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RESEARCH NEEDS AND REQUIREMENTS IN THE CONTEXT OF CLIMATE CHANGE ADAPTATION AND MITIGATION

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Abstract

Research improves knowledge of the health and environment effects of climate change and provides sustainable solutions for communities to effectively manage and reduce the impacts of a changing climate. Climate impacts research is typically interdisciplinary and frequently involves the construction of climate impact models. Some key research themes include: ecology, water resources, agriculture, human heath, the economy and built infrastructure. This paper deals with research gaps in climate change, sand climate change research needs. It outlines the climate change research areas, research options in climate change mitigation and adaptation in agriculture, and research options in climate change adaptation and mitigation in forest sector. This paper brings to attention on research options in fisheries sector and human health. This paper concludes with some interesting findings along with policy suggestions.

Key words: *Research gap, research needs, research areas, research options, adaptation and mitigation*

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Introduction

Climate change is a change in the statistical distribution of weather patterns when that change lasts for an extended period of time in terms of decades to millions of years. Climate change may refer to a change in average weather conditions, or in the time variation of weather within the context of longer-term average conditions. Climate change is caused by factors such as biotic processes, variations in solar radiation received by Earth, plate tectonics, and volcanic eruptions. Certain human activities have been identified as primary causes of ongoing climate change, often referred to as global warming. There is no general agreement in scientific, media or policy documents as to the precise term to be used to refer to anthropogenic forced change; either "global warming" or "climate change" may be used.

Scientists actively work to understand past and future climate by using observations and theoretical models. A climate record—extending deep into the Earth's past—has been assembled, and continues to be built up, based on geological evidence from borehole temperature profiles, cores removed from deep accumulations of ice, floral and faunal records, glacial and periglacial processes, stable-isotope and other analyses of sediment layers, and records of past sea levels. More recent data are provided by the instrumental record. General circulation models, based on the physical sciences, are often used in theoretical approaches to match past climate data, make future projections, and link causes and effects in climate change.

It could be noted that climate change is a serious problem affecting the life support system. The impacts of climate change have been identified and adaptation and mitigation measures have been undertaken. However, there are some gaps and constraints visible in the knowledge of adaptation and mitigation aspects. Key knowledge gaps include the linkages between impacts of climate change and adaptation and mitigation options. More research is required to better understand climate change challenges and cost-effective solutions at the local levels and to fill knowledge gaps. Despite the emergence of more and more regional and country-specific studies on climate change in India in recent years, knowledge gaps remain huge. There is an urgent need for undertaking more research at regional level to better understand the climate change and its impact, risks and vulnerability, adaptation needs, and mitigation potential at local levels. To undertake such type of research activity, there are many barriers.

Research Gaps in Climate Change

There is a considerable gap in our knowledge on various aspects of climate change, such as: First, there is much to learn about the potential magnitude and rate of climate change at the regional and local levels, and subsequent impacts on the full range of biodiversity endpoints and ecosystems. Second, there is no consolidated literature of proven biodiversity conservation techniques, or climate adaptation techniques, covering all the eco-regions of India. Third, detailed analyses need to be developed for each of the priority climate change threats to biodiversity and other natural resources.

A further strategic approach is needed for detailed research on different ecosystem services and functions to estimate the potential impacts of climate change. Such research could develop adaptation mechanisms and/or highlight mechanisms that have already been implemented by local people in response to the changing environment. Detailed indicative research is also essential to define mitigation strategies at the policy level, which need prioritizing at the government/international level. Apart from the above, some potential areas of research that should be considered are the inter-comparison of key physical and biological processes along a series of transects placed over the region; the establishment of a comprehensive regional database; and an in-depth study of the major forest areas of India.

Studies on Climate Change Research Needs

UNEP (2013), identified the research priorities in climate change mitigation and adaptation at the global level on the basis of literature analysis Survey of 120 experts in the area of climate change vulnerability, impacts and adaptation consultations with 30+ policy-makers and consultations with members of PROVIA Scientific Steering Committee. UNEP identified the research gap and research priorities with respect to measuring and mapping vulnerability, developing and strengthening indicator and monitoring systems, understanding risks of extreme events, non-linear impacts and tipping points, developing integrated cross-disciplinary solutions to maximize co-benefits, identifying factors that support or hinder vulnerability reduction and adaptation, conducting focused research on implementation, improving approaches for valuing adaptation, advancing criteria for prioritizing adaptation strategies, conducting studies on communication, participation and capacity building, determining how communication between

the research community and policy-makers can be more effective and advancing research on lessons learned from developing country experiences and local and traditional knowledge.

