017). Pingali et al., (2017) in their study highlighted the need for a robust and integrated food policy in India, which is beyond staple grain dependency and incorporates diverse nutritional needs.

1.3 Sustainability Challenges

The degradation of mountain ecosystem (soil erosion, deforestation, water pollution, tourism), habitat fragmentation and natural resource depletion has created sustainability challenge for the agricultural based as well as non-agricultural based communities who dwell on indirect ecosystem services (Mondal & Zhang, 2018; Meiyappan et al., 2016) further leading to completion and conflicts for limited available resources (Rasul, 2014). Also, also agricultural intensification in WHR towards economically beneficial horticulture practices has created water and environmental stress on forest ecosystems like vegetation, insect

population and plant diversity (Tewari, Verma, & von Gadow, 2017; Prasad & Sohoni, 2020). The frequent climate induced disasters (flash floods, GLOF, landslides) have forced marginalised and vulnerable communities to migrate to cities for livelihood, rupturing their social fabrics, traditions, culture and nurturing a systemic poverty cycle and social unrest (Prasad & Sohoni, 2020). These displacements create a huge socio-political, economic turmoil in the lives and livelihoods of communities with despair and uncertainty with alienation affecting their long term wellbeing and sustainability.

1.4 Theoretical Framework

The WHR hold a significant geopolitical and cultural importance for the nation for its rich biodiversity, economic and socio-political histories.. The National Action Plan on Climate Change (NAPCC) was launched by the Government of India in the year with an agenda to develop framework, so as all stakeholders can contribute to climate adaptation in the Indian subcontinent catering to local and regional needs. Among its eight missions, two important missions, namely National Mission for Sustaining Himalayan Ecosystem (NMSHE) and National Mission on Strategic Knowledge for Climate Change (NMSKCC), highlighted concern for Himalayan ecosystem and recommended location centric climate adaptation measures supported by local civil society organisations (DST, 2010). The climate induced challenges the region is facing requires collaborative and multidisciplinary approaches. The socio-ecological systems framework highlights the symbiotic relationship between ecological systems and human systems, it further emphasise to understand their synergies and trade-offs for sustainable development (Mondal & Zhang, 2018). Another, framework by (Tewari, et. al., 2017) based on vulnerability and adaptation evaluates the susceptibility of communities and ecosystems to climate change impacts and assists in the development of adaptive strategies catering to regional vulnerabilities. Also, Food Systems Framework examines the food production, distribution and consumption giving insights on the broader implications of climate change on food security (Rasul, 2014). Further, Meiyappan et al., in 2016 discusses the ecosystem services framework which captures vital services provided by the ecosystem and helps develop conservation strategies to ensure ecological resilience.

2. Methodology

This conceptual paper investigates the interrelation of climate change, food security and sustainability in the WHR from diverse range of data sources. The study adheres to the PRISMA guidelines for systematic literature review and an extensive desk review was undertaken. Peer-reviewed research articles, policy documents, books etc., published between 2000 and 2020 has been referred. A multi-stage search approach was adopted across major academic databases (Scopus, Web of Science, PubMed, and Google Scholar) and relevant regional databases-using a permutation of keywords customised to the thematic focus areas. The keywords included “climate change,” “food security,” “western Himalayan region,” “sustainability”, “agriculture,” “water resources,” “glacier,” “adaptation,” “vulnerability,” “community resilience,” “livelihoods,” “traditional knowledge,” “climate-smart agriculture,”

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"policy," and "governance.". This methodological approach ensured a vigorous and comprehensive fusion of existing knowledge and also underlined gaps and opportunities for future research. By assimilating diverse viewpoints it offers a critical understanding of the challenges and potential solutions for achieving food security in the Western Himalayas amidst a rapidly changing climate. The findings are intended to apprise policymakers, researchers, and practitioners to evolving nature of climate change impacts on food security and sustainability for the communities in the WHR.

3. Discussion

The western Himalayan regions (WHR) are a repository of civilizational biodiversity, tradition, culture and habitat preserved by the communities. These agricultural and nature dependent communities are facing challenges due to Climate Change in terms of food insecurity, disaster and sustainability issues. Their concerns need to be address through region specific sectoral approach and community participation.

