DST-SCCC (2nd Phase)-NMSKCC

NATIONAL MISSION ON STRATEGIC KNOWLEDGE FOR CLIMATE CHANGE (NMSKCC)

Proposal for Strengthening the State Climate Change Centre under NMSKCC (SCCC-NMSKCC) in the State of Karnataka

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Ministry of Science & Technology
Department of Science & Technology
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PART A (General Information)

1.0 Programme Title:

STRENGTHENING THE EXISTING KARNATAKA STRATEGIC KNOWLEDGE CENTRE FOR CLIMATE CHANGE (KSKCCC) ESTABLISHED UNDER NMSKCC AT EMPRI TO ACENTRE OF EXCELLENCE (CoE) IN CLIMATE CHANGE RESEARCH

1.1 Programme summary:

Environment Management and Policy Research Institute(EMPRI), an autonomous body established in 2002 under Department of Forest, Ecology and Environment, Government of Karnataka, is designated as the nodal agencyfor climate changein 2014 for providing technical support for conducting research, trainings and capacity building in climate change programs. Department of Science and Technology (DST) under the SPLICE division (Climate Change Programme Division) of NMSKCC, established the **Strategic Knowledge Centre for Climate Change** in EMPRI in 2016.This project has led to the creation of a State of art Climate Change Laboratory for research studies. An interactive web-portal named "Karnataka State Climate Change Strategic knowledge portal" has been developed and hosted in Karnataka State e-Governance Centre (https://www.karccc.com). To pursue long-term studies on climate change, EMPRI has established Permanent Preservation Plots (PPPs) in the year 2017 in two major forest areas viz., Bannerghatta National Park (BNP) and Doresanipalya Reserve Forest (DRF) in Bangalore. A five year plan is developed to strengthen the climate change laboratory and the research activities of the centre to transform it to a **CENTRE OF EXCELLENCE IN CLIMATE CHANGE RESEARCH.**

Karnataka state is one of the most climate change impacted states in India and because of its heterogeneous geography and ecology, the diverse ecosystems and sectors are differently exposed to the threats and risks and are vulnerable to the impacts of climatic variability and change. We have conducted pioneering studies, first of its kind in the country to characterize the bio ecological aspects and climatic conditions of pristine natural forests. Intensive studies on biophysical and edaphic parameters were undertaken during the last 3 years. However, to interpret the impact of climatic variability/change, long term research studies are essential. Vulnerability and risks of the forest flora to changing climatic conditions need thorough assessment across a long term period. Hence, the present proposal is prepared to continue the efforts to identify the effects/impacts of climatic variation on the bioecological and physiological aspects of natural forest ecosystems. Health, agricultural, water, forest, urban heat island sector require a district wise vulnerability and risk assessment which has hitherto been not assessed and analyzed. Hence the present project aims to target sectors like health, agriculture, water, forests, and urban heat island.

The other components proposed are developing web based applications for portal for interaction with public, students, departments on climate change and its impacts. Databases of floral and faunal diversity are proposed to be developed through citizen science activities in the model as developed for Butterfly monitoring Program through BIA (Butterfly

Identification App) in Phase 1. Capacity building is an important activity for the successful implementation of any program. In this direction, it is proposed to strengthen training unit dedicated to impart trainings on climate change related issues and programs to the governmental authorities as well as the public. Human resource development through networking with academic institutions, training and conduct of national and international conferences are also planned. EMPRI has prepared a roadmap for the decadal plan of implementing state climate actions through its SAPCC version 2 which is submitted to MOEF&CC, Govt of India. This phase 2 proposal for duration of five years is intended to support EMPRI to fulfill the master plan framed in the SAPCC V-2. The implementation of programs and schemes need critical evaluation for its environmental performance / greenness and climate resilient outputs, which can be monitored using the specific toolkits (green index toolkit) already developed by the Department of Climate Change, EMPRI in collaboration with the Indian Institute of Science. It is envisaged that in five years, Karnataka State will be able to combat climate change with its knowledge bank/vulnerability/risk profiling, action bound schemes and critical monitoring and implementing mechanisms for sustaining a climate smart state. Hence this project will cater to the goals of NMSKCC mission to be achieved through **Building a Climate Resilient Karnataka state**.

1.2 Key words: Strategic knowledge centre, Knowledge Portal, Climate change, training centre, climate change research laboratory, SAPCC, climate smart state

1.3 Duration (in years): 5 years

1.4 Total cost (in lakhs): 294.97

1.5 FE component: ---

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PART B (Information about the Programme)

2.0 Introduction

UNFCCC formed in 1992 prescribed code of conduct for action among nations to achieve climate justice through environmentally Sustainable Development. The Intergovernmental Panel on Climate Change (IPCC), 2007 report projected an increase of 2.7 – 4.3°C in temperature by the 2080s, an increase in rainfall of 6-8% and sea level rise of 88 cm by 2100. As per the Intergovernmental Panel on Climate Change (IPCC) 2014 Synthesis Report, the increase of global mean surface temperature by the end of the 21st century (2081–2100) relative to 1986–2005 is likely to be 0.3°C to 1.7°C under RCP2.6, 1.1°C to 2.6°C under RCP4.5, 1.4°C to 3.1°C under RCP6.0 and 2.6°C to 4.8°C under RCP8.5 (RCP=Representative Concentration Pathway). This can have dramatic ill consequences for the environment, ecosystems and biodiversity. National Action Plan on Climate Change (NAPCC) released in June 2008 has emphasized on appropriate long-term mitigation strategies promoting sustainable development and growth with climate "co-benefits". Importance of green growth is reflected in many government and private sector initiatives. NAPCC was to be implemented by each of the states through their state action plans on climate change approved and facilitated by the Indian government.

India's National Action Plan has a clear set of actions in each of the key sectors of governance concerning natural resources (land, water, forests, biodiversity, etc.), energy, agriculture, infra-structure development and industry. The four strategies of Climate Management are Mitigation, Resilience, Adaptation and Clean Development Mechanism enforced through Capacity-Building and enhancement. The NAPCC through its eight sectoral missions provided a detailed road map for achieving the desired objectives. Paris Agreement in 2015 had set forth international environmental jurisprudence, to endeavor for achieving the common goals. Many countries and their states have come forward to hold the increase in the global average temperature to well below 2°C above pre-industrial levels, increasing the ability to adapt to the adverse impacts of climate change and lowering the greenhouse gas emissions, and promoting climate resilient development. Intervention areas include renewable energy, water management, agriculture, forestry, waste management and public transport. States are bound to assess their climate actions based on their domestic priorities under their State Action Plan on Climate Change and link them to the key metrics that align with India's goals under the Nationally Determined Contributions.

The 2030 agenda for global sustainable development envisioned that development and the application of technology are climate-sensitive, respect biodiversity and are resilient. One of the major goals is to take urgent action to combat climate change and its impacts. Emphasis is to be laid on cross-sectoral planning for recognizing and incorporating interacting priorities, such as agriculture, health, forestry, land-use planning, water resources, energy, education, etc. India requires rapid and sustained development not only for poverty eradication but also for the purpose of building up her capacity to cope with, or adapt to, the impacts of climate change. How should a low-income country like India respond to climate change? It is obvious that we must build up our capacity to cope with climate change and adapt to its impacts. This will be possible only if we can overcome the currently severe constraints of financial, technological and human resources. The only hope lies in rapid economic and social development in fields such as education and public health. We currently have only a broad picture of the likely impacts of climate change on India and it is not feasible to design short-term strategies exclusively for climate change. We need to identify the risks,

vulnerabilities and elements of our existing development plans which are likely to also enhance our capacity for adapting to climate change and plan science based solutions to mitigate the climatic changes.

Many research and development institutes in the state of Karnataka are into climate change research and also training. EMPRI is the lead organization to anchor and coordinate and dissipate the knowledge and organize the activities in specific knowledge domains. This proposal envisages strengthening the existing Strategic Knowledge Centre to a Centre of Excellence to take the pivotal role in building climate resilience through science oriented projects and programs catering to the needs of the academia, administration, executives, public and all stakeholders for whom climate change matters in their daily lives. National Mission on Strategic Knowledge in Climate Change programme of Government of India aims at establishing an effective mechanism through creation of knowledge networks for sharing and access of climate related data both within Government and also with public. With the support from CCPD, DST (Govt of India),EMPRI is in a most befitting position to carry out the mission activities from lab to land and plan to programs to build a climate resilient Karnataka state.

3.0 Status of State Action Plan on Climate Change (SAPCC) in your State.

EMPRI being the State nodal agency for Climate Change, Government of Karnataka entrusted EMPRI the work of preparing the State Action Plan on Climate Change (SAPCC). Accordingly, EMPRI prepared the 'Karnataka State Action Plan on Climate Change – 1st Assessment'. Under the chairmanship of ACS & Development Commissioner, GoK in consultation with all the GoK Departments (sectors), EMPRI submitted the plan to GoK and later to Government of India (GoI) in 2015. The Expert Committee on Climate Change of MoEF&CC recommended the approval of KSAPCC to the National Steering Committee on Climate Change of MoEF&CC. The National Steering Committee on Climate Change in its fourth meeting held on August 26, 2014 recommended the endorsement of the KSAPCC- 1st Assessment subject to incorporation of the additional information on targets and goals of all activities, activities to be taken up and break up of available and additional fund requirements. In 2015 the KSAPCC 1 was endorsed by MoEF&CC and published online.

As per the directives of the Ministry of Environment, Forest and Climate Change to Karnataka State in 2019, EMPRI has revised the 1st State Action Plan on Climate Change (SAPCC V-1). The Core group was formed under the Chairmanship of Additional Chief Secretary and Development Commissioner, Government of Karnataka for revision of the action plan. Chapter-wise discussion meetings were held to discuss the broad outline of each of the chapters and representatives from various research and academic institutes were involved in chapter writing for the action plan. The 1st, 2nd, 3rd and 4th chapter-wise meetings were held with the concerned officials and resource persons to discuss about the various chapters of SAPCC. Nodal officers for Climate Change were designated from each of the state departments. A training program cum 1st Stakeholder meeting was organized to train the nodal officers and facilitate interaction between the nodal officers and experts/authors. Four modelling projects were assigned to experts in other institutes so that the revised SAPCC will have projections for the future which can help in the planning of climate actions in different sectors. Two review meetings were held to review the progress of work on State Action Plan. Prioritization meetings were held with different departments. **The draft report of SAPCC version 2 has been finalized and submitted to MoEF&CC through Government of Karnataka.**

4.0 Details of actions proposed to be undertaken under revised SAPCC (if already approved)

The 1st State Action Plan approved in 2015 comprised of a comprehensive actionplan spanning all the sectors identified. It defined morethan 200 action points necessary to enhance Karnataka'spreparedness for climate change. The plan identified 56 key challenges sector-wise and defined 219 actions inresponse. Thirty one of these were prioritized as entrypoints. Many of these have helped to enhance the resiliencein pursuing sustainable development while exploitingopportunities that could come with climate change.The revision of SAPCC is based on the commitmentsmade in light of Nationally Determined Contributions (NDC) targets. Based on the MoEF&CC guidelines for the preparation of the revision of the KSAPCC, the action points are framed in tune with each of the NDC targets. Some potential programmes and projects that could be implemented in Karnataka to promote activities contributing to the NDC targets of the country under the Paris Agreement are listed below:

Proposed Mitigation Strategies/Activities

Power

- Installation of solar-based electricity generation needs to be prioritized
- Shifting to solar PV from conventional fossil-fuel-based generation would reduce the state's dependence on other states for coal.
- The developers need to make the investment; the state should focus on attracting investment by introducing regulatory changes.
- The state should also focus on improving T&D infrastructure, even though the potential is lower.

Transport

- A rigorous implementation of the state EV policy
- Provision of demand incentive through the FAME India scheme until 2030
- The government should prioritise the augmentation of its bus services to improve the first- and last-mile connectivity.
- The state should also focus on improving the public transport network across Karnataka by improving the bus fleet and adding new routes across the state under various road transport corporations.

Industry

- The state needs to prioritize the implementation of energy-efficiency measures in all industrial units in addition to the ones already covered under the PAT scheme.
- The only refinery in Karnataka—Mangalore Refinery and Petrochemicals Limited (MRPL)—has been included in the PAT scheme from Cycle II onwards.

The implementation of subsector-wise specific energy consumption (SEC) reduction targets would be feasible when implemented in various stages.

Buildings

- Innovative methods to boost ECBC adoption—including helping consumers realise the returns on their investment, such as energy saving and a reduced electricity bill—are necessary.
- Incentive mechanism on additional FSI could also be an option to encourage ECBC-compliant buildings.
- There should be a strong focus on enhancing the distribution network. This, for example, could involve local entrepreneurs with a larger customer base and outreach.
- The state also needs to run effective advertisement campaigns that inform consumers of the benefit of switching to efficient appliances.
- The success of the UJALA scheme indicates that such an initiative could be replicated for other electrical appliances.

Agriculture

- With the 2020 Union Budget's renewed emphasis on solar energy for farming (with the PM-KUSUM scheme), installation of solar pumps is a clear priority.
- Karnataka is one of the early adopters of energy-efficient pumps, and is likely to continue with the installation, considering the success of the pilot projects.

Forestry

- Climate Resilient Afforestation Programme
- Agro-forestry for Resilience Building in Rural Communities and Farmers
- Linking of Protected Areas, Corridors and Fragmented Forests
- Research for Climate-Resilient Silviculture

A few mitigation actions that the state could prioritize are:

- Higher uptake of renewables: With a high potential of renewables within the state, Karnataka could install an additional 5 GW of wind and 13.8 GW of solar-power based projects (including RTPV) by 2030.
- Boost energy-efficiency programmes in all demand sectors (agriculture, industries, buildings) within the state
- Ensure that solar pumps comprise at least one-third of all irrigation pumps
- Adopt efficient lighting: The state should continue distributing subsidised LED bulbs, so that at least 75% of the residential lighting points are LED-based.
- Mandate and include ECBC in residential building by-laws
- Improve the state's charging infrastructure for higher uptake of electric vehicles
- Creation of carbon sinks in wastelands and fallow lands.

The highest mitigation potential in the energy sector is from RE installations, followed by energy-efficiency improvements in industries and agriculture. Energy-efficient pumps, solar-powered agricultural feeders, and solar pumps offer a huge reduction in energy consumption and subsidy (for free electricity to irrigation pumps $\leq$ 10 HP). Similarly, there is a good opportunity for GHG mitigation by reducing SEC in key industries like cement, iron and steel. Forestry provides an opportunity for creating carbon sinks, along with multiple co-benefits in the short- and long-term.