UNDP (2011), pointed out the research gap and research priorities in climate change mitigation and adaptation at the global level on the basis of survey of 662 respondents, affiliated mainly with universities and research institutions, United Nations agencies, and local or community non-governmental organizations. UNDP (2011), identified the research gap and research priorities with respect to Resources on addressing water shortage, loss of livelihoods, decreased food security, and damaged ecosystems, socio-economic, cultural, and psychological impacts of climate change, integration of disaster risk reduction and biodiversity conservation into adaptation, resources on how to achieve co-benefits of climate change mitigation and adaptation, information on financial and policy barriers to adaptation and how to overcome them and resources on the evaluation and designing/planning phases of adaptation initiatives.

Africa Adaptation Programme (2012), indicated the research gap and research priorities in climate change mitigation and adaptation at the African Continent level on the basis of survey of 229 members of national teams for the Africa Adaptation Programme (AAP), across 20 countries, members of the project management unit, staff at UNDP Environment Unit, government officials, members of the project steering and technical Committees, national consultants. Africa Adaptation Programme (2012), identified the research gap and research priorities with respect to climate change risk/impact assessments, climate data relating to climate scenarios, integrated modelling results, resources on overcoming barriers, especially financial and technological barriers, and knowledge resources on addressing water shortages, decreased food security, and loss of livelihoods.

Stockholm Environment Institute (2012), indicated the research gap and research priorities in climate change mitigation and adaptation at the Asian Continent level on the basis of country-level scoping studies of adaptation research, capacity-building and other needs in Asia, a desk-top study of capacity gaps and needs across East Asia, and insights from the Knowledge Management Workshop on Harnessing Adaptation Knowledge in the Asia Pacific Region. Stockholm Environment Institute (2012), identified the research gap and research priorities with

respect to downscaled projections of climate change impact, historical meteorological records, hydrological models, downscaled climate models and vulnerability assessments.

Hanger et al. (2013), indicated the research gap and research priorities in climate change mitigation and adaptation at the European level on the basis of mapping and analysis of policy documents and interviews with 30 policy-makers across Europe. Hanger et al. (2013), identified the research gap and research priorities with respect to better filtered, synthesized and accessible information, better structured and accessible data, regionally explicit information on impacts, information on vulnerability and socio-economic implications of adaptation, costs of adaptation measures and best practices.

Ford and Tristan (2010), indicated the research gap and research priorities in climate change mitigation and adaptation at the Western Canadian Arctic region level on the basis of Systematic review and analysis of scientific and grey literature. Ford and Tristan (2010), identified the research gap and research priorities with respect to interaction between projected climate change and associated impacts, and socio-economic–demographic trends, insights for future vulnerability and the level of capacity for adapting to future climate change, location-specific assessments of climate change impacts, cost-benefit analysis of adaptation options, and assessment of non-climatic co-benefits, ways to develop and implement adaptation options, level of support for various adaptation options among stakeholders and community members, and the performance in terms of effectiveness, durability, and long-term viability of adaptation options under different climate change scenarios and in light of multiple stresses and competing policy priorities.

Doswald et al. (2014), indicated the research gap and research priorities in climate change mitigation and adaptation at the Global level, with a focus on Ecosystem-based adaptation approaches on the basis of systematic review and analysis of ecosystem-based adaptation relevant peer-reviewed literature, and a sample of grey literature. Doswald et al. (2014), identified the research gap and research priorities with respect to detailed comparisons between ecosystem-based adaptation and alternative adaptation strategies, taking into account, social, environmental and economic considerations, discussion of thresholds, boundaries and tipping

points across a range of ecosystem-based adaptation options, in varying climatic zones, the potential costs of ecosystem-based adaptation approaches in terms of economic costs as well as actual and potential adverse environment and social effects, the temporal and spatial aspects of ecosystem-based adaptation effectiveness, and information on whether ecosystem-based adaptation is being supported by local/national/international policies and on the success of ecosystem-based adaptation projects regarding instigating policy change.