3.1 Sustainable Agricultural Practices

The Western Himalayan zone, which is a sensitive area for agriculture and biodiversity, is exposed to the severe issues of climate change (Huber, 2005). Sustainable use of agriculture makes a strong contribution to resolving food security and environmental sustainability in the sensitive area. Some studies highlight the importance of adaptation to reverse the negative impacts of climate change on agriculture in South Asia, for instance, the Western Himalayas (Aryal, 2019). Such adaptations include the conservation of agricultural productivity, reducing vulnerability, and enhancing the resilience of agricultural systems (Aryal, 2019). Some practices in the production system have been proposed and tested to reduce the impact of climate change (Aryal, 2019). However, the socioeconomic and political situation dictates the adoption and effectiveness of such practices. Some approaches allow for adaptation, but others discourage it (Aryal, 2019).

One of the most crucial areas of concern is the development of new varieties of crops with increased compatibility with altered climatic conditions (Ignaciuk, 2014). R&D investment is necessary to construct agricultural resilience and to enhance innovation in this direction (Ignaciuk, 2014). This entails the exploration of the likely effects on yield and market price and investigation of implications for yields, prices, and food security generated by R&D action and innovations in irrigation technology (Ignaciuk, 2014). Moreover, research into the investment requirements public and private on R&D and development of cost-saving technology is necessary (Ignaciuk, 2014). Climate smart agricultural practices be implementing with high yielding climate-resilient crops and techniques, including encouragement of agroforestry with integrated pest management, and water conservation approach, can enhance agricultural productivity and sustenance (Mondal & Zhang, 2018; Meiyappan et al., 2016).

Organicfarming is another source of sustainable practice (Scialabba,2010). Organic agricultur e has high potential for climate change mitigation in terms of carbon sequestration and reduced greenhouse gas (GHG) emissions (Scialabba, 2010). Organic farming systems can have lower N2O emissions through well-managed nutrient use, which enhances soil health and sustainability (Scialabba, 2010). Organic farming also provides multiple income streams for farmers, particularly in the context of rising energy prices and input costs (Scialabba, 2010). Resilient food systems with the help of organic agriculture principles enhance food security under climate uncertainty (Scialabba, 2010). Organic agriculture's yield potential to reach conventional agriculture levels makes it a sustainable livelihood option (Scialabba, 2010). More research is needed to solidify estimates of emission savings from organic agriculture (Scialabba, 2010). Comparison of diversified biologically diversified farming systems with conventional farming systems shows that diversified farming practices enhance ecosystem services and improve food security under change conditions (Kremen, 2012). This increased biodiversity improves resilience against climate variability and promotes community-based adaptation options (Kremen, 2012).

3.2 Diversification of Livelihoods

Diversification of livelihoods is crucial for enhancing food security and sustainability in the Western Himalayan Region (WHR), where climate change poses significant threats to traditional agricultural practices. It is an important adaptation strategy in the Western Himalayan region (Ensor, 2019). Traditional agriculture is under threat from rising education levels, land abandonment, increasing wages, mechanization, and high migration to the global labor market (Ensor, 2019). This transition requires a wider perspective on rural livelihoods and their transformation (Ensor, 2019). In central Nepal, for example, a study found that most (61%) of the households diversified their income into non-farm activities (Khatiwada, 2017). Livelihood diversification, especially into business/enterprise and commercial agriculture, is important for poverty reduction (Khatiwada, 2017). Land holding size, education, agricultural skill training, access to credit, and market center distance influence the adoption of higher-returning strategies (Khatiwada, 2017). Encouraging market-oriented farm enterprises and upgrading vocational infrastructures are historic for poverty reduction in rural societies (Khatiwada, 2017). This diversification strategy can be incorporated into community-based adaptation strategies (Khatiwada, 2017). The incorporation of indigenous knowledge (IK) into climate strategies can also stimulate sustainable agricultural practices and livelihood diversification by scaling up solutions to local contexts (Chanza, 2016). Training and empowering communities to adopt adaptive strategies are crucial for success (Chanza, 2016).