Proposed Strategies for Adaptation

Agriculture Sector

- Weather-based cropping pattern.
- Strengthening the agromet advisory services in the State
- Flood adaptation strategies (Long Range)
- Organic farming
- Soil health
- Rainwater management in rainfed areas

Animal Husbandry

- Identifying and strengthening local breeds that have adapted to local climatic stress and feed sources
- Improving local genetics through cross-breeding with heat and disease-tolerant breeds
- Promotion of interregional trade and credit schemes
- Removing or introducing subsidies, insurance systems
- Understanding and awareness of climate change in agro-ecological technologies and practices
- Provision of shade and water to reduce heat stress from increased temperature
- Reduction of livestock numbers in some cases
- Changes in livestock/herd composition
- Improved management of water resources
- Genetic development of less sensitive breeds
- Improving water availability
- Improving animal health
- Female empowerment
- Early warning system and communication
- Capacity building programmes

Other livestock adaptation strategies

- Developing and promoting drought-tolerant and early-maturing crop species
- Adopting Integrated Disease Surveillance Response systems and emergency preparedness to prevent, mitigate, and respond to epidemic
- Strengthening meteorological services to provide timely weather and climate forecast/information early-warning systems
- Promoting and strengthening aquaculture, poultry raising, and the like as alternative livelihood options
- Developing and promoting guidelines for using herbal and alternative medicine for improving livestock production
- Increasing agriculture extension activities
- Migration of herds along the rivers to find better fodder during drought
- Conserving natural genetic resources
- Identify ecologically and socially sound options for improving water availability
- Developing technological interventions to meet the climate change challenge
- Strengthen access to appropriate veterinary services, including community animal health workers.

Coastal Sector and Fisheries

- Reduce the pressure on marine fisheries
- Provide alternative livelihood to the fishing communities
- Identify low lying salinized land area and promote agri cum fish culture
- Promote mariculture
- Promote edible oyster, seaweed, pearl oyster culture
- Establish hatcheries for the production of fish and shellfish fingerlings/spats for undertaking culture
- Identify eroding sides and adapt suitable erosion control methods for preventing erosion
- Skill development
- Provide safe housing
- Provide appropriate rescue relief and rehabilitation
- Assess all the existing fisheries related infrastructure

Groundwater

- Demand management
- Micro irrigation
- Regulatory measures
- Quality monitoring
- Training on efficiency and judicious usage
- Installation of a low-cost water measuring device.

5.0 Please provide list of priority actions proposed under as part of SAPCC linked to NMSKCC

	Challenges	Actions proposed
Agriculture		
1	Agriculture consumes a significant portion of energy, causing a roughly proportionate emission of GHGs emissions from energy alone.	• Data on the seasonal peak power consumption pattern. • Data on the number of power consuming machineries at farms. • Identifying intervention areas for providing energy efficiency at farm levels
2	Subsidies supporting farming lack mechanisms for shifting cropping patterns in line with projected climatic shifts across agro-climatic zones.	• Preparation of an inventory of cropping patterns and changes in the same with respect to agro-climatic zones of the state.
3	The current level of knowledge on the spatial dimension, time scale and magnitude of climatic changes is too limited to make predictions for cropping pattern with the necessary certainty.	• Web based services to provide all weather related information through a single window, preferable trough Karnataka State Natural Disaster Monitoring Centre

4	Widespread absence of scientific dry-land farming practices	• Creation of model farms and villages, establishment of fodder banks under use of instruments provided by National Mission on Sustainable Agriculture
5	Significant untapped minimisation potential in the application of synthetic agro-chemicals (pesticides, fertilizers)	• Block wise data on the agro-chemical usage at farm level. Soil resource mapping using GIS and remote sensing.
Horticulture		
1	Significant unutilised portions of degraded land/arid land are unsuitable for agriculture but suitable for horticulture, especially in northern Karnataka.	• Comprehensive block-wise data on the type, area and problems of degraded lands.
Animal Husbandry		
1	Lack of mechanisms, initiative and incentives for preserving indigenous climate tolerant breeds of cattle (amrithmahal, hallikar, khillar) and buffalo (pandharpuri, surthi)	• Maintaining data on the number of indigenous breeds and trends observed.
Water Resources		
1	Over-extraction of ground-water resources, especially in 35 over-exploited and 3 critical taluks.	• Prepare and update an inventory of sectorial use of groundwater. • Groundwater resource mapping using GIS tools. • Spatial and temporal assessment of micro-watershed based water availability using models such as the Soil and Water Assessment Tool (SWAT).
2	The vast potential for collection of rainwater for productive use, groundwater recharge and temporary storage in water bodies in order to reduce the irrigation dependency on groundwater (at pre-sent it is 45%) remains to be utilised	• Demonstrate best practices at pilot scale. • Prediction of actual water availability and trends in the state using high resolution climates impacts studies at block level.
3	Reuse of treated water in industries and urban local bodies (ULBs) has been unable to make significant in roads.	• Priority Action13: Integrated water resources management to commence in public buildings to set examples and inspire confidence • Create awareness in order to enhance social acceptability of treated water
4	A minimum flow of rivers in the dry season is not being maintained, leading to excessive	• Estimate a safe minimum water flow for maintenance of ecosystems

	concentrations of pollutants	
Forestry, Wildlife and Biodiversity		
1	Long-term carbon capture strategies would require a currently not envisaged return to timber as building material from mature and sustainably managed forests and plantations	• Monitoring of carbon stocks through collaboration of Karnataka Forest Dept. with Indian Institute of Science (IISc) and other universities
		• Devise strategies to identify market-linked opportunities for development of robust carbon sinks as well as in-creasing income for local communities
2	Biodiversity hotspots such as the Western Ghats are insufficiently protected	• Rigid protection from biotic and abiotic interferences • Comprehensive documentation of the status of flora and fauna • Priority Action15: Estimate the carrying capacity of the Western Ghats for settlements, agriculture, roads and mines
3	Forest degradation due to unplanned extraction of firewood, fodder, NTFP, green manure etc.	• Systematic recording of unplanned extraction of fuel wood, fodder, non-timber forest products (NTFP), green manure etc.
4	Invasion of alien species (*Tilapia* sp, *Eupatorium* sp etc.).	• Develop and maintain a database containing information on the control and management of invasive alien species that is easily accessible to public. • Priority Action16: Scientific research on eradication, containment and control methods and technologies for priority invasive alien species
5	Encroachment of forests by human settlements, agriculture, coffee plantations and mines.	• A database to be established and maintained tracking encroachments, evictions and reforestation measures
6	Vast tracts of forest fall victim to forest fires every year. Both fire prevention and emergency response appear inadequate to tackle the challenge	• Research on adopting modern technology to locate and forecast fires. Fire risk zones prioritisation and monitoring based on satellite imageries
7	Gradual loss of green cover in urban areas.	• Biodiversity inventories of specific are-as within cities should be documented.
Coastal zone		
1	Coastal pollution due to industries, aquaculture, port activities and sand mining has the potential to upset the fragile coastal ecological balance	• Data on type and amount of hazardous chemicals released by sector • Data on area under mangrove ecosystem and temporal change in the same • Research on the implementation of advance treatment technology to reduce pollutants entering the sea • Conduct research into the scope, options and viability for turning conventional into organic

		aquaculture
2	In portions of the coastline the scale of marine fishing is ecologically unsustainable, leading to substantial seasonal fish population decimations. Dependent communities have in a number of cases moved on to shell collection and sand mining for the sake of livelihood while labour cost along coast is high.	• Conducting a socio-economic impact study due to change in ecological conditions and impact on livelihood
3	Very limited research publications are available that investigate the link between climate change and behavioural responses of fish and other marine biodiversity	• Development of a marine resources information system • Promoting web based services to provide information on coastal climate and resources • Research on regional level predictions of likely impact of climate change on coastal fisheries and ecosystems • Review of options for establishment of a network for collection of additional data: Hydro-meteorological and hydrological data from the coastal region, coastal and estuarine water, salinity and tidal water levels and the changing discharges in both directions in estuarine areas
4	No systematic mapping of Karnataka's 320 km coastline has been undertaken to project the possible impact of the anticipated sea level rise and determine protection measures and timeframes	• Reassessment and mapping of coastal resources. Concerned departments and research institutes to store and publish data related to sea level, sea erosion, flood, river flow and change in biodiversity etc. • Establishment of a sea level monitoring station under the aegis of the National Institute of Oceanography • Establishment/ strengthening of a groundwater monitoring network with observation wells, sanctuary wells for coastal aquifers • Research on flood forecasting, downscaled climate change projections with improved grid resolution • Research on impact of sea level rise on groundwater salinity including hydro-chemical and solute transport modeling • Research into marine biogeochemistry and influence on GHG sources and sinks • Establishment of an inventory of wetlands, mapping of vegetation cover, silting, encroachment, conservation of mangrove areas conservation, afforestation,

		hydrological and hydro-meteorological data, salinity, well observation, sea level rise, sediment transport in the river etc. • Mapping of encroachments, change of land use, infrastructure development, pollution, growth of invasive species and over-fishing
5	Bengeres, coastal settlements locked between the sea and river, are completely unprotected. A natural disaster such as a tsunami or typhoon could wipe out its population	• Coastal rehabilitation activities
6	The mangrove ecosystem and coral reefs are insufficiently protected	• Establish a mangrove study center, which will take up research on mangroves and associated biodiversity vis-à-vis climate change • Monitor the relationship between changes in mangrove species under changing climate patterns
Energy		
1	The power deficit is likely to remain unaddressed in the short and mid-term, leading to load shedding and a continuation of large investments into secondary energy infrastructure such DG sets and UPSs which increase the burden on the environment through air pollution, noise levels and disposal of lead acid batteries	• Aggregate data on load shedding and to develop a procedure to allocate it judiciously across the sectoral customers to reduce dependence on secondary sources
2	High transmission and distribution losses of currently 22%	• Computation of T&D losses by Aggregate Technical & Commercial (AT&C) losses to capture the difference between billing and collection of power under the Restructured Accelerated Power Development and Reform Programme (R-APDRP)

3	Energy effiiciency failed to make substantial inroads. Energy audit still has low visibility, the necessary professional capacities remain to be created at scale, the Energy Conservation Building Code (ECBC) is yet to be notified at state level, the concept of Green Rating for Integrated Habitat Assessment (GRIHA) is also not in force as it is a part of ECBC. Altogether, the Market Transformation for Energy Efficiency (MTEE) under the NAPCC are not on the horizon in Karnataka yet	• Collection of data for trend analysis in electricity demand before/after incorporation of energy efficient measures • Conduct market surveys to evaluate the penetration potential of energy efficient appliances in the domestic sector • Carry out studies to assess the scope of energy saving at farm level through voltage stabilization and more efficient appliances (electric motors, agricultural pump sets etc.), possibly in conjunction with the NirantaraJyothi Scheme • Assess the impact of the *Belaku* scheme in terms of power savings, CFL lifetime and consumer confidence over a period of at least 2 years
4	The estimated potential of renewables has till date been harnessed to 11.5%. Large-scale pilots projects are not on the horizon yet, apart from KPCL's demonstration plants of 3-5 MW capacity	• Tracking the success rate and performance of implementation of renewable energy projects • Research interventions to tap biogenic gas generated from methanogenic organisms in marshes, bogs, landfills and shallow sediments
5	Except from traditional firewood use, the use of bio-fuels failed to make substantial inroads at scale.	• R&D to focus on piloting viable options for subsequent larger-scale deployment of bio-fuels as substitutes for fossil fuel for diesel and petrol engines (vehicles and DG sets);
6	The use of improved cooking stoves (*chulas*) is too limited for its potential of reducing wood consumption while reducing indoor air pollution and safeguarding human health, especially of women who spend considerable time indoors	• Conduct a larger field survey of indoor air pollution in respect of traditional and improved stoves under real-life conditions across Karnataka and identify reasons impeding further deployment of improved stoves
Urbanization		
1	Strom water drains are unable to deal with water from moderately heavy rainfalls while climate change may lead to greater precipitation in shorter intervals than previously encountered	• Data on potential for rainwater harvesting and artificial recharge possibility • Develop a better rainfall run-off model in the urban context to improve on the empirical system still followed for sizing of storm water drains
2	Much remains to be done to manage municipal solid waste in line with good practices and legislative requirements	• Assessment of impediments in proper management of municipal waste at the level of urban local bodies (ULBs); • Using GIS/ remote sensing techniques for tracking disposal of waste

		• Targeted exploration of new and economically viable recycling options.
3	Large untapped energy potential from solid waste (135 MW) that could be an interim solution until better composting is realised	• R&D on techniques and methods to generate energy from waste
4	Considerable inadequacy in sewage collection, treatment and reuse of treated water	• Installation of sewage/waste water treatment plants in urban area
5	Basic needs of the urban poor in respect of water, sanitation, electricity unmet for many	• Ensure continuation of the work of Karnataka Slum Development Board in ensuring access to safe water and sanitation in slums
6	Difficult to change behavioural patterns result in road humps that increase fuel consumption, air pollution and noise apart from being undesirable for commuters	• Actions for addressing this issue may be defined in forthcoming editions of the Karnataka SAPCC.
7	Gradual loss of green cover in urban areas.	• Maintain data on annual tree plantations and removals.
Health		
1	Absence of a health status inventory	• Maintenance of data related to mortality and morbidity at district/block level
2	The relationship between human health and climate change (vector borne disease, heat stress etc.) is not well established in published literature	• Development of a database on the cases of vector borne diseases and transmission • Conduct region wise research on diseases related to water availability and quality • Procure, develop and customize high-resolution health impact models in collaboration with national and international agencies to exchange knowledge • Studies on climate change linked parasite activities and impact on human health
3	Most vulnerable regions of the state in the context of health remain to be identified	• Conduct research on the trend of vector borne diseases and identify vulnerable regions under use of GIS mapping.

6.0 State of the art of present knowledge in the area of climate change and related aspects in your state including assessment of gap areas

There are many institutions in Karnataka engaged in climate change research with whom EMPRI as the nodal agency, has made institutional arrangements to conduct collaborative research. The institutes are Indian Institute of Science (IISc), Indian Institute of Technology, Hyderabad (IITH), Centre for Study of Science, Technology & Policy (CSTEP), National Institute of Advanced Studies (NIAS), Institute of Social and Economic Sciences (ISEC), University of Agricultural Sciences (UAS), Central Institute of Marine Fisheries Research (CIMFR), Indian Institute of Management, Bangalore (IIMB) and NGOs like Bangalore Climate Change Initiative - Karnataka (BCCI-K), The Energy research Institute (TERI), etc. Institutes like IISc and the Divecha centre for climate change is deeply into the science of climate change, modeling the impacts in a futuristic way and spreading awareness on the

phenomenon and need for its adaptation/ mitigation. EMPRI in collaboration with expert institutes has conducted research on diverse areas to study the integrated vulnerability of districts to certain indicators as prescribed by IIT, Mandi. Also we have developed Green index tool kit to measure the environmental performance of Governmental schemes. An overall schematic showing various components, projects & outputs under climate change action envisaged at the organization level is shown in figure 1.