Niang et al. (2014), indicated the research gap and research priorities in climate change mitigation and adaptation at the African level. They identified the research gap and research priorities with respect to vulnerability and impact assessments with greater continuity, country-specific socio-economic scenarios and greater knowledge on costs and benefits of different adaptation measures.

Magrin et al. (2014), indicated the research gap and research priorities in climate change mitigation and adaptation at the South America level. They identified the research gap and research priorities with respect to high resolution high quality and continuous climate, oceanic and hydrological data, interdisciplinary integrated studies elucidating the interactions between natural and socio-economic systems, the various processes and determinants of adaptive capacity and assessments of the efficiency of adaptation processes.

Climate Change Research Needs

Climate change research needs can be identified by the way of continue efforts to improve the understanding, modeling, and projections of climate changes, especially at the regional scale, including driving forces of emissions and land-use change, changes in temperature, precipitation, soil moisture, runoff, groundwater, evapotranspiration, permafrost, ice and snow cover, sea level change, and ocean processes and chemistry.

Climate change research needs can be understood by the way of improve characterization of important sources of uncertainty, including feedbacks and possible thresholds in the climate system associated with changes in clouds, land and sea ice, aerosols, greenhouse gases, land use and land cover, emissions scenarios, and ocean dynamics.

In order to understand the climate change impact, research methods should aim to develop indicators that allow for timely reporting and enhanced public understanding of climate changes and that allow anticipation and attribution of changes, including abrupt changes and extreme events in the context of a changing climate; and advance understanding of the interactions of climate change and natural variability at multiple time scales, including seasonal to decadal changes and consideration of climate oscillations including the El Niño Southern Oscillation, Pacific Decadal Oscillation, and the North Atlantic Oscillation, and extreme events such as hurricanes, droughts, and floods.

There is a need to improve understanding of climate impacts and vulnerability. In this context, there is a need to maintain and enhance research and development of data collection and analyses to monitor and attribute ongoing and emerging climate impacts including changes in ecosystems, pests and pathogens, disaster losses, water resources, oceans, and social, urban, and economic systems. Here major research priorities include ensuring enhanced geographic coverage of impacts research; the assessment of economic costs and benefits, as well as comparative studies of alternative response options; social science research focused on impacts; and the use of geospatial data systems;

Research is required to increase the understanding of how climate uncertainties combine with socioeconomic and ecological uncertainties and identify improved ways to communicate the combined outcomes. In this connection efforts could be made to develop measurement tools and valuation methods for documenting the economic consequences of climate changes; expand climate impact analyses to focus on understudied but significant economic sectors such as natural resources and energy development for example, mining, oil, gas, and timber; manufacturing; infrastructure, land development, and urban areas; finance and other services.

Research is needed to increase understanding of adaptation pathways. In this connection, efforts could be made to identify the best practices for adaptation planning, implementation, and evaluation across central, state, and local agencies, tribal entities, private firms, non-governmental organizations, and local communities. This requires the rigorous and comparative analysis of the effectiveness of iterative risk management, adaptation strategies and decision

support tools for example, in terms of stakeholder views, institutional structures including regional centers and multi-agency programs, cost/benefit, assessment against stated goals or social and ecological indicators, model validation, and use of relevant information, including traditional knowledge; and understand the institutional and behavioral barriers to adaptation and how to overcome them, including revisions to legal codes, building and infrastructure standards, urban planning, and policy practices.

Research is needed to identify the mitigation options that reduce the risk of longer-term climate change. The importance of research to understand and develop emission reductions through: 1) identifying climate and global change scenarios and their impacts; 2) providing a range of options for reducing the risks to climate and global change; and 3) developing options that allow joint mitigation-adaptation strategies, such as buildings that are more energy efficient and resilient to climate change impacts.