Landslides, fueled by climate change and extreme weather, disrupt livelihoods and result in loss of life and property (Cieslik, 2019). Occupational diversification among landslide hazard-prone communities is an indication of adaptive strategies fueled by demographic factors and local knowledge (Cieslik, 2019). Citizen

science engagement can enhance monitoring and response strategies for disaster resilience (Cieslik, 2019). Incorporation of experiential knowledge and community participation is important for the development of effective adaptation and mitigation strategies (Cieslik, 2019). Rasul (2014) stated that encouraging alternative income sources, such as organised ecotourism and local handicrafts, reduces dependency on agriculture and enhances economic resilience.

3.3 Community-Based Adaptation and Local Knowledge

Empowering local communities through participatory adaptation strategies fosters resilience and strengthens traditional knowledge integration (Prasad & Sohoni, 2020). Studies emphasize the importance of incorporating traditional knowledge and community-driven approaches in adaptation efforts (Prasad & Sohoni, 2020). Community-based adaptation (CBA) must include local-level perceptions in climate adaptation planning (Archer, 2014). Perceptions of local communities are the foundation for effective planning and execution of adaptation interventions (Nay, 2014). Mainstreaming of CBA must involve multi-stakeholder approaches and reforms of institutions to build community adaptation capacity (Archer, 2014). Inclusion of local knowledge and perceptions in adaptation studies is needed to grasp vulnerabilities and opportunities for building resilience (Ensor, 2019). Inclusion of indigenous knowledge (IK) can enhance climate governance and inform intervention design (Chanza, 2016). Decentralization, accountability, and engagement of local communities are needed for effective government, enabling community-based adaptation approaches (Chanza, 2016). Mainstream adaptation approaches overlook the social context altogether (Ensor, 2019). More holistic attention is needed that prioritizes social, economic, and political contexts (Ensor, 2019). For vector-borne disease, community-based adaptation approaches are also needed, which prioritize public engagement with health systems (Bardosh, 2017). In forest-dependent societies, local knowledge constitutes a vital component of adaptation approaches (Rahman, 2016). Communities utilize knowledge of climate events and their impacts to devise management approaches that consist of land use adjustments and other approaches to reduce risk and enhance food security (Rahman, 2016). The concept of "community" itself, however, is problematic and must be given careful thought in development and disaster-related initiatives (Titz, 2018). Employment of the term is followed by confusion and scope for ineffective engagement with communities (Titz, 2018).

3.4 Early Warning Systems

Strengthening disaster preparedness through improved forecasting and response mechanisms can mitigate the impact of extreme weather events (Meiyappan et al., 2016). While existing literatures do not explicitly mention early warning systems in the Western Himalayas, preparedness and planning

for disruptions have been found to be crucial components of resilience (Bahadur, 2013). This is an indirect suggestion of the need for effective early warning systems to prepare and respond to climate events, including landslides (Cieslik, 2019) and extreme weather (Bardosh, 2017). The creation of such systems must be aligned with the local knowledge and community engagement to facilitate effective planning and response. Further research is needed to respond to the development and implementation of early warning systems specifically tailored to respond to the unique challenges of the Western Himalayan environment.

3.5. Investment in Research and Development

Investment in research and development (R&D) is critical in addressing the effects of climate change, food insecurity, and sustainability in the Western Himalayan region (Ignaciuk, 2014). Investment in R&D is required to create new crop varieties that are climate-resistant (Ignaciuk,2014).Improvement of irrigationtechnologies and sustainable agriculture s ystems requires additional research and development efforts (Ignaciuk,2014). Investment in research on organic agriculture is required to synthesize emission reduction estimates and to determine its full potential for sustainable livelihoods (Scialabba, 2010). Understanding the complex dynamics between climate change, agriculture, and livelihoods requires a multidisciplinary research framework with social, economic, and ecological approaches (Ensor, 2019). Research on the effectiveness of community-based adaptation interventions and the integration of local knowledge is required to develop effective and context-specific interventions (Chanza, 2016), (Khatiwada, 2017). Research on the development of effective early warning systems is required to ensure targeted research and investment (Cieslik, 2019), (Bardosh, 2017). More emphasis on doubling double-rice systems in high-yield gap provinces could enhance self-sufficiency and return on investment in research and development (Deng, 2019). But the question is how to mobilize funds effectively and invest in these reforms, designing dynamic policies for long-term adaptation rather than technology (Aryal, 2019). Enhancing climate-resilient crop varieties, irrigation technologies, and sustainable land management practices is essential for long-term sustainability (Mondal & Zhang, 2018; Tewari, Verma, & von Gadow, 2017).