Review on Research Areas

A. Risk and vulnerability

Climatic change manifesting as extremes of temperature and precipitation is recognized as the most severe environmental threat for ecology, development of human society and human health (Alley et al., 2003; Haines et al., 2006). Alterations in frequency and intensity of rainfall, temperature, storm due to climate result in millions of causalities, damage to public health infrastructure, loss to livelihood and economy (Berry et al., 2013). The health effects of climate change include drowning, injuries, and heat related illnesses, or indirect and delayed, such as waterborne infections, vector-borne diseases, air-borne diseases, mental health consequences, and food shortages. Frequency and severity of climate variability and extremes including floods, drought, heat waves, cold waves, cyclones, storm surges will increase in future, as projected by (IPCC, 2014). IPCC (2014) also projected that the global surface temperature will rise by 1.1°C to 2.6°C (RCP4.5) and 2.6°C to 4.8°C (RCP 8.5) by the year 2080-2100 relative to the time period of 1986-2005. It is expected that frequency, duration, and magnitude of temperature extremes i.e., heat stress and cold waves will also increase by the end of 21st century (IPCC, 2014). Less precipitation is expected in mid-latitude, subtropical arid and semi-arid regions while more precipitation in many moist mid-latitude regions under the RCP 8.5 scenario. Moreover, mid latitude land masses are likely to experience more intense precipitation and severe storms. Surface evaporation and runoff rate is likely to increase in northern latitude (IPCC, 2014). In Indian context, rainfall frequency is projected to decrease over western and central part and increase near Himalayan foothills, Uttarakhand and in Northeast India. Heavy precipitation, tropical cyclones including typhoons and hurricanes will become more intense by the end of 21st century (MoEF, 2014)which would aggravate the severity of health risks over entire Indian subcontinent. The projection by IPCC warns us to take preventive actions to avoid further damage in the future.

Access and availability of food is dependent on agriculture sector which is facing several challenges related to crop yield, sustainability, efficiency and vulnerable situation of farmers and agricultural labours further aggravates the agrarian crisis (Joshi 2015; Basu et al. 2016; Swami et al. 2018). Significant potential for improvement in agricultural output lies in the semi-arid regions of developing countries such as India due to their dependence on rainfall and more number of smallholder farms (ICRISAT 2009). Irrigation facilities are not properly developed in India and thereby, Indian agriculture is mainly dependent on monsoon and temperature variability (Dwivedy 2011). Imbalanced climatic conditions such as extremes of temperature and monsoon i.e., high frequency and intensity of rainfall and temperature negatively affects the crop productivity of a region (Lobell and Field 2007; Ghosh et al. 2009; Singh et al. 2014). For instance, Kumar and Parikh (2001) found that increase in temperature by 2 ^{o}C and precipitation by 7% would lead to loss of 8.4% in total revenue for India. Hebbar et al. (2013) projected that temperature rise of 3.2 ^{o}C will decrease the cotton yield by 268 kg/hectare in central India. Singh et al. (2009) also reported that temperature rise from 1 to 4 ^{o}C will reduce the soybean yield between 11-36% in India. India experienced an around 18%

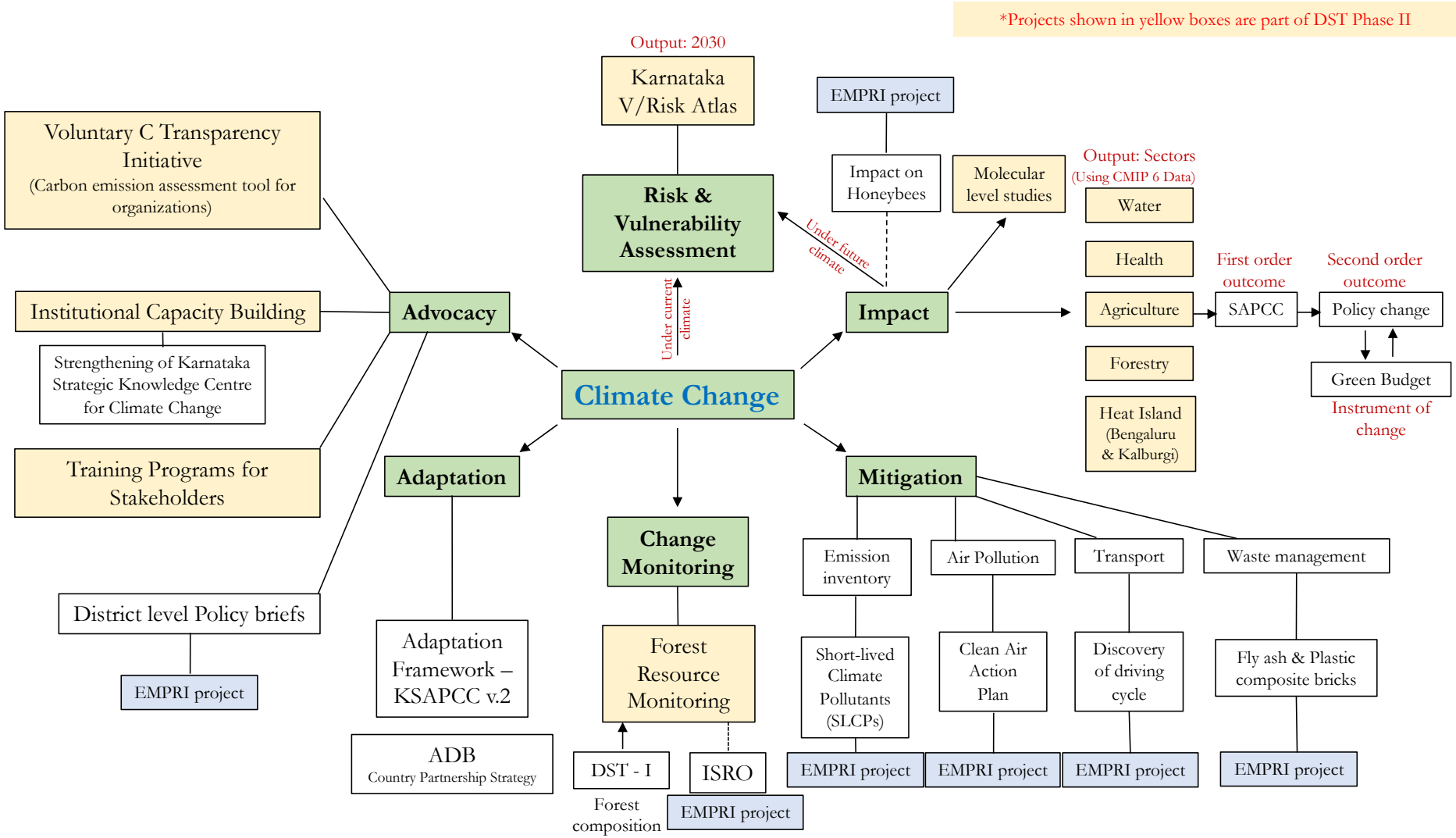


Fig 1. An overall schematic showing various components, projects & outputs under climate change action envisaged at the organization level

decline in food grain production in 2002 due to 19% reduction in monsoon rainfall in the year 2002 in comparison to the year 2001 (Mall et al. 2006).

We found that earlier vulnerability assessments were done for countries but the variability among different regions in terms of environmental factors and their education status, income level, and their different adaptation responses led to a more focused and district-specific approach for assessing vulnerability, which is also highlighted by Wang et al. (2014). Despite knowing the significance of regional assessment of climate variability and vulnerability, district scale assessment for identification of the linkage between different sectoral vulnerability& risk, climate variability, infrastructural and agro-ecological factors has not been attempted comprehensively. District scale analysis of risk under climate change would help in resolving the regional level issues which remain unaddressed. It can also motivate civil society organizations and government agencies to allocate more funding to the districts that are showing increasing trend for vulnerability& high ride.The impact of climate variability on crop productivity across different regions of the globewere only limited to either climatic or socio-economic variables and did not incorporate the effect of multiple factors simultaneously i.e., human capital, infrastructure, land use parameters on agriculture sector, which is an advancement of the proposed study over earlier approaches. Impact assessment using latest Coordinated Regional Downscaling Experiment *(*CORDEX) data is now possible. We are proposing to address these research gaps by locating the hot-spots of risk under CC and identifying the factors reinforcing such risk at district level in Karnataka, India.

B. Databases on diversity

Documentation of biodiversity in relation to the geographical/ climatic parameters is very scanty and limited to very few groups, which are very specifically susceptible / vulnerable**.** Many of the groups are bio indicators of climate change. As a pioneering effort, the Strategic Knowledge Centre for Climate Change in EMPRI has initiated a **Butterfly monitoring program for Karnataka**. Monitoring involves the identification and reporting of butterflies in different districts of the state. We have prepared simple easy to use field guides for Bengaluru/ Karnataka butterflies. A mobile App (BIA-Butterfly Identification APP) is developed by EMPRI for the double purpose of helping in field identification of butterflies and sending the information to EMPRI. BIA is linked to EMPRI website and also the Karnataka Climate Change Strategic knowledge portal (https://empri.karnataka.gov.in/info-4/Mobile+Applications/en). The dashboard developed for processing the butterfly data is hosted in Karnataka State Data Centre (KSDC) and shall be accessible to everyone interested to know the details. The program is to be further promoted across all districts of Karnataka through identified nodal agencies (NGC schools, public, citizen science forums Range Forest Offices etc.) If executed meticulously, this will be the first of its kind in the country to monitor the diversity of butterflies and to use them as bio indicators of climate change. It is also planned to create citizen based science applications for capturing the diversity data of more groups of climate sensitive organisms like moths, birds, reptiles etc. in climate sensitive areas.

C. Research gaps

We found that earlier vulnerability assessments were done for countries but the variability among different regions in terms of environmental factors and their education status, income level, and their different adaptation responses led to a more focused and district-specific approach for assessing vulnerability, which is also highlighted by Wang et al. (2014). Despite

knowing the significance of regional assessment of climate variability and vulnerability, district scale assessment for identification of the linkage between agriculture vulnerability, climate variability, infrastructural and agro-ecological factors has not been attempted comprehensively. District scale analysis would help in resolving the regional level issues which remain unaddressed by formulating the policies at larger scale i.e. by considering the state and entire nation as one unit (Dubash and Joseph 2016). It can also motivate civil society organizations and government agencies to allocate more funding to the districts that are showing continuously increasing trend for vulnerability. Another gap is that although these studies (O'Brien et al. 2004, Patnaik et al. 2010, Rama Rao et al. 2016, and Ravindranath et al. 2011) modelled the impact of climate variability on crop productivity across different regions of the globe but were only limited to either climatic or socio-economic variables and did not incorporate the effect of multiple factors simultaneously i.e., human capital, infrastructure, land use parameters on agriculture sector, which is an advancement of the proposed study over earlier approaches. We are proposing to address these research gaps by locating the agriculturally vulnerable hot-spots and identifying the factors leading to agricultural vulnerability of districts in Karnataka, India.

7.0 Problems intended to be addressed by proposed project.

The project will boost the setting up of the institution structure including laboratories, in the identification and acquiring people and skill set for augmenting existing capacities, identify methods for implementing the state action plan on climate change and training need assessment and training partners. It will enable to strengthen the capacity at State level to address climate issues and to integrate climate change and development imperative in policy, plans and programmes in various sectors. Reliable and detailed regional information, including current and future assessments of climate variability and change, is essential in the design of effective strategies for adaptation to climate change for the state. A wide range of knowledge-based decision support tools and analytical environments would be created to support policy bodies for adaptation and mitigation actions.

Vulnerability is the extent to which a system is prone to, or unable to cope with, adverse effects of climate change, which includes climate variability and extremes. It is the function of the character, magnitude and rate of climate variation to which a system is exposed, the sensitivity and adaptive capacity. Exposure is the nature and degree to which a system is exposed to climate change. Sensitivity is the degree to which a system is adversely affected by climate change. Adaptive capacity refers to the capability of a system to better adjust to climate change (IPCC 2007). **The study intends to undertake district level impact & risk assessment for different sectors (water, agriculture, forest, health & urban heat island) for Karnataka.**

Creation of databases on indicator species, both animal and plant groups is intended to be achieved through citizen science programs enabled through mobile Apps. The databases will grow year after year and the correlation with climatic data will help to assess the impacts on biodiversity.The research studies in field and laboratory **through biochemical assays are intended to know the physiological impacts due to climate Change**. In view of the long-term nature of the climate change issue and the very broad scope and dimensions of the problem, it will be important to develop a diverse portfolio of capacity-building interventions in a targeted and strategic manner. The training centre would serve the training and capacity building needs for administrators and the public. Real lab to land action points will be implemented in the state to strengthen its climate resilient sustained growth.

8.0 How the problem has been identified and its relevance to the stated objectives of NMSKCC? Kindly visit following link to refer NMSKCC document:

India has been rapidly enhancing its climate change actions at the domestic level and the Government of India has taken several initiatives in terms of policies and programmes to explore and implement low carbon development strategies. Karnataka is considered to be vulnerable with respect to climate change. The State of Karnataka has rich bio-diversity and vast forest cover and the people in the state are dependent on climate-sensitive sectors like agriculture and forestry for their livelihoods and have socio-economic and ecological reasons to be concerned about the impacts of climate change**.** Several research organisations, NGOs, and individuals in Karnataka pursued independent approaches to deal with climate change issues at the state level. Most of these initiatives were triggered by the imminent threat that climate change had posed to large vulnerable populations in Karnataka. While these first initiatives were laudable and succeeded in soliciting a societal response, they could by and large not initiate concrete actions. The lack of success can be attributed to the fact that they were voluntary in nature.

A wide range of knowledge-based decision support tools and analytical environments would be required to support policy bodies to implement adaptation and mitigation actions. There exists a significant level of current knowledge on climate change vulnerabilities, mitigation and adaptation strategies for Karnataka. The information are spread across and in possession of many governmental and non-governmental agencies and there is no coordination of all knowledge inputs for practical use. Reliable and detailed regional information, including current and future assessments of climate variability and change, is essential in the design of effective strategies for adaptation to climate change for the state. It is essential to anchor all climate related knowledge available in every nook and corner of the state in a common platform and make it available to use as knowledge products, information and data to undertake climate compatible planning, implementation and monitoring, which will help to facilitate respective stakeholders in undertaking activities and projects on climate change.

Strengthening knowledge and institutional capacity in key scientific areas follows directly from the main mandate of the Ministry of Science and Technology. In view of the long-term nature of the climate change issue and the very broad scope and dimensions of the problem, it will be important to develop a diverse portfolio of capacity-building interventions in a targeted and strategic manner. The assistance of Mission for Strategic Knowledge on Climate Change programme (NMSKCC) of Department of Science and Technology is required to address the state's concern through setting up the institution structure, identification of people and skill set for augmenting existing capacities, plan mechanism for acquiring people and skill sets for addressing climate change, identification of funding sources for implementing the action plan and training need assessment and training partners.

The purpose of the State Knowledge Centre as envisaged in the objectives of NMSKCC is to strengthen the capacity at Karnataka State level to address climate issues and to integrate climate change and development imperative in policy, plans and programmes in various sectors.

9.0 How will the project outputs dovetail into the overall development strategy of the state? Specifically how will the project contribute towards the planning, policy formulation and implementation processes for climate change adaptation at the state level?