The research activities are required to develop information that supports analysis of new technologies for energy production and use, carbon capture and storage, agricultural and land-use practices, and other technologies that could reduce or offset greenhouse gas emissions. This involves, as a priority, the assessment of the economics of impacts, mitigation, and adaptation; improve understanding of the effectiveness and timescales of mitigation measures through deepened understanding of the relationship between the fate of human-induced and natural carbon emissions, uptake by the terrestrial biosphere and oceans, and atmospheric concentrations. Further, there is a need to and identify the critical social, cultural, institutional, economic, and behavioral processes that present barriers and opportunities for mitigation at the national and international levels and by individuals, state and local governments, and corporations.

Interdisciplinary research is needed, to: understand how hydrological drivers of water supply interact with changing patterns of water demand and evolving water management practices to increase risks of drought, or influence the effectiveness of adaptation and mitigation options. Further, the interdisciplinary research is needed to understand climate change in the context of multiple stresses on earth, ecological, and human systems bring together economic and

quantitative assessment of climate impacts and policies with other more qualitative assessments that include non-market and cultural values; and integrate the understanding of human behavior, engineering, and genomics to expand the range of choice in responding to climate change by providing and thoroughly evaluating new options for adaption and mitigation that improve economic development, energy, health, and food security.

Climate Change Research Areas

The amount of change a system can be exposed to without irreversible damage and the ability of that system to bounce back after impact. Current research thinking on resilience includes the ability of systems to self-organize, to learn and adapt and thus to change to some extent so that the Major research areas include:

Monitoring climate change impact is an important aspect of researcher. In this context, there is a need to improve methods and indicators for monitoring to better inform policy makers and stakeholders about how India's climate is changing and the associated impacts.

Climate projection is an important of research. It can be done through various ways and means. In this connection, there is a need to continue improving methods to "downscale" global climate projections to a scale appropriate for assessments and policies. Convert the large number of projections into probabilities that support risk assessments and into a set of representative projections to support vulnerability assessments and adaptation planning at state, regional, and local scales and GHG accounting can be done by the way of refine emissions accounting methods, especially for short-lived climate pollutants with high potential for warming the atmosphere and for difficult-to-quantify sectors such as agriculture, waste

Research on reducing GHG emissions is very important aspect of climate change research. It can be performed through investigating the multiple pathways that could achieve climate goals related to emissions reductions from the energy, transportation, agriculture, water, waste management, and industrial sectors. Special attention should be paid to the option of electrification of energy services and provision of a low- or no-carbon electricity grid as a cornerstone. This research will advance both innovative technologies and understanding of

consumer behavior. Further. There is a need to frudent management of natural and working lands to sink carbon and preserve their health, without which their ability to sequester carbon will be compromised, is also a priority.

Research on preparing for a changing climate should receive due afternoon in the area of climate change research. Incorporating, new climate science into a risk assessment framework using probabilistic climate and sea-level projections and identifying robust adaptation strategies that would fare well under multiple potential climate scenarios. Vulnerability to extreme events is a particularly critical research gap and it should be explored from local to statewide levels. Further, the research areas include socio-economic effects of climate impacts and policy responses, analyzing the effects of climate change and potential responses in important crosscutting areas, such as economics and jobs, consumer choice, and environmental justice.

Research Options in Climate Change Mitigation in Agriculture

- Full lifecycle analysis of current and alternative farming, livestock and forest systems, including direct and indirect emissions and removals, life cycle fossil fuel use;
- Development of production systems with lower life cycle emissions, that are sustainable, including with respect to impacts on other environmental attributes, and capacity to adapt to climate change;
- Investigation of the potential for low-rainfall tree species to be integrated into farming systems, to provide environmental benefits in addition to carbon sequestration with respect to salinity mitigation and biodiversity enhancement, and for products such as biomass for bioenergy production and composite wood products;
- Research into methods to reduce methane emissions from ruminant livestock;
- Research into methods to reduce nitrous oxide emissions from applied fertiliser;
- Research into methods to manage emissions from manure in intensive livestock industries;
- Research into use of char and recycled organics as a soil amendment to sequester carbon, improve soil organic carbon, improve water holding capacity and nutrient cycling.
- Development of technologies for production of bioenergy and other products from agricultural and forest biomass:

- Examination of a range of feedstocks for suitability for bioenergy production, including novel sources such as mallee eucalypts, woody weeds, arundo donax, jatropha, pongamia, algae;
- Breeding for bioenergy traits through high starch wheats and high biomass grasses;
- Assessment of biochemical options, including concept of biorefinery, whereby high value chemicals are produced from biomass in addition to energy products.
- Quantification of the impacts of management practices on soil carbon and parameterisation of models of soil carbon dynamics for agricultural and forest systems.
- Soil C parameterisation needs to consider coastal systems using C4 perennial grasses and the associated impact of farm practices.