3.6. Policy Interventions

Enforcing climate mitigation policies, promoting renewable energy, and implementing disaster risk reduction programs can support adaptation efforts (Rasul, 2014). Climate models project continuous temperature increases across South Asia, necessitating adaptation strategies that consider shifts in snow and ice accumulation and their implications for water resources (Almazroui et al., 2020). Ethical considerations should also play a role in food security policies, balancing environmental sustainability with individual dietary needs (Fanzo, 2015). Moving forward, further research and collaborative efforts will be essential in shaping effective and sustainable responses to these pressing challenges. Effective policy

interventions are required to enhance sustainable agricultural systems, livelihood diversification, and community-based adaptation in the Western Himalayan region (Aryal, 2019),
(Ignaciuk,2014). Institutionalframeworks must be strengthened for the implementation and di ssemination of technical solutions to agriculture (Aryal, 2019). Investment in dynamic policies on long-term adaptation strategies is required (Aryal,2019).Government investment plays a crucial role in improving postharvest management and safety of vegetable production, and market access for smallholder farmers (Schreinemachers,2017). Diversification and uptake of sustainable agriculture requires polic y interventions (Kremen, 2012). Moreover, policies must consider the ethics of response to adaptation and the boundaries of adaptation (Klein, 2015). Mainstreaming of indigenous knowledge into climate practices requires flexible and adaptive governance practices that incorporate local knowledge and practices into policy responses (Chanza, 2016). Mechanisms and regimes for systematic learning and monitoring of adaptation processes and governance regimes also lack (Brink, 2017). Incorporation of the challenges of mainstreaming community-based initiatives into governance regimes requires close attention to competing values and histories (Nursey Bray, 2018). The contribution of local governments towards enabling organization influences political change (Chu, 2017). Building initial climate-sensitive sector strategies requires federal support for implementation (Moser, 2011). Policy interventions on unsustainable use of water and their impacts on food security and land use are also required (Liu, 2017). Moreover, policies must enable development and implementation of early warning systems and ensure participatory adaptation of meaningful public participation (Bardosh, 2017). Finally, policies must promote adoption of sustainable agriculture practices and diversification of livelihoods to enhance community resilience (Khatiwada, 2017).

4. Conclusion

Climate crisis has created havoc in terms of loss of biodiversity, shrinking traditional livelihoods and sustenance among the communities inhabiting the WHR. Unsustainable and unplanned development has jeopardized the ecological balance affecting food security, water availability and ecosystem services. Shifting climatic conditions are affecting agricultural practices impacting crop yield with increased pest infection and plant diseases. Change in grazing land patterns, fodder availability and erratic weather conditions have forced the high-altitude pastoralism, a traditional livelihood of communities with challenges of co-existence conflicts. Further, glacial retreat and melting are great area of concern and requisite immediate attention for water security and management for domestic and agricultural needs. Declining agricultural productivity, rising food inflation has impacted nutritional security and access to healthy food among marginalised communities. The rich cultural and traditional knowledge systems are under threat due to climate induced displacement and migration. The need of hour is to blend technological advancement with local traditional knowledge for inclusive climate change adaptation. Drought resistant crops, climate smart agricultural behaviour, non-agricultural income generation activities, intensive diversification strategies

in livestock with strong supply chain supporting local markets creation will help in resilient building among communities. Strengthening local community based institutions, fostering participatory and informed decision-making, and ensuring equitable access to resources and information are critical for building community solidarity and resilience. Further, evidence based robust policy framework considering the fragile ecosystem of the WHR need to be developed on sectoral basis with ecosystem based adaptation, sustainable land use planning, invest in R &D for local solutions. Also, strengthening early warning system, training and capacity building will save lives in case of hazards and disasters. Social safety nets be strengthen at the grassroots among the hill communities becomes important to mitigate the climate related stress. The complex issue of climate change, food security and sustainability need to be looked holistically and multi-dimensional approach should be adopted to preserve and conserve the fragile and stressed Himalayan socio-ecological systems, so as to ensure climate resilient, empowered and prosperity among communities in the WHR is sustained with a equitable social order.

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