Karnataka is a progressive state with vast natural resources and knowledge capital of information technology. Physical and financial progress is reflected in the life style and modern technologies and population build up has adversely affected the environmental health. Though this is a common phenomenon globally and in India also, some of the cities in Karnataka are badly hit by the climate change impacts. As per the guidelines of NAPCC, the State Action Plan on Climate Change has been prepared by EMPRI and accepted by the state government. The SAPCC has outlined various challenges and has also given feasible action points to be implemented by various sectors of administrationin the state. The action points basically fall in four categories

- **Research and knowledge generation**
- **Compilation and presentation of information in a common accessible platform**
- **Workshop and Capacity building of the people who are the implementers of the action points**
- **Dissemination of information to grass root level and creation of awareness in the youth and the public**

The revised SAPCC gives a roadmap for the future plans to address the serious issues. The project planned will pave way for the assessment of vulnerability and analysis of risk factors of climate change especially in agriculture, water, forest, health and urban heat island sectors so that adaptation strategies can be planned and implemented. Long term monitoring of climate change through research in permanent preservation plots in forests and the biochemical studies will create knowledge base for understanding the impacts and formulate sustainable action bound programs for the state.

10.0 Concerned parties/ targets users of the outputs of proposed project

The proposed Centre will cater to the needs of researchers, administrators and also the public to build a climate resilient Karnataka state. The target users of the project output will be the all the development Departments, planners at State / District / Block / Administrative circle level and State Government as a whole. The output will also be useful to the different NGOs, academic institutions and other implementing agencies engaged in climate resilient activities in the state and the region as a whole.Younger generations are targeted to impart and spread awareness as they are the flag bearers of the future of the state.

11.0 Relevance of the programme to the work already going on in the organisation. Need of the study/importance of the present proposal

EMPRI is an organization meant to do studies on environment related issues, most of which have direct or indirect relevance to climate change issues. EMPRI's mission is to carryout research on concurrent environmental issues and to provide world class training and advisory services on environmental management, to enable and encourage the civil society, the government and the industries to safeguard and manage natural resources effectively.Most of the studies brought forth the reality of environmental issues, both natural and anthropogenic and pointed out the resolutions and futuristic approach to problem management. The proposed project will certainly help to achieve newer dimensions to the current efforts of EMPRI to build climate resilience in the state.

12.0 Rationale to understand the Continuity of SCCC to 2nd Phase:

Karnataka state is one of the most climate change impacted state in India and because of its heterogenous geography and ecology, the diverse ecosystems and sectors are differently exposed to the threats and risks and are vulnerable to the impacts of climatic variability and change. In 2016, Department of Science and Technology (DST) under NMSKCC, established a Strategic Knowledge Centre for Climate Change at EMPRI. This project has led to the creation of a State of art laboratory for research studies. An interactive web-portal named "Karnataka State Climate Change Strategic knowledge portal" has been developed and hosted in Karnataka State E Governance Centre (https://www.karccc.com). To pursue long-term studies on climate change, EMPRI has established Permanent Preservation Plots (PPPs) in the year 2017 in two major forest areas viz., Bannerghatta National Park (BNP) and Doresanipalya Reserve Forest (DRF) in Bangalore.

We have conducted pioneering studies, first of its kind in the country to characterize the bio ecological aspects and climatic conditions of pristine natural forests. Intensive studies on biophysical and edaphic parameters were undertaken for the last 3 years. However, to interpret the impact of climatic variability/change, long term research studies are essential. Risks and vulnerability of the forest flora to changing climatic conditions need thorough assessment across a long term period. Hence, the present proposal is prepared to continue the efforts to identify the effects/impacts of climatic variation on the bio ecological and physiological aspects of natural forest ecosystems. Health, agricultural, water, forest, urban heat island sector require a district wise risk and vulnerability assessment which has hitherto been not assessed and analyzed. Hence the present project aims to target sectors, forests, water, agriculture and human health.

12.1 Expertize available with Host Institute and ongoing activities related to the NMSKCC mandate

EMPRI has prepared a roadmap for the decadal plan of implementing state climate actions through its SAPCC version 2 which is being submitted to MOEF&CC, Govt of India. This phase 2 proposal proposed from January 2023 for duration of five years is intended to support EMPRI to fulfill the master plan framed in the SAPCC V-2. The implementation of programs and schemes need critical evaluation for its environmental performance / greenness and climate resilient outputs, which can be monitored using the specific toolkits already prepared by the Centre for Climate Change. Building a climate resilient Karnataka through concerted efforts is predominantly planned through this project proposal. It is envisaged that in five years, Karnataka State will be able to combat climate change with its knowledge bank; risk/vulnerability profiling, action bound schemes and critical monitoring and implementing mechanisms for sustaining a climate smart state. Hence this project will cater to the goals of NMSKCCC mission to be achieved in the state.

12.2 Relevance of the project and work carried out in 1st Phase

EMPRI is an organization meant to do studies on environment related issues, most of which have direct or indirect relevance to climate change issues. EMPRI's mission is to carryout research on concurrent environmental issues and to provide world class training and advisory services on environmental management, to enable and encourage the civil society, the government and the industries to safeguard and manage natural resources effectively. Most of

the studies brought forth the reality of environmental issues, both natural and anthropogenic and pointed out the resolutions and futuristic approach to problem management. The proposed project will certainly help to achieve newer dimensions to the current efforts of EMPRI to build climate resilience in the state. The salient work carried out during 1st phase is as follows:

a. The Centre for Climate Change in EMPRI is strengthened into a Strategic Knowledge Centre on Climate Change through establishing a climate change laboratory, developing a knowledge portal, undertaking research projects, training and capacity building programmes.
b. EMPRI has signed memorandum of understanding (MoU) with a total of 17 renowned institutes (IISc, IITs, NIAS etc.) in the state and country for collaborative research and capacity building.
c. A state of art climate change laboratory is established at EMPRI to analyse environmental and climate change parameters including air, noise and water quality, and soil edaphic factors.
d. The climate change laboratory has strengthened the research facilities for analysis of about 40 parameters related to climate change studies. These facilities would help in conducting environmental monitoring and other research in future.
e. EMPRI laboratory will cater to the needs of other external agencies to generate analytical data for research/other investigations.
f. The Laboratory is accredited with ISO (9001:2015, 45001:2018, NABL IEC 17025) certification and recognised as an Environment Laboratory, under the Environment (Protection) Act, 1986.
g. The EMPRI laboratory is under consideration for recognition as a Government Laboratory by Government of Karnataka.
h. Developed a Karnataka State Climate Change Strategic Knowledge Portal (KSCCSKP) (https://www.karccc.com) for knowledge dissemination on climate change.
i. A green index portal is developed to evaluate the governmental schemes towards achieving the climate resilience (https://greenindex.karnataka.gov.in/#/login).
j. A Butterfly Identification App (BIA) - Pathanga is developed for field identification of butterflies to facilitate the Butterfly Monitoring Program (BMP) for Karnataka. The database on butterflies created under BMP from different districts of Karnataka across months, seasons and years shall help in documentation of biodiversity of butterflies and serve as Bio indicators of Climate Change. BMP is hosted in the KSDC server with link https://bmpempri.karnataka.gov.in.
k. Established three permanent preservation plots (PPPs) in the tropical forest of Bangalore to study the vegetation changes due to the impacts of climate change. Installation of Weather monitoring stations in the PPPs to continue recording the weather parameters.
l. A total of 410 training and capacity building programs were conducted to 45,938 participants of various departments and stakeholders.
m. EMPRI has organised National and International seminars/webinars on Climate Change, Green Budget and Short lived climate pollutants.
n. Karnataka state action plan on climate change (KSAPCC) with action points for various sectors in planning adaptation and mitigation measures is submitted and hosted in MoEFCC, GoI (https://moef.gov.in/wp-content/uploads/2017/08/Karnataka.pdf).

o. Revision of Karnataka State Action Plan on Climate Change (2021) is submitted to MoEFCC for approval.
p. Vulnerability Profile of Karnataka State: District Level Vulnerability Assessment is Prepared and submitted to IIT Mandi in the year 2020. Report "Climate Vulnerability Assessment for Adaptation Planning in India Using a Common Framework" is available online. https://dst.gov.in/sites/default/files/Full%20Report%20%281%29.pdf.

12.3 Please specify the technical linkage of the outcome of 1st Phase with the proposed Objectives of 2nd Phase.

i. Development of Karnataka State Climate Change Strategic Knowledge Portal

Karnataka State Climate Change Strategic Knowledge Portal (https://www.karccc.com) is a web-based platform to assist in capacity building and knowledge development that provides access to comprehensive global, regional, and state level information, data, and tools related to climate change and development.

KSCCSKP contains environmental, disaster risk, and socio-economic datasets, as well as synthesis products, such as the climate change adaptation methods, which are built and packaged for climate change thinkers on global climate change perspectives. Vulnerability, Risk Reduction and Adaptation of Climate Change methodologies to provide a quick reference source for development practitioners to better integrate climate resilience in development planning and operations. The portal also provides intelligent links to other resources and tools. Users can evaluate climate-related vulnerabilities, risks, and actions for a particular location on the globe by interpreting climate and climate-related data at different levels of details.

The e-portal will serve to disseminate the information and data on the climate related aspects of the state of Karnataka. It will establish links with all knowledge institutions. The portal will serve academicians, researchers, policy makers and the public.

ii. Dashboard for monitoring the butterflies in Bengaluru/others districts in Karnataka

As Butterflies are bio indicators of Climate Change, to monitor the butterfly diversity in Karnataka state, a Butterfly Identification App (BIA) (android based mobile application) is developed and the dashboard for the same has been hosted in the web-portal.

A Butterfly Identification App (BIA) - Pathanga is developed for field identification of butterflies to facilitate the Butterfly Monitoring Program (BMP) for Karnataka. The database on butterflies created under BMP from different districts of Karnataka across months, seasons and years shall help in documentation of biodiversity of butterflies and serve as Bio indicators of Climate Change. BMP is hosted in the KSDC server with link https://bmpempri.karnataka.gov.in.

iii. The climate change laboratory established in the 1st phase has strengthened the research facilities for analysis of different parameters related to climate change and environmental studies at EMPRI.

iv. The floristic data generated for permanent preservation plots at BNP and DRF would become a baseline data for continuous monitoring studies to record changes in the vegetation due to climate change.

12.4 Is there any value addition in terms of proposed deliverables?

The climate risk assessment/mapping tool at the district level in Karnataka would be made available to stakeholders on public domain.

13.0 Which concerns of revised SAPCC would be undertaken in phase-2 project.

Climate variability and extremes, and sustainable development have long been important in many decision-making contexts. Responding to climate-related risks involves decision making in a changing world, with continuing uncertainty about the severity and timing of climate-change impacts. Adaptation choices in the near term will affect the risks of climate change throughout the 21st century. Thus, there is an urgent need to consider how impacts and risks related to climate change can be reduced and managed through adaptation, while taking into consideration system vulnerabilities, for sustainable development.

The present knowledge on how climate change is anticipated to impact Karnataka is limited. It is not known exactly where, when and to what degree climate change affects Karnataka. Indicative projections on the range of possibilities are drawn and discussed in various scientific and technical forums and continuous efforts are made to identify required immediate and long-term actions.

A comprehensive and coordinated action plan with identified and accepted indicators/parameters is the need of the hour. Integration of impacts, vulnerabilities/risks and adaptation strategies is necessary to assess and prioritize the actions in consultation with stake holders.

14.0 Broad aims and objectives of the proposed project (Not exceeding 500 words. Specific objectives may also be provided in the bullet form)

With the assistance of Mission for Strategic Knowledge on Climate Change programme of Department of Science and Technology, a Strategic Knowledge Centre for Climate Change for the state of Karnataka is established in EMPRI through setting up the institution structure (a climate change laboratory), identification and acquiring people and skill set for augmenting existing capacities and undertaking research and development activities and creation of a strategic knowledge portal for climate change. The main purpose was to strengthen the capacity at State level to address climate issues and to integrate climate change and development imperative in policy, plans and programmes in various sectors. With the commitment to the cause of restoring a climate resilient Karnataka state and with the proven leadership, expertise and experience in hand to create action bound awareness in the people who matter most; EMPRI could raise to an institute of national repute in tackling climate Change issues of the state of Karnataka.

A wide range of knowledge-based decision support tools and analytical environments would be required to support policy bodies on responses through adaptation and mitigation actions. Reliable and detailed regional information, including risks and vulnerabilities, current and future assessments of climate variability and change, is essential in the design of effective strategies for adaptation to climate change for the state. It is essential to anchor all climate related knowledge available in the state into a common platform and make it available to use in existing knowledge products, information and data to undertake climate compatible planning, implementation and monitoring which will help to facilitate undertaking activities and projects on climate change by the respective stakeholders.

In view of the long-term nature of the climate change issue and the very broad scope and dimension of the problem, it will be important to develop a diverse portfolio of research and capacity-building interventions in a targeted and strategic manner. Through the currently on-going CCPD project, EMPRI has built its foundation for shouldering the responsibility of building climate change resilience in the Karnataka state. **Full-fledged capacity and competence can be achieved in continuing the mission objectives further for another five years.**

To achieve the targets, the following major objectives are listed.

1. Vulnerability assessment and Risk analysis - Risk assessment for water, agriculture, forest, health & urban heat island sectors at district level in Karnataka.
2. Establishment and monitoring Permanent Preservation Plots (PPP) in natural forests for of long term research studies on climate change.
3. Strengthen the Climate Change Knowledge Portal to make it more dynamic, interactive and user friendly.
4. Knowledge dissemination through workshops and creation of an *App* enabled databases for climate sensitive plant/animal groups through citizen science.

15.0 Specific Problems/Objectives to be mandatorily addressed in the present proposal/ programme that may include the following broad components to synergise with SAPCC priority areas:

15.1 Vulnerability and risk analysis

Risk identification and assessment are the two important steps that form the basis for successful implementation of climate change adaptation practices. This involves identification and assessment of current (climate variability) and future (climate change) risks and associated societal vulnerabilities. Climate risk identification is the process of defining and describing a climate-related hazard, including its physical characteristics, magnitude and severity, probability and frequency, exposure and consequences. For risk assessment & profile first impact will be assessed using models & latest cordex climate parameter data.

a. Assessment of health vulnerability/risk to climate change at district level for Karnataka

To our knowledge, no research has comprehensively assessed health risks from climate change in Indian subcontinent. To reduce the adverse effects of changing climatic conditions, the health sector needs to be actively involved in developing long-term plans to respond to climate change. Conducting a vulnerability and risk assessment is a key instrument for identifying and preparing for changing health risks in India. Comprehensive vulnerability assessment will help in providing relevant information to policymakers which will help in prioritizing the districts with climate-sensitive health risks. Therefore, aim of current work is to assess the health sector vulnerability of Karnataka State in India. It will help in identifying the climate sensitive current and future health risks across districts of Karnataka. This research may be used as a framework to develop health vulnerability index for other parts of the country as well.

b. District-wise agricultural vulnerability/risk for Karnataka, India

Studies highlight the relationship between agriculture vulnerability and climate variability, and understanding this relationship will help in minimizing the adverse impacts due to climate variability and enhancing the agriculture yield and farmers' adaptive capacity. Following this, the present study investigates the relationship between different components of agricultural vulnerability i.e., climate variability, sensitivity and adaptive capacity. Identifying these relationships will ascertain why and how few regions are highly agriculturally vulnerable in comparison to the other regions.

c. Risk mapping of Water Sector at district level

Existing projections suggest that the Cauvery basin and north-eastern Karnataka may see reductions in total annual rainfall, the frequency of droughts will increase in the eastern plains region as a whole, there could be complex shifts in seasonal patterns, and increased intensity of rainfall**.** In Karnataka, the amount of rainfall does not show an equal distribution, either in space or in time. It varies from heavy rain to scanty in different parts. It also has great regional and temporal variations in distribution. The study of rainfall distribution pattern and its temporal variations is very important, as it depicts the drought vulnerability of an area due to climate. To consider risk from water sector assessment of Drought Vulnerability, which is multi-dimensional than only the delineation of drought prone areas considers many indicators. The three elements hazard, exposure & vulnerability, and their composite index would be used to delineate the areas under risk.

d. Risk mapping of Forest Sector at district level

Forests are subjected to stress from climatic and non-climatic sources. Assessment of vulnerability is a critical pre-requisite to plan forest adaptation in dealing with the risk to forests under climate change. However, there are very few studies thatassess vulnerability of forests for risk assessment under climate change. The available empirical studies consider limited stress factors such as pestilence or fire or drought. The objective is to identify the forests that are under risk under a changing climate.

e. Studying urban Heat Island Effect for Bengaluru & Kalburgi urban areas

It is well observed that urban areas have higher surface and air temperatures than surrounding suburban and non-urban areas, a phenomenon known as the urban heat island (UHI) effect. There are various factors that influence UHI intensity. Bengaluru has a rapidly increasing population and increasing extent of urban areas, but its UHI intensity and corresponding impacts have not been studied. Given Bengaluru's originally dense vegetation due to its previous nickname (i.e., Garden City), high and increasing aerosol loadings, and the fact that increasing urban temperatures can cause more heat related illnesses in a populated city, it is important to study the impacts of urbanization on surface temperature. It is proposed to study UHI for Bengaluru & Kalburgi urban areas. The importance to attain a better understanding of the characteristics of the urban heat island (UHI), its recent trends, and its formation mechanisms is helpful to urban planners, as they will be able to develop optimal mitigation strategies to curb urban heat effect.