Research Options in Climate Change Adaptation in Agriculture

Agriculture is a key sector in India, as a vast population base of the country still lives in rural areas and depends for its food and livelihoods requirement on agriculture.

The agriculture sector is hugely dependent on climate parameters such as rainfall and temperature, and therefore, a significant amount of the country's resource needs to be expended in identifying appropriate adaptation strategies for the agriculture sector, so as to ensure food security for the nation as well livelihoods security for its vast population. Some adaptation strategies are listed below, which would require considerable research resources in the future.

The climate change adaptation options include the following:

- Breeding for increased tolerance of water stress and improved nutrient use efficiency; tolerance of high temperatures during grain fill; quicker maturity; and lack of requirement for winter chill for bud burst.
- Extending introduced species into medium-low rainfall 'dry margins' environments
- Developing perennial legumes for hot/dry conditions
- Developing perennial grasses for low rainfall areas that are especially sensitive to changes in climate, drought tolerance and climate variability
- Developing species with greater tolerance of overgrazing and uncontrolled grazing.
- Research into the interactive effects of increased atmospheric carbon dioxide in a water and nutrient limited environment on growth of major crop, pasture and forest species. Good understanding of the impacts of climate change will inform adaptation strategies.

- Research into the impacts of climate change on product quality, in all agricultural and forest systems, to inform breeding programs and development of adaptation strategies.
- Research into the impacts of climate change on pests and diseases and resulting impacts on plants and animals.
- Development of strategies for minimising water losses, both on-farm and at regional scale.
- Improved water use efficiency for irrigated agriculture.
- Development of systems to minimise heat stress in the intensive livestock industries.
- Interaction of grazing and climate change on resilience of ecosystems; are systems under greater climatic stress more susceptible to grazingin the form of affecting carrying capacity and degradation risk)
- Impact on weeds and management, particularly herbicide efficacy.
- Landscape management- benefits of categorising to land capability for productivity, more targeted fertiliser management, revegetation etc.

Research Options in Climate Change Adaptation and Mitigation in Forest Sector

Identification of specific research themes related to adaptation and mitigation aspects of forests.

Our present state of knowledge on the relationship between climate and plant performance is grossly inadequate for the purpose of modelling future climate change impacts. Research in the following areas is thus a key prerequisite for coming up with robust adaptation strategies.

1. Ecological research on plant and animal species and communities in relation to climate variability and change: Keeping in view the sensitivity of plant and animal species to climate variability and change, the ecological studies of plant and animal species, plant–animal interactions, and community in relation to climate variability and change are required to be carried out.

2. Dynamic vegetation modelling of climate change impacts on forest ecosystems, biodiversity and adaptation: The few studies so far conducted in India are largely based on equilibrium models, which assume that one forest type is replaced by another forest type under changing climate. The varying climate tolerances of different plant species and the transient phase

response of plant species subjected to climate change are not analysed. There is a need to adapt the existing dynamic vegetation models for application to the diverse tropical forest types in order to analyse the implications of climate change at species level. The ultimate goal is to develop adaptation strategies and practices to reduce vulnerability of forests to climate change. The modelling effort should incorporate adaptation.

3. Impact of climate change on mitigation potential, carbon sinks, and adaptation: India has a large afforestation programme, and it is important to understand the likely impacts of climate change to ensure sustainable management of forests and flow of timber, industrial wood, and non-timber products and conservation of biodiversity. There is a need to analyse the climate impacts using dynamic vegetation models and developing adaptation strategies.

4. Mitigation potential assessment: There is also a need to develop a database on biomass growth rates and soil carbon accumulation rates in forests and plantation systems in different agro-ecological zones of India. This data is required for a realistic assessment of the mitigation potential of the forest sector in India.