15.2 Institutional Capacity building and R&D for data base/Information generation as per the SAPCC and NMSKCC requirements

EMPRI conducts National and International seminar/conferences dealing with the Climate change, its impacts and adaptation and mitigation measures. With the fund support from DST, **EMPRI could successfully conduct three National Seminars on Climate Change during 2017, 2019 and 2020. Books titled, "Climate change: Challenges and Solutions" and "Building Climate Change Resilience" were published based on the contributions in the seminars.** EMPRI has been in the forefront to impart training on wide array of environmental subjects to diverse stakeholders. EMPRI along with Indian Institute of Science (IISc) conducted Green Skill Development Programme (GSDP) course on "Valuation of ecosystem goods and services/Green GDP" for a duration of 15 days (August 2018). EMPRI had conducted **four training workshops for IFS officer during 2016-17, 2017-18, 2019-20and 2020-21. The topics for the trainings were 1.Water resource management in the context of climate change. 2. Finance opportunities towards Establishing Climate Resilient Forests. 3. Ecosystem services: valuation and policy issues and 4. Conservation Issues related to Inland Lakes in the Country in the context of climate change.**

Other than conducting such workshops/seminar/conferences/training, EMPRI aims to transform the existing Karnataka State Climate Change Strategic Knowledge portal into a platform for discussion that contributes to the management of climate change impacts. The forum will provide extensive opportunities to the seekers of climate change solutions. It is aimed to make the platform accessible and one of the globe's most resourceful knowledge base.

A five year plan is proposed to strengthen the climate change knowledge portal with efficient activities for the needs of the existing knowledge Centre by transforming the portal into an interactive forum for public, students, departments on climate change. Enhancement of the Human resource development through collaboration with academic institutions, training and conduct of national and international conferences will be done by channelizing the knowledge portal. The web portal can also act as a stage for the young nature warriors to solve the climatic issues which are causing the drastic change in the climate.

Proposal is also to build a smart mobile application (using Artificial intelligence application soft wares)to create awareness and means of actions to control the carbon footprints (through Reduce, Recycle and Reuse principles).The artificial intelligence incorporated mobile app comprehends smart ways to help in adaptation and mitigation of climate change.

15.3 Trainings for stakeholders including Government officials, researchers, community based organizations, media, etc.

EMPRI had conducted workshops with the senior level government officials to identify the areas and expertise required to strengthen the capacity of departments. Thereafter, a series of training programmes were conducted with the financial support of the Government of Karnataka for officers of various departments. The sectors identified were Forestry, Agriculture, Horticulture, Sericulture, Health, Energy, Urban, Water, Animal Husbandry and Coastal & fisheries. Interaction sessions have been organised for many officers from different sectors on climate change challenges and actions since 2014-15. The training centre was strengthened further and tailor made programmes and interactive sessions and stakeholder meetings were arranged in an organised manner.

Some of the training /programs conducted are on Biomedical Waste Management, Climate change, Plastic ban and Soild Waste Management, Awareness training on ISO 9001:2015 and OSHAS 18001:2007, Laboratory Procedures, Inventorization of water bodies, Environmental Laws and its applicability to EMPRI's activities. Marathon programme for awareness on Plastic ban, Training on green skill development programme (GSDP), Awareness campaign, forest observation, wetland day programme, Butterfly monitoring program, Hazardous waste management rules, Construction and Demolition Waste Management, Wastewater Treatment Plant Training Program etc.Concurrent relevant topics on environment and climate change will be dealt in detailed way to different grades of government officials and public to create awareness leading to the proper implementation of the state action plan on climate change.

Workshop & publicity and advocacy material publication and programs are proposed to be organised regarding risks and dealing with the risks under a changing climate. These programs are driven by encouraging participation and evolving consensus action program to be executed by different stakeholders/authorities.

15.4 Public awareness for community

Awareness on Environmental hygiene and best practices for environmental protection and mitigation of Climate change will be imparted to the public through diverse activities and programs (electronic and print media).

15.5 Any Other

Wide publicity will be given to the Centre for Climate Change and its Strategic Knowledge Portal. Programmes will be scheduled for school and college going children and the staff of different departments in the state for promoting Citizen Science.

16.0 Overall outcome and deliverables of the project based on objectives given in paras 14.0 and 15.0

Objectives	Deliverables
To undertake risk assessment for water, agriculture, forest, health & urban heat island sectors at district level in Karnataka.	District-level Risk Atlas for the state for identified sector.
Long term phenological, carbon stocks and soil character studies in Permanent Preservation Plots (PPP) established in natural forests (Bannerghatta National park and Doresanipalya Forest) of Karnataka.	Monitoring CC impacts on forests through PPPs. Strengthening of climate change has for analysis of air, soil, water & other parameters relevant to CC studies.
Strengthen the Climate Change Knowledge Portal to make it more dynamic, interactive and user friendly.	Better engagement with public in general by disseminate information and data on the climate particularly related to aspects of the state of Karnataka. It will establish links with other knowledge institutions. The portal will serve different stakeholders including academicians, researchers, policy makers and the public.

Knowledge dissemination through workshops and creation of an *App* enabled databases for climate sensitive plant/animal groups through citizen science.	Citizen science platform (Mobile phone based Application) for development of database of identified indicator faunal (say fireflies/butterflies) & floral (say trees of PPPs) species. Workshop & publicity and advocacy material publication and programs are proposed to be organised regarding risks and dealing with the risks under a changing climate. These programs are driven by encouraging participation and evolving consensus action program to be executed by different stakeholders/authorities.

17.0 Detailed methodology and approach for undertaking tasks given in paras 14.0 and 15.0. If necessary, please provide suitable diagram, flow chart, tables etc.

1) Vulnerability assessment and Risk mapping at District level for different sectors in Karnataka

Proposed methodology

We are proposing to use indicator based method to assess vulnerability at district scale for Karnataka. The indicator method of quantifying vulnerability is based on selecting some indicators from the whole set of potential indicators and then systematically combining the selected indicators to indicate the levels of vulnerability. This approach has been widely used (Gbetibouo et al. (2010); O'Brien et al. (2004); Patnaik et al. (2010); and Ravindranath et al., 2011).

Climate data

Daily monsoon and temperature data will be obtained from Indian Meteorological Department (IMD) which releases monsoon data at a resolution of 0.25^{o} latitude × 0.25^{o} longitude and temperature data at resolution of 1^{o} latitude × 1^{o} longitude, where 0.25^{o} and 1^{o} resolution refers to 25 km and 100 km respectively. Finer resolution i.e., 0.25^{o} provides more number of data points within each district in comparison to 1^{o} or coarser resolution. IMD gridded data has been used extensively for long-term monsoon trend analysis by Ghosh and Mujumdar (2009); Singh et al. (2014); and Swami et al. (2018), and long-term temperature trend analysis by Kothawale et al. (2005); and Pal and Al-Tabbaa (2009).

Agriculture data

Data for crop productivity will be acquired from the International Crop Research Institute for Semi-Arid Tropics (http://vdsa.icrisat.ac.in/vdsa-database.htm), Directorate of Economics and Statistics, Karnataka and Ministry of Agriculture, Government of India at district scale for Karnataka state, India. The database consists of agriculture related parameters such as crop yield, barren land, marginalized land holdings, livestock, mechanized equipment etc.

a) **Choosing relevant indicators**:

Exposure parameters include monsoon and temperature variability parameters. Sensitivity indicators include water holding capacity of soil, rural population density, area and number of marginalized land holdings, drought and flood proneness, per capita income, rural households not having provision of drinking water and electricity, land degradation, percentage of irrigated land, and crop diversification index, as reported by Gbetibouo et al. (2010); Maiti et al. (2017); and Rama Rao et al. (2016). Adaptive capacity indicators include leadership, communication skills, personal growth, team building, time management, literacy rate, availability of agricultural labour (Rao and Varghese 2009), infrastructure, medical and educational facilities, paved roads and rural electrification (Maiti et al. (2017); and Rama Rao et al. (2016)). Other adaptive capacity indicators are livestock, water availability, farm harvest price, total wages of agricultural labour, overall production, cropping intensity and average crop yield.

b) **Normalizing the indicators:**

Indicators are normalized using maxima-minima method, which is widely used by a number of studies i.e., Gbetibouo *et al*. (2010); Patnaik *et al*. (2010); Ravindranath *et al*. (2011); and Wiréhn et al. (2015). A similar approach was followed by the United Nations Development Program to formulate Human development index. Formula used for normalizing the indicators is given in equation (2) which provides the values in the range of 0 to 1.

Normalized Indicator Value = (Actual Value – Minimum Value)/ (Maximum Value – Minimum Value)

c) **Finding functional relationship:**

The index will be formulated in such a manner that the higher value of vulnerability index would indicate high vulnerability and vice versa. Keeping this in mind, indicators leading to decrease in vulnerability (e.g., adaptive capacity indices) will be subtracted from one as the highest value for any indicator after normalization was one. While, indicators contributing to increase in vulnerability (e.g., sensitivity indices) will be kept as it is and not subtracted from any number as they are already increasing the vulnerability of a system.

d) **Weighting method:**

Expert judgment will be used to give weightage to the selected indicators.

e) **Aggregating the indicators to form index:**

Vulnerability index for each district will be formulated using the model shown below:

V = f (Sensitivity, Adaptive capacity)

Indicators of health vulnerability to Climate change

Hazard	Sensitivity	Adaptive Capacity
Number of climate change events manifesting as heat/cold waves, floods, drought occurring annually	Number of cases with epidemic dengue haemorrhagic fever occurring annually	Establishment of district wise steering committee in responding climate change, natural disasters and emergencies.
Number of extreme cold episodes (days) with absolute minimum temperature	Number of dengue haemorrhagic fever cases / 100000 people	% districts have a specific health action plan to respond to climate change
Number of heat waves	Number of diarrhoea	% of health policies that are integrated

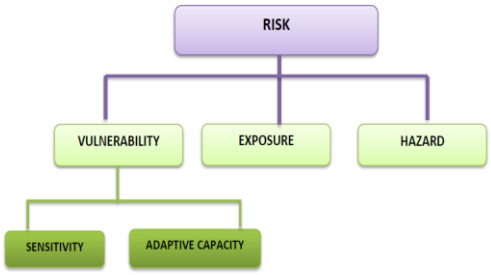
occurring annually	cases / 100000 people	with relevant climate change response contents.
Number of days with extreme heavy rain occurring annually	Number of influenza cases / 100000 people	There is a budget line for climate change adaptation in the health sector at district level.
Number of drought months occurring annually	% of poor households	The Health Sector has training programs and short courses for health staff at different levels in planning for and responding to climate change.
	Population density (people/km^2)	% of health staff trained in climate change and health adaptation, Infrastructure, medical products, technologies
	% of children under 5years of age who are malnourished (underweight)	% district hospitals and commune health stations applied measures to response to health impacts of climate change.
	% of children under 5years of age who are malnourished (stunting: low height-for-age)	% district hospitals and commune health stations with adequate infrastructure, medical products and equipment for disaster and emergency responses
	% households in rural areas without access to improved drinking water	% districts with organized community-based communication programs/activities to raise public awareness of climate change and health
	% households in rural areas without access to hygienic toilets	Number of research projects at district level implemented in the last year on climate change and health and on adaptation options
	% of the elderly>60years old	Health sector has developed and used an early warning system for health risks from natural disasters, including extreme weather events and climate variability
	Number of deaths due to dengue haemorrhagic fever annually / 100000 people	Number of hospital beds per 10000 population
	Number of deaths due to diarrhoea annually/ 100000 people	Number of doctors (physicians) per 10000 population
	Number of deaths due to influenza annually / 100000	

2) Risk analysis Methodology

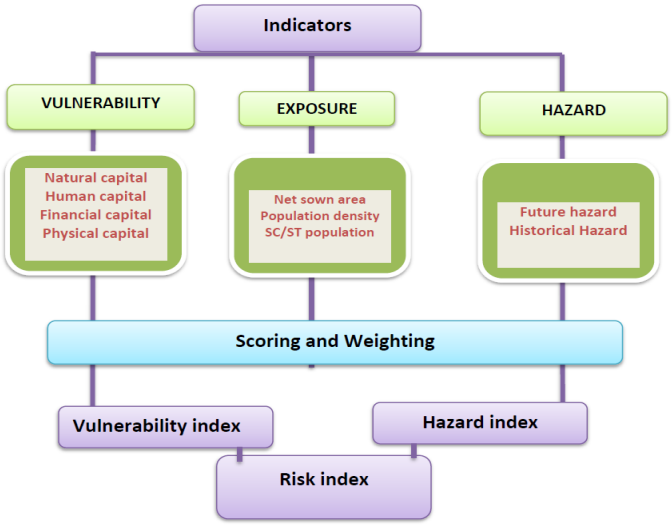
Risk identification and assessment are the two important steps that form the basis for successful implementation of adaptation practices. This involves identification and assessment of current (climate variability) and future (climate change) risks and associated societal vulnerabilities. Climate risk identification is the process of defining and describing a climate-related hazard, including its physical characteristics, magnitude and severity, probability and frequency, exposure and consequences. Risk assessment is a methodology to determine the nature and extent of risk by analysing potential threats and evaluating existing conditions of vulnerability that could pose a potential threat to property, livelihoods and the environment on which they depend. Climate risk maps – identifies areas at risk and vulnerable members of the community. This also includes analysis of available resources that can be used by community members for climate risk management and involves the community in preparing local risk maps. Matrix ranking – prioritizes climate risks, needs and options. Latest models and the data shall be used for risk analysis. The risk mapping at district level will enable the action plans of state and nation to propose adaptation/mitigation strategies in different sectors. Using Indicator based method we can assess the Risk.

Risk = f (Hazard, Exposure, Vulnerability)

Framework of vulnerability and risk as given by IPCC, 2014



Indicator based method to assess the Risk



Based on the index values the categorization of districts can be done.

In addition, a certain amount of secondary information is needed for climate risk assessment.

- Daily rainfall, temperature and evaporation data to assess the moisture deficit and drought periods (early, mid and late season),
- Agro-climatic indicators such as crop evapotranspiration and rainfall ratios,
- Groundwater depths, dry spells, wet spells, and periods of water deficit,
- Trends of heat waves, extreme temperatures, hail storms and wind storms,
- Climate change scenarios and anticipated future impacts on agriculture sector,
- Land use changes over the years, onset of climate risks such as delayed monsoon, early withdrawal of rainfall, intermittent dry spells, extended wet spells, water stagnation, etc.,
- Geographical coverage of the climate risk based on the past records (e.g. droughts), frequency of each risk based on past historical records

2. Long term research studies on climate change in Permanent preservation plots established in Natural forests

a. Establishing new permanent preservation plots for plant phenology based long term study of climate impact on forest vegetation response using PhenoCAM

Plant phenology indicates significant seasonal events such as sprouting, leaf development, flowering, fruiting, and leaf fall in the growth cycle of a plant, which has an influence on ecosystem functioning by controlling energy carbon through the interactions between the atmosphere and plant communities (Richardson et al., 2013; Rihan eta l., 2017). Temperature, precipitation, and day length are the major factors controlling plant phenology. Monitoring plant phenology will help us to understand the vegetation response to changes such as rising temperatures, frequent and intense droughts, changes in rainfall distribution, and extreme weather events (Cremonese et al., 2017). Multiple studies have confirmed the impact of climate change on plant phenology at an ecosystem scale, such as advanced Greenup and delayed senescence (Zhang et al., 2003; Parmesan et al., 2003). Monitoring phenology is essential for understanding the atmosphere-vegetation interactions, land surface energy balance, vegetation productivity, and the global carbon cycle (Richardson et al., 2013). It is crucial to precisely record and analyzes the present and previous cycles of plant phenology to assess plant phenological changes in the future accurately. India lacks a long-term ground-based phenological monitoring system in all of its 16 forest types, and satellite-based monitoring has several limitations, there is a need for a new monitoring network that can address all these difficulties. These challenges can be resolved by making daily phenological observations with a time-lapse digital camera over a long period (Graham et al., 2010; Filippa et al., 2018).

PlantFATE will be used to explore how adaptations at different organisational levels and across multiple temporal scales determine the differential resilience of forests to climate change; (i) short-term acclimation of plant physiology, (ii) mid-term changes in community composition, and (iii) long-term evolution of plant functional traits. Plant-FATE is ideally suited to assess the response of single-species and multi-species forests to climate change and management regimes.

Three PPPs will be established in Karnataka, one each in the dry deciduous, moist deciduous and semi evergreen forests to examine the long term effects of climate change.

Outcome of the studies:

i. Generate field observation based vegetation related datasets from the field of view of the PhenoCAM (ex-Leaf area Index, NPP, GPP, NDVI, tree biodiversity, plant traits at species level);

ii. Generate state of art weather data round the year from the automatic weather station (AWS) for the site where the AWS is installed.

iii. Examine how forest phenology is changing over the specific forest type in Karnataka over the last two decades- (Deliverable after 2 years of the initiation of the PhenoCAM, by integrating daily historical satellite data with our PhenoCAM observation for a period of one year)

b. Long term monitoring of Permanent preservation plots (Bannerghatta National park and Doresanipalya Reserve Forest)

Two permanent preservation plots (PPPs) were established in Bannerughatta national park (BNP) and one in Dopresanipalya Reserve Forest (DRF) in Bangalore, Karnataka of 1 hectare each following the protocols prescribed by the Centre for Tropical Science (CTFS (Condit 1998). Plot establishment involved two stages, the first stage being gridding, and the second stage enumeration. Gridding involved dividing the entire plot into blocks (sub-plots) of 20 m X 20 m with the help of Theodolite after making corrections for the slope. Each 20 m X 20 m block (sub-plot) was further divided into blocks of 10 m X 10 m temporarily with ropes. In each 10 m X 10 m block, all woody individuals >1 cm dbh (dbh refers to diameter at 1.37 m above the ground) were identified, marked with a unique tag number and measured for the size. Trees and shrubs with multiple stems branching out below breast height were measured. All the marked individuals were mapped for spatial location by measuring the X and Y coordinates to nearest 10 cm accuracy. The X and Y coordinates of each individual in a sub-plot was always measured from south-west corner of the plot considering it as the origin. The X and Y coordinates for multiple stemmed trees and shrubs were measured for the stem with largest size (dbh). Later X and Y coordinates of all individuals were converted to global X and Y values for spatial mapping.

The individuals in the plot were distributed into different size classes. Only the main stem was considered for size class distribution whereas all the stems of an individual were accounted for the basal area. The different size classes were 1- 4.99 cm, 5 - 9.99 cm, 10 - 14.99 cm, 15 - 19.99 cm, 20 - 24.99 cm, 25 - 29.99 cm and > 30 cm.

c. Re-census

Re-census involves the re-measurement of the previously tagged individuals in a PPP after a period of 2 years. The re-census involve 3 main components viz.

1. Re-measurement of surviving tagged individuals.
2. Mortality studies and
3. Recruitment of new individuals that are >1cm dbh.

The re-census will be continued every two years during the course of the phase-II project.

d. Bioecological and physicochemical studies

The following studies undertaken during the phase-I project will be continued as per the methodologies standardized during the phase-I project.

1. Phenological studies on selected tree species of Thalewood house, Bugurikallu and Doresanipalya permanent preservation plots at Bannerghatta National Park.

2. Estimation of Carbon stock in permanent preservation plots in Bannerghatta National Park (BNP) and Doresanipalya Reserve forest (DRF), Karnataka, India.
3. Soil character studies in Permanent Preservation Plots (PPP) established in natural forests (Bannerghatta National park and Doresanipalya Forest.
4. BIA enabled Butterfly monitoring program for Karnataka.

As a pioneering and first of its kind in the country, the Strategic Knowledge Centre for Climate Change in EMPRI has initiated a Butterfly monitoring program for Karnataka. Monitoring involves the identification and reporting of butterflies in different districts of the state. We have prepared and published simple easy to use field guides for Bengaluru/ Karnataka butterflies. A mobile App (BIA- Butterfly Identification APP) is developed by EMPRI for the dual purpose of helping in field identification of butterflies and sending the information to the database in the Karnataka Climate Change Strategic knowledge portal. The BIA is available in google play store. The dashboard developed for processing the butterfly data is hosted in Karnataka State Data centre (KSDC) and shall be accessible to everyone interested to know the details. The program is to be promoted across all districts of Karnataka through identified nodal agencies (NGC schools, Science clubs, citizen forums and Range Forest Offices)

3. Strengthen the Climate change knowledge portal to make it more dynamic, interactive and public friendly

An interactive web-portal named "Karnataka State Climate Change Strategic knowledge portal" has been developed and hosted in Karnataka State E-Governance. Centre (http://skcccempri.karnataka.gov.in).It is planned to reinforce the log of web portal on to the global information network to create awareness and to build resilience to climate change. Strengthening web portal as a tool of spreading and advancing knowledge of high quality with regard to climate change is planned. Based on these considerations, we propose some knowledge management approaches for portal-based collaborative environments to create an interactive database in the public domain for public awareness and utility. The portal is meant for collecting and processing information on all aspects of climate change in the state of Karnataka. Information will be collected and collated from diverse sources through published literature and database of different organisations.

- Methodology involves a different approach – focused on managing information portals as channels between people, within or without groups, and within and between Organizations/institutions
- Incorporating global level database management systems by reinforcing expandable database scalability for the lifelong storage and management of the information related to climate change
- Making the web portal extensively active by transforming it into a live forum for knowledge transfer events like live Online Quiz with provision of certification and constructing an exceptional catalogue of knowledge, ideas, standards, best practices, and lessons learned in the form of dynamic forum of information exchange.
- Initiating networking and collaborative mechanism with other research institutions and transforming the web portal to a professional level knowledge Centre designed and built out in advanced level computer languages like JavaScript, python and advance programming languages.
- Facility to interact with the authorities on a day-to-day basis shall be planned with the proposed video conferencing unit at EMPRI. Knowledge management through the

web portal is the utmost goal by itself to disseminate science and technology related area.

4. Knowledge Dissemination through creation of App enabled Databases for climate sensitive plant/animal groups through citizen science

The concept of citizen science gaining rapid popularity in India and citizen science projects have considerable potential to contribute to environmental monitoring, regulation and even decision making. People participating in such projects are not scientists themselves or even students of science. All they need is inclination towards science and basic knowledge about data collection. Growing interest of people in participating in science is central to this development. Though there are butterfly monitoring programs in European countries enabled through public participation, there are no such unified efforts in any state in India to utilize citizen science into processed information to monitor the butterfly populations The Strategic Knowledge Centre for Climate Change in EMPRI has initiated a Butterfly monitoring program for Karnataka. Monitoring involves the identification and reporting of butterflies in different districts of the state. A mobile App (BIA- Butterfly Identification APP) is developed by EMPRI for the dual purpose of helping in field identification of butterflies and sending the information to the database in the Karnataka Climate Change Strategic knowledge portal. The BIA is available in google play store. The dashboard developed for processing the butterfly data is hosted in Karnataka State Data centre (KSDC) and shall be accessible to everyone interested to know the details. The program is to be promoted across all districts of Karnataka through identified nodal agencies (NGC schools, Science clubs, citizen forums and Range Forest Offices)

5. Implementing evaluation and monitoring mechanisms for climate resilience building

- **Conduct research on contemporary topics related to the climate resilience in the state of Karnataka:** Karnataka is the most vulnerable state and Bangalore being in the forefront of development, faces innumerable climate and health related issues. The biodiversity and the environment is worst affected. It is proposed to conduct research on the current issues related to climate change and environmental health.
- **Conduct workshops on topics related to climate change and its impact in the different sectors:** Workshops will be scheduled for different strata of stakeholders and experts drawn from other knowledge institutes also will be utilised for successful conduct of training schemes.
- **Networking the knowledge institutions, conducting seminars for exchange of information:** It is proposed to sign MOUs with knowledge partners like IISC, TERI, CSTEP etc. The MOU has been approved by the partner institutes and is under processing. It is proposed to conduct International and national conferences on climate change issues.
- **Advocating and promoting climate friendly, sustainable and cheaper technologies for public use:** The capacity building wing will be given wide publicity to attract both youngsters and adults. The technologies will be demonstrated and the consumers will be assisted in the procurement and installation of the same.
- **Evaluate the percolation of knowledge into the daily life of common man:** Surveys will be conducted and feed backs will be collected to study the awareness, utility and advantage of adapting climate friendly techniques in the day to day life.

- **To provide a synthesis of available information, assess major knowledge gaps:** Being a management and policy institute, the information will be processed and synthesised into valuable knowledge and ready to use technology for public life. The gaps in information will be identified and efforts to highlight them to the academia and also executives and government will be streamlined.

18.0 Work plan [Please provide a bar diagram to depict the proposed timelines and schedule]

Project Period April 2023 to March 2028

	Objective – Wise Activities	Start month	End month	Final Quantified Outcome/Specific Deliverables for Monitoring
1.	**Vulnerability and risk analysis** Proposed Activities Assessment for different sectors at district level	Apr 2023	Mar 2025	Risk mapping of water/health/agriculture/forest/ urban heat island sectors
2.	**Institutional Capacity building** Proposed Activities i. Strengthening Karnataka Strategic Knowledge Centre for Climate Change	Apr 2023	Mar 2024	i. Creation of infra-structure and HRD components
	ii. Strengthening the Capacity Building Wing of EMPRI	Apr 2023	Mar 2024	ii. Workshops and public events
	iii. Updating the Interactive database / knowledge portal	Apr 2023	Mar 2028	iii. Hosting of the database in public domain
	iv. Training the staff on methodologies on climate change assessments	Jul 2023	Mar 2028	iv. HRD for successful implementation
	v. Creation of a database on experts in the field and facilities for networking/ video conferencing	Jul 2023	Mar 2028	v. Knowledge networking
3.	**Workshops for stakeholders** Proposed Activities Workshop for higher executives	Jul 2024	Mar 2028	Number of personnel involved
	Workshop for middle level officials	Jul 2024	Mar 2028	

4.	**Public awareness for community** Proposed Activities i. Creation/updating an interactive database on climate change ii. Arranging lectures/ talks by experts on climate change for the students of local schools/ colleges (Bimonthly programmes – total 6 programs per year)	Jul 2023 Jan 2024	Mar 2028 Mar 2028	Contributions by citizens Number of students and other participants
5.	**Others, If any** Proposed Activities **A. Research activities** Long term research studies on climate change in Permanent preservation plots established in Natural forests **B.** Plant phenology based long term study of climate impact on forest vegetation response using PhenoCAM in newly established PPPs	Jul 2023 Jul 2023	Mar 2028 Mar 2028	The changes in the ecology and physio-chemical characteristics will be co-related with the climatic variability / change i. Field observation based vegetation related datasets from the field of view of the PhenoCAM ii. art weather data round the year from the automatic weather station (AWS). iii. Examine how forest phenology is changing over the specific forest type in Karnataka over the last two decades
	B. Other activities			
	Conducting national and international conferences	Yearly		Number of participants
	Participation in national and international conferences	Yearly		Number of events/ participants
	C. Compilation of data, statistical analysis and preparation of final report. Publication of research paper	Oct 2026	Mar 2028	Project completion report Research papers in SCI journals

Work plan [Time Schedule of Activities through BAR Diagram may also be required]

SCHEDULE	2023-24				2024-25				2025-26				2026-27				2027-28			
	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4
Vulnerability and risk analysis																				
Vulnerability assessment and Risk mapping at District level for different sectors in Karnataka																				
Institutional Capacity building																				
Strengthening Karnataka Strategic Knowledge Centre for Climate Change																				
Strengthening the Capacity Building Wing of EMPRI																				
Updating the Interactive database / knowledge portal																				
Training the staff on methodologies on climate change assessments																				
Creation of a database on experts in the field and facilities for networking/ video conferencing																				
Workshop for stakeholders																				
Workshop for higher executives																				
Workshop for middle level officials																				
Public awareness for community																				
Creation/updating of interactive database on climate change																				
Arranging lectures/ talks by experts on climate change for the students of local																				

SCHEDULE	2023-24				2024-25				2025-26				2026-27				2027-28			
	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4
schools/ colleges																				
Others																				
A. Research Activities																				
Long term research studies on climate change in Permanent preservation plots established in Natural forests																				
Plant phenology based long term study of climate impact on forest vegetation response using PhenoCAM																				
B. Other activities																				
Conducting national and international conferences																				
Participation in national and international conferences																				
Final Report preparation and Submission																				

19.0 Expertise, Strength and Capacity of the Nodal Agency to implement the proposed programme

The nodal agency, Environment Management and Policy Research Institute (EMPRI) is one of its kinds in the state engaged in applied research and training in the areas of environmental conservation and natural resource management, serving administration, industry and civil society. With suitable infrastructure and personnel, EMPRI is the leading organization of the ministry of Ecology and Environment, Government of Karnataka in the field of Environment management. The institute has 8 centers for operational convenience and ENVIS centre of the state is functional here. Also, it is executing a NGC program to extend the information and awareness on environment to communities especially student and younger generation.