Research Options in Climate Change Mitigation and Adaptation in Fisheries

Climate changes can impact fisheries and aquaculture directly, by influencing production quantities and efficiency, or indirectly, by influencing the market price of fish or the costs of goods and services required by the fisheries and aquaculture sectors. We therefore address mitigation and adaptation of climate change across four domains:

1. Analyzing vulnerabilities of fishery systems in regions, countries and communities. New vulnerability indices are used to understand how climate change will affect ecosystems and the capacity of fisheries and their dependent communities to adapt to such impacts. The results provide a foundation for innovation in management and governance.
2. Within vulnerable systems, assessing who and what is most vulnerable, the sources of vulnerability, and the modes of impact. There is a need to identify practical ways fishers can reduce vulnerability and increase resilience to the effects of climate change, with a focus on the higher-risk fishery systems.

3. Developing and testing interventions to increase adaptive capacity at regional, national and local scales to enable fishers to better manage external opportunities and threats.

4. Researching aquaculture technologies to reduce vulnerability and increase adaptive capacity. To overcome the negative impacts and harness the new opportunities presented by climate change, research will focus on developing technological innovations such as resilient fish production traits, integrated farming systems, marine fishmeal replacements and novel aquafeed ingredients as climate-smart aquaculture solutions.

Research options in sustainable marine and freshwater ecosystems should include: Research into sustainable development of marine and freshwater ecosystems, to ensure that they are ecologically healthy as well as economically productive under the predicted impacts of climate change;

- Evaluation of impacts of alternative management and harvest strategies using large scale biogeochemical ecological models;
- Robust monitoring systems to understand impacts of climate change especially on recreationally and commercially harvested fish and invertebrates;
- Research into impact of climate change on ecological health;
- Evaluation of proposed adaptation strategies for marine and freshwater fisheries;
- Research into impacts of increasing acidity of the oceans;
- Research into impacts of sea level rise on estuarine salt marsh communities.

Research options in impact of climate change on human health

Climate change is having direct and indirect impacts on the health of people. More extreme weather events, heat waves, spread of infectious diseases and detrimental impacts on air and water quality are having impacts on our health.

In this context, the research is required to identify and characterize communities and people at greatest risk to climate change and air pollution, assess the individual and synergistic impacts of climate change and air quality on human health, develop approaches to assess the likelihood and effects of extreme events on human health and identify potential societal and behavioral responses to human health risks from climate change.

Conclusion

It could be seen clearly from the above discussion that research needs and requirements in the context of climate change adaptation and mitigation are highly required to overcome the negative impact of climate change on human life support system. It is evident that a lot of research gaps in climate change impact assessment and climate change mitigation and adaptation options. This paper has identified the a lot of research gaps with respect to impact of climate change on agriculture, forestry, fisheries, health, and climate change projections. In order to fulfill the research gaps many research areas and research options have been indicated in this paper with reference to agriculture, forestry, fisheries, health, and climate change projections. Hence there is a need to concentrate research in these areas with a view to develop mitigation measures and adaptation practices to overcome the negative impact of climate change. In order to promote research in climate change impact and its adaptation and mitigation practices, the following policy measures can be considered.

1. The government should allocate more funds for climate change research and publishing its results.
2. Efforts should be made towards developing and improving the infrastructural facilities required for conducting research in climate change impact
3. The government should encourage the researchers and scientist towards undertaking research on climate change impact adaptation, and mitigation practices by the way of providing research grants and other financial assistance.
4. The government should develop climate change research centers in different parts of the country and regular undertaking survey on changing climate scenario and its required adaptation, and mitigation practices
5. The government should promote research on climate smart agriculture by the way of encouraging the agriculture scientists along with provision of necessary financial support and other required infrastructural facilities
6. The government should promote interdisciplinary research and multi disciplinary research towards analyzing the multiple impacts of climate change on human life support system
7. Efforts should be made to disseminate the climate change research to the people in general and farm households in particular through mass media and government extension programmes

8. The government should promote action oriented applied science research towards developing effective climate change adaptation practices.

9. The government should promote climate change mitigation research with a view to undertake mitigation measures to overcome the negative impact of climate change on human life support system

10. The government should promote sector specific policy oriented research in climate change mitigation measures and adaptation mechanism

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