1. ENVIS Centre at EMPRI

The Environmental Information System (ENVIS) Centre of Karnataka with the subject area "State of environment and related issues" is functioning in the premises of EMPRI since December 2002. In the initial years though it was designated as ENVIS Node and upgraded to a full-fledged ENVIS Centre with effect from October 12, 2004, after less than two years of operation. Since establishment the ENVIS Centre Karnataka was hosted by Indo-Norwegian Environment Program (INEP) under the Department of Forest, Ecology & Environment, and Government of Karnataka. INEP ceased operations as a project on December 31, 2008. EMPRI assumed the responsibility of running the ENVIS Centre with effect from January 01, 2009.

The ENVIS centre Karnataka provides environmental information services at state and national levels relevant to present needs and capacity building/enhancement to meet the future needs of users on issues related to the state of environment in Karnataka. It has a dedicated website on the NIC CMS portal – www.karenvis.nic.in . The website is updated on a regular basis with environment related issues, publications, Latest Environmental News and Upcoming events. Every year the website has approximately 3lakh to 4lakh visitors from around the world. The Indian State-Level Basic Environmental Information Database (ISBEID) is an ambitious programme of the MoEF, GoI in order to make environmental status easily available to researchers, students, policy makers and the general public at large. Data updation for all the modules is done at a regular basis with authentic and resourced data from different Government of Karnataka Departments. Also, the data updation has been complete for the following modules for the years 1990-2020 ; Forest Resource: Type of Wetland (District), Recorded Forest (State), Tourism and Heritage: Tourism and Heritage (State and District), Industry: Category of Industry (State), Administrative: Climate (District), Air Pollution: Vehicular Pollution (District), Sanitation: Water Borne Diseases (Districts).The centre has published quarterly newsletters under the name "Parisara" addressing various environmental issues. Currently 59 issues have been published on different environmental issues.

EMPRI library has 3336 resource books and also has collection of various reports, survey, case studies, projects and conference/Seminar proceedings. Using the KOHA open source software all the books, reports etc., have been automated, which can be accessed through the online tool OPAC (Online Public Access Catalogue).
Immediate objectives of the ENVIS Centre

- Providing environmental information services at state and national levels relevant to present needs and capacity building to meet the future needs of users on issues related to the state of environment of Karnataka

- Building up, store, retrieve and to disseminate information to users quickly.
- Promoting national and international networking and liaison for exchange of environment related information.
- Promoting exchange of information among countries and regions.
- Long term objectives of the ENVIS Centre
- Building up repositories and dissemination centres on environmental protection and environment management issues.
- Adopting modern technologies of information gathering, processing, storage, retrieval and dissemination.
- Supporting and promoting research, development and innovation in environmental information technology**.**

2. NATIONAL GREEN CORPS - NGC

Changing the attitudes of 100 crore people on their outlook on environmental protection is not going to happen overnight. The best way to attempt to bring about a change in the attitudes in the society is through children. With this realization, the Ministry of Environment and Forests, Government of India has launched the National Green Corps Programme (NGC) in the country in the year 2001-02, with a view to provide an opportunity for children to redirect the consciousness and actions towards a more sustainable planet through a different kind of educational approach that takes into the depth of things. The main objectives given below have a direct bearing on the action programme for climate change related awareness and mitigation and adaptation methods.

- To make children understand environment and environmental problems.
- To provide environmental education opportunities for school children.
- To utilize the unique position of school children as conduits for awareness of the society at large.
- To facilitate children's participation in decision making in areas related to environment & development.
- To bring children into direct contact with the environmental problems facing the society they live in and make them think of solutions.
- To involve children in action based programmes related to environment in their surroundings.

EMPRI is the Nodal agency for NGC in Karnataka, since Jan, 2009. A Nodal Agency selected by the state would facilitate and coordinate the implementation of the programme in the State/UT including organizing training of Master Trainers, follow up of actions, periodical monitoring of the overall plan and implementation. As per the guidelines of Government of India, Eco-clubs were established in all 34 educational districts of Karnataka at the rate of 500 schools per districts. Each eco-club has 30-50 children, who are interested in environment related issues. Each Eco-club is supervised by a Teacher in-charge, who is selected from the school on the basis of his/her interest in environment related issues. Till date 16,839 eco-clubs have been established. Monetary support of Rs. 5000/- per annum is being given to each eco-club for organizing variety of activities that support environmental conservation.

The NGC programme can be integrated with climate change awareness and management measures so that the children, the basic pillars and future of the nation/ state will be able to lead and work for the cause of environment protection.

20.0 Experts/agencies/institutions to be consulted for the proposed project

i. Dr. N H Ravindranath

Dr. Ravindranath is a retired Professor at the Centre for Sustainable Technologies, Indian Institute of Science Bangalore. His broad areas of research and development include climate change, forestry, bioenergy and biomass production, environmental and ecosystems services and citizen science. His contributions include research into various areas of climate change, forests, renewable energy and ecosystem services; participation in various international and national efforts to address climate change (IPCC, Global Environment Facility, Committees of the Ministries of Environment and Science and Technology, World Bank and UN Agencies); creating awareness on the science, impacts, mitigation and adaptation aspects of climate change - nationally and internationally; designing climate change mitigation and adaptation projects, and building capacity in institutions to address climate change mitigation and adaptation. He is an author of four books on climate change. He has also written 16 book chapters related largely to climate change and forestry. He is an author for 12 IPCC Assessment Reports, including the latest IPCC Report (AR5), 2014. He is one of the Convening Lead Authors for the two reports on Greenhouse Gas Inventory Guidelines of IPCC for land use sectors – Agriculture, Forests and other land uses. He has published 130 peer reviewed scientific journal articles out of which over 60 papers are related to climate change and he is also on the Editorial Board of Four International Journals.

ii. Dr Indu K Murthy

Dr. Indu K Murthy was a Research Officer at the Centre for Sustainable Technologies, Indian Institute of Science, Bangalore. Her areas of research, spanning nearly two decades include climate change vulnerability profiling, land use change and forest sector mitigation and adaptation, environmental and ecosystems services and citizen science. She is a contributing author to two Intergovernmental Panel on Climate Change (IPCC) Reports - IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4: Agriculture, Forestry and Other Land-Use (AFOLU), 2006. Chapter 4, Forest Land and Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, 2004. Chapter 3, LUCF Sector Good Practice Guidance. She has also published extensively in peer reviewed national and international journals. Currently she is the Principle Research Scientist at CSTEP, Bengaluru.

iii. Prof A K Gusain, IIT Delhi

Dr A K Gosain Professor Emeritus, Department of Civil Engineering Indian Institute of Technology-Delhi. Dr. Ashvani K. Gosain is an Emeritus Professor in the area of Water Resources Engineering and GIS Technologies, in the Civil Engineering Department, IIT Delhi. Prof. Gosain pioneered the climate change impact assessment on Indian water resources that was incorporated in the NATCOMI & II–two National Communications made to the UNFCCC. He has also been reviewer for AR4 and AR5 of IPCC. Prof. Gosain contributed to the formulation of the Ganga River Basin Management Plan (GRBMP), of which he was the Team Leader of the Water Resources Management group. He has also formulated the Drainage Master Plan of NCT of Delhi for the Delhi Government. He is part of the expert committees appointed by the National Green Tribunal to suggest solutions to deal with the ever-increasing pollution levels in Ganga and Yamuna. Prof. Gosain has to his distinction the formulation of the Ganga Act on behalf of the Ministry of Water Resources as a member of the committee. Prof Gosain has served as Head of the Civil Engineering Department and the Computer Services Centre of IIT Delhi.

iv. Dr Rajiv Chathurvedi, Asst Prof, BITS Goa

Dr. Rajiv Kumar Chaturvedi is currently an Assistant Professor at BITS, Pilani's, Goa campus. He obtained his PhD from Indian Institute of Science (IISc) in Ecology from the Centre for Ecological Sciences, and a masters in Geography from Delhi School of Economics, Delhi University. Dr. Chaturvedi has been a National Environmental Sciences Fellow at IISc and has contributed to more than 40 peer reviewed articles, and to two books in the areas related to forestry, environment and climate change. Dr. Chaturvedi has worked extensively with communities, Government officials, NGOs, and UN organizations. Dr. Chaturvedi is currently the co-chair of IUCN's forest ecosystems' group. He is currently involved with India's national greenhouse gas inventory programme and is listed as an UN expert on GHG inventory in the land-use and forestry sector. He has been a lead author for the regional assessment reports of the UNEP (United Nations' Environment Programme) and IPBES (Intergovernmental Panel on Biodiversity and Ecosystem Services).

v. Dr Ravindran DS IFS (R)

Dr D S Ravindran (PhD), is a Retd. IFS officer (Indian Forest Service 1986 Batch) and the former Principal Secretary to the Government of Kamataka (Khajane - 2 Finance Department) with over 34 years of experience in the areas of administration, civil service, research, financial planning, Information Technology, Public Policy Planning & Implementation Process, Renewable Energy etc. He is a Post Graduate in Agriculture and has pursued a programme in Public Policy & Management at IIM-B. He also holds PhD in Forest Economics (from University of Wales, U.K.)

vi. P P Mujumdar

Prof. P P Mujumdar is currently serving as the KSIIDC Chair Professor in the Department of Civil Engineering. He holds Associate Faculty positions in the Divecha Center for Climate Change and Center for Earth Sciences at IISc Bangalore. His area of specialization is Water Resources with a focus on climate change impacts on hydrology/water resources, statistical downscaling of GCM outputs, urban flooding, planning and operation of large scale water resources systems, and uncertainty modeling. His recent research contributions include detection and attribution of hydrologic change, development of downscaling models, uncertainty combination in climate change impacts and reservoir operation for adaptation to climate change. He is also serving as the Chairman of the Water Resources Management section of the International Association for Hydro-Environment Engineering and Research (IAHR). He has served as a reviewer for the Assessment Report 5 (AR5) of the IPCC. His areas of professional consultancy include urban storm water drainage, floodplain management, river basin planning, reservoir operations, lift irrigation, hydropower development and impact assessment of water resources projects.

vii. Dr K N Murthy

Dr. K N Murthy is a retired IFS officer at the Karnataka Forest Department. He conducted research on the topic 'Adaptation to Climate Change in Rural India: Evidence from Chitradurga district in Karnataka State' from IIM, Bangalore. He is a climate change and forestry expert, having worked in all wings of the Forest Department: Territorial, Wildlife, Research, Working Plans, Social Forestry, Watershed and so on.

21.0 When do you think the project will become self-sustaining?

After the scheduled closing of the NMSKCC project after 5 years, the activities in the Strategic knowledge Centre for Climate change will continue as aimed. The infrastructure and functional mechanisms would have got established and the institutional funds along with support from national / international funds, the research components/ activities shall continue. The training and demonstration activities can continue with the EMPRI funds supported by the Karnataka government. The Climate Change centre will be the renowned in the country and the state and it will continue to serve the future generations as well.

22.0 Possible Steps for ensuring utility/ replicability of the programme outcomes

1. Being a Government of Karnataka organization, EMPRI will ensure adequate mainstreaming of program outcomes through awareness and utilization of the knowledge Centre by concerned government departments/ agencies through training / capacity building / demonstration of climate resilient technologies.

2. Net work with the best experts from different scientific and developmental institutes will help in disseminating up to date information relevant for students, public, researchers and administrators

3. Publicity through various media- print, television, newsletter and programmes like NGC.

23.0 Anticipated risks during the project implementation; if any and what steps will be taken to reduce the impacts of these risks:

1. Non co-operation from the collaborating agencies and non-utilization of the facility created by the Centre. The Memorandum of understandings (MoUs) are signed with the repute institutes in the state and across the country for collaboration. Collaborating/ consulting organizations and their participation in advisory/ executive meetings will be ensured.

2. Technical problems involving maintenance of hard and software for the knowledge portal. Being an IT city, the problems can be solved through the IT experts. Government of Karnataka has established separate E governance departments and also state data center where all government institutes can interlink.

24.0 Suggested plan of action for utilization of expected outputs from the project:

1. EMPRI will ensure adequate awareness and utilization of the knowledge Centre by concerned government departments/ agencies through training / capacity building / demonstration of climate resilient technologies.
2. Knowledge Network with the best experts from different scientific and developmental institutes will help in disseminating up to date information relevant for students, public, researchers and administrators.
3. Publicity will be given through various media- print, television, newsletter and other governmental programmes.
4. Reports, research papers and other publications shall help in dissemination of knowledge across academia, researchers and administrators.
5. The intellectual and technical outputs of the project will guide the framing of future policies of the state to make it totally climate resilient and make Karnataka as a model state for the rest of the country to follow.

25.0 How will the project outcome benefit the scientific community, climate change adaptation planning and implementation within the state as well as the society at large?

This climate change impact assessment carried out using latest models & cordex data will inform development of next versions of climate change action plan in the state & strengthen capacity of government & other stakeholders to undertake such experience in future. Climate change risk profile at district level was greatly enhance knowledge base & development of adaptation measures.

The Strategic knowledge centre for climate change will strive to harness the strengths in Science with participation of national and international research groups to understand climate change in the state and to enable better assessments of impacts and vulnerability of different sectors for evolving effective policies for adaptation and mitigation anchored on values of sustainability. It will help to direct all climate related knowledge available in the state into a common platform and make it available to use in existing knowledge products, information and data to undertake climate compatible planning, implementation and monitoring which will help facilitate undertaking activities and projects on climate change by the respective stakeholders. The **Karnataka Strategic Knowledge Centre on Climate Change (KSKCCC**) will become the flag bearer of all climate change related activities of the state of Karnataka and also will serve as a model for such initiatives in other states. It will be first of its kind in the country and through the mediation and leadership of EMPRI, it will be the centre of excellence in knowledge pooling and advocating and practicing the climate resilient technologies for human welfare.

26.0 Quantitative Outcomes of the first phase, in terms of: (pl provide summary (not exceeding one page) and may annex the details): **Given as Annexure 2**

a. Research papers published (Please provide a list along with their impact factors)
b. Reports/Monographs/Internal publications brought out (please give list)
c. New techniques/models developed, if any
d. Patents filed/awarded, if any.
e. Details of workshop/ conferences/ seminars/capacity building programmes organised (Please give complete list along with topics, dates, duration, number of participants, details of reports published, etc)
f. Number of personnel trained (Please provide a list of courses along with number of people trained)
g. Number of post-graduate/doctoral candidates completed their courses(Please give a list of such candidates)
h. Foreign deputation/visit of PI/Co-PIs/students, if any

27.0 Strategic Knowledge generated from the 1st phase:

a) Floristics of the permanent preservation plots (PPPs) in tropical forests
b) Climate related phenology of tropical forest ecosystem
c) Carbon dynamics in Permanent Preservation Plots
d) Biochemical and microbiological characterization of forest soils
e) Vulnerability assessment under climate change for Karnataka at district level
f) Database of indicator species (Butterflies)

28.0 Name of the nearest official branch of the Bank of Maharashtra:

Account in Bank of Maharashtra can be started on approval of the project.

Name of the nearest branch of the Bank on which bank draft should be issued or electronically transferred:

Beneficiary name : Director General, EMPRI

Name of Bank : STATE BANK OF INDIA

Branch Name : JP Nagar Branch

Account No. : 38107686429

IFSC Code : SBIN0015643

29.0 Budget estimates:

*FEC- Foreign Exchange Component (in US$) equivalent of rupee amount at the prevailing rates may be furnished.

	Budget Item	BUDGET					(in Rupees)
		1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
A	Recurring						
	1.Salaries	30,50,400	30,80,160	32,04,408	32,04,408	32,56,748	1,57,96,124
	2. Consumables	6,00,000	6,00,000	6,00,000	6,00,000	6,00,000	30,00,000
	3. Travel	4,00,000	4,00,000	4,50,000	4,50,000	4,50,000	21,50,000
	4. Other costs including surveys, App development (Workshops/Printing reports, Consultations, data collection)	5,00,000	5,00,000	5,00,000	5,00,000	5,00,000	25,00,000
						Sub-Total	**2,34,46,124**
B	Equipment	48,00,000	-	-	-	-	48,00,000
	Total		-	-	-	-	**48,00,000**
C	Overhead	2,50,000	2,50,000	2,50,000	2,50,000	2,50,000	**12,50,000**
	Grand total (A+B+C) / Total FEC*	96,00,400	48,30,160	50,04,408	50,04,408	50,56,748	**2,94,96,124**

29.1 Budget for Salaries/wages

Designation & number of persons	Monthly Emoluments	BUDGET					(in lakhs)
		1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
Project Scientist -II - 1no.	67,000/-+ (24% HRA) 5% hike every 2 years	9,96,960	9,96,960	10,46,808	10,46,808	10,99,148	**51,86,684**
Research Associate – 1no.	47,000+(24% HRA)	6,99,360 (47,000+ (24% HRA)	7,29,120 (49,000+ (24% HRA)	8,03,520 (54,000+ (24% HRA)	8,03,520 (54,000+ (24% HRA)	8,03,520 (54,000+ (24% HRA)	**38,39,040**
Senior Research Fellow-1no.	35,000/-+ (24% HRA)	5,20,800	5,20,800	5,20,800	5,20,800	5,20,800	**26,04,000**
Project Associate II - 2no. (General-1 Lab-1)	28,000/-+ (24% HRA)	8,33,280	8,33,280	8,33,280	8,33,280	8,33,280	**41,66,400**
Total Requirement per Year		30,50,400	30,80,160	32,04,408	32,04,408	32,56,748	**1,57,96,124**

Justification (The norms/scales as per the DST's guidelines may be followed for the salary component) http://dst.gov.in/whats_new/main-new.htm#1

Project Scientist: PhD in Science or Masters degree in Engineering or Technology with three years research experience for executing and managing the research components of the projects.
Research Associate- PhD in Science for managing the web portal on climate related database and knowledge portal and other research work.
SRF – Post graduate in Basic science or graduate/ Post graduate in professional course for basic research on climate related projects.
Project Associate -Master's degree in natural or agricultural or life sciences/ Bachelors degree in Engineering or Technology with 2 years' experience for assisting in project activities.

29.2 Budget for consumable materials:

		BUDGET					(in lakhs)
Item		**1st Year**	**2nd Year**	**3rd Year**	**4th Year**	**5th Year**	**Total**
	Q*	--	--	--	--	--	--
	B**	6,00,000	6,00,000	6,00,000	6,00,000	6,00,000	30,00,000
	F***	-	-	-	-	-	-
Total	**B**						
	F						
							30,00,000

*Q: Quantity or number, ** Budget, ***F: Foreign Exchange Component in US$

Justification (Itemized details for consumables, if any, may be provided)
To undertake biochemical and microbiological characterization of forest soils in permanent preservation plots, various chemicals, glassware and other labware are required.

29.3 Budget for travel:

		BUDGET					(in lakhs)
		1st Year	**2nd Year**	**3rd Year**	**4th Year**	**5th Year**	**Total**
	Travel (Only inland travel)	4,00,000	4,00,000	4,50,000	4,50,000	4,50,000	21,50,000

Justification [Tentative tour plans/field trips with proposed cost per visit during the project period may be given]

Visit to field for research related works, Travel for attending meetings and national seminars/ workshops.

29.4 Budget for other costs:

	BUDGET					(in lakhs)
	1st Year	**2nd Year**	**3rd Year**	**4th Year**	**5th Year**	**Total**
Other costs including surveys, App development, workshops, report prints, Consultations, data collection)	5,00,000	5,00,000	5,00,000	5,00,000	5,00,000	25,00,000

29.5 Budget for Equipment's

	Generic name of the Equipment along with make & model	**Imported/ Indigenous**	**Qty**	**Unit Rate (lakhs)**	**Total cost (lakhs)**	**Spare time for other users (in %)**
1.	Phenocam & Metereological Monitoring Station	Imported	3	16.00	48.00	50
				Total	**48.00**	

Justification for the proposed equipment:

Phenology is the study of reoccurring life cycle events that are driven by environmental factors. The timing of these events is driven by both short- and long-term variability in climate and is valuable in understanding the effects of climate change. Phenocam imagery is vital for tracking plant phenology. The long term climate impacts of forest vegetation cover will be examined using Phenocam. Data from Phenocam can be used for phenological model validation and development, evaluation of satellite remote sensing data products, benchmarking earth system models, and studies of climate change impacts on terrestrial ecosystems.

30.0 List of facilities being extended by parent institution(s) for the project implementation

A) Infrastructural Facilities:

Sr. No.	**Infrastructural Facility**	**Yes/No/ Not required Full or sharing basis**
1.	Workshop Facility	Not required
2.	Water & Electricity	yes
3.	Laboratory Space/ Furniture	yes
4.	Power Generator	yes
5.	AC Room or AC	yes

6.	Telecommunication including e-mail & fax	yes
7.	Transportation	yes
8.	Administrative/ Secretarial support	yes
9.	Information facilities like Internet/ Library	yes
10.	Computational facilities	yes
11.	Animal/ Glass House	Not required
12.	Any other special facility being provided	-

31.0 Equipment available with the Institute/ Group/ Department/ Other Institutes for the project:

Equipment available with	Generic Name of Equipment	Model, Make & year of purchase	Remarks including accessories available and current usage of equipment
Climate change Laboratory	COD Digestor	DBK Instruments DBK5129/4 19.10.2016	Digestion of samples to measure the COD
	Digital Weighing Balance	TTB3 Wensar 13.02.2017	Capacity: 0.1g-3kg
	Digital Weighing Balance	TTB10 Wensar 13.02.2017	Capacity: 0.5g- 10kg
	Digital Weighing Balance	Scale-TEC 15.02.2017	Capacity: 0.1g-3kg
	Digital Conductivity Meter	LMCM-20 Lab Matrix 21.02.2017	Measurement of electrical conductance (EC)
	pH Meter Digital	101 Lab Matrix 01.03.17	Measurement of pH
	Leaf Area Meter	PSM L200 Biovis 17.11.17	Performs leaf area measurements
	Centrifuge	R-24 Remi 18.12.17	Separation of various components of fluids
	Flame Photometer	130 Systronics 18.12.17	Inorganic chemical analysis to determine the concentration of certain metal ions
	Bod Incubator	BOD-4-SF Heat Control Instruments & Services	Incubation of samples

		18.12.17	
	Hot Air Oven	HAO-18/24.200 Heat Control Instruments & Services 18.12.17	Samples being dried with a controlled temperature
	Soil Moisture Meter	PH3-8PH Servewell 18.12.17	Measurements of field moisture content
	Soxhlet Extraction Unit	Servewell 18.12.17	-
	Deep Freezer	Bio-CB-1088 Biocare 04.01.18	Sample storage at lower temperatures
	2400 CHNS/O Series II System	2400 CHNS/O Series II System Perkin Elmer 21.02.18	Estimation of CHNS content in sample
	Telemetric Weather Station (TWS)	Varsha 16.02.18	Rain gauge, collects information of various weather parameters
	Telemetric Weather Station (TWS)	Varsha 28.02.18	Rain gauge, collects information of various weather parameters
	Water Distillation Unit	17.03.18	Distilled water for experiments
	Digital electronic Balance	BL 220H Shimadzu 17.03.18	Capacity 220gm, sensitivity: 0.001 gm
	Vertical Laminar Flow	Biotek 23.03.18	For microbiological studies
	Mini Rotary Shaker	RS-12 26.03.18	For proper mixing of samples at constant speed over a period of time
	Autoclave Portable	27.08.18	Sterilization and Decontamination
	Infrared Gas Analyzer	CIRAS-3 02.04.18	Portable Photosynthesis measurements
	Nikon Microscope	Ci-L Nikon 07.07.18	To see enlarge view of specimen
	Microbalance	XA6.4YM Radwag 03.08.19	Performs weighing operations in range of milligrams
	Digital Tree Calliper	MD 11 Haglof	Measurement of tree girths

		25.9.19	
	Atomic Absorption Spectrophotometer	AA-6800F Shimadzu 06.06.19	Estimation of heavy metals
	Greenhouse Gas Analyzer	Polytector III G999 GFG 21.01.20	Measurements of greenhouse gases
	Refrigerator	VC325D Visi Cooler Bluestar 19.05.20	Storage of samples and also certain chemicals
Water Laboratory	Hot Plate	YSI-1320 Hasthas Scientific	Heating purpose
	Double Distillation Unit	Srinivasa Products	For double distilled water
	Water Bath	Equitron	To incubate samples in water at a constant temperature over a period of time
	Hot Plate with Magnetic Stirrer	2-MLH Remi	Heating purpose along with constant stirring
	Precision Analysis Weighing Balance	AUW220D Shimadzu	For weighing of sample and chemicals
	Bench top Electrical Conductivity /TDS meter	MK-509 Systronics	To determine the EC and TDS of the sample
	UV-Vis Spectrophotometer	2205 Systronics	For the quantitative determination of different analytes
	Bench Top Turbiditymeter	135 Systronics	To determine the Turbidity of the sample

32.0 Curriculum Vitae of investigators (as per the format provided as Annexure 1):

Provided as Annexure 1

33.0 Details of any other programme being implemented or completed by the Nodal Person/Project Coordinator with the support from DST and any other govt. ministries / departments.

Project Title	Start date	Completion date	Project Cost (in lac)	Sponsoring Organization

Establishing/Strengthening the state climate change centre/cell under NMSKCC (SCCC-NMSKCC) in the state of Karnataka	01.10.2016	30.09.2021	295.57	Department of Science and Technology (DST), GoI

34.0 Any other information, you wish to share.

Environmental Management and Policy Research Institute is striving to practice what we preach. Keeping in line with EMPRI's commitment to protect and improve the environment, both the Main and Annex buildings of EMPRI are constructed incorporating the 'Green Building Concept'. The salient features are:

- Reduced carbon footprint while maintaining the ecological values of the site.
- The indoor built environment quality has been optimized in terms of visual and thermal comfort through adaptive climate design features.
- The energy demand has been reduced by adopting passive design features, efficient lighting fixtures and other appliances usage.
- Integration of renewable energy to reduce dependency on external grid.
- Adoption of Rainwater harvesting techniques.
- Use of low energy intensive materials and technologies

ADaRSH, (Association for Development and Research of Sustainable Habitats) an independent platform for the interaction on scientific and administrative issues related to sustainable habitats in the Indian subcontinent, supported by MNRE (Ministry of New and Renewable Energy, Government of India) identified **Environmental Management and Policy Research Institute** for its outstanding efforts and execution for compliance with GRIHA criteria and bestowed "Exemplary Demonstration of Passive Architecture Design Award" in their 6th annual conference, "The GRIHA Summit 2015". EMPRI received the award for its new Green building based on various criteria like Lighting, Air Circulation, Thermal Regulation, Energy Efficiency, Solar Photo voltaic cells, Rainwater Harvesting, Courtyard, Additional windows and ventilation.

Accreditation and Recognition: EMPRI has implemented following management system and has received EPA recognition.

Institutional Management System (IMS) Certification

EMPRI has undergone recertification for Institutional Management System (IMS) – IS0 9001:2015 (Quality Management system) and ISO 45001:2018 (Occupational Health and Safety Management System) and is approved for certification.

ISO: 17025:2017 Accreditation

EMPRI laboratory (Lab Id – 5657) has received National Accreditation Board for Laboratory (NABL) accreditation (ISO: 17025:2017) for Testing Laboratory in the month March 2021 (Period of Accreditation: 01.03.2021 to 28.02.2023). The accreditation is obtained in the stream of Chemical Testing, for the two groups i.e., 1. Pollution & Environment 2. Water (10 sub-groups), in which 18 parameters are considered.

EPA Recognition

EMPRI has obtained Recognition of Environment Laboratory, under the Environment (Protection) Act, 1986 on 1st of June 2021 for 5 years for the following Parameters groups. Physical, General (Chemical & non-metal and metals), Organics, Microbiological, Toxicological, Biological, Soil/Sludge/Sediments, Characterization of Hazardous waste, and air pollution parameters for analysis of Ambient air, Source emissions/ stack monitoring, Noise level and Micrometeorological parameters.

NABET Accreditation for EIA Consultant Organization

EMPRI has applied for the accreditation as EIA Consultant Organization from National Accreditation Board for Education and Training (NABET) and is undergoing the assessment for obtaining the accreditation.

Environmental Management and Policy Research Institute with the above mentioned recognitions/accreditation is an acclaimed research & policy institute in Karnataka capable of executing climate change research in its different dimensions and is poised to become a **Centre of Excellence** in climate change research and dissemination of knowledge/information to all stakeholders to build a Climate resilient Karnataka State.

Since the birth of EMPRI two decades ago, the status of natural environment and sustainable development have become central to developmental planning. Governments at all levels - national, state, district, and village – are concerned about status of natural resources – air, water, soil, minerals, forests, biodiversity.

Natural environment is a 'good public commons', and its deterioration has implications for equity, and capability to attain sustainable development. Also, both economic wellbeing and social wellbeing rest on environmental wellbeing. Moreover, mired with several environmental crises, the present decade is considered most vital in the human history, as the sustainability of 'earth systems' would be determined by the course correction of 'developmental pathway' undertaken now.

Deepening its engagement with the mandate of environmental management and policy development, EMPRI launches its 3rd decade of existence in the above context. Fresh capabilities on impact and carrying capacity assessment for sustainable development, and baseline data and modelling for air pollution and climate change are being augmented. To enhance the quality of research output, and realizing that the capabilities lie distributed, new alliances are developed with the organizations of national and international repute. Environmental monitoring under a changing climate remains a major focus. The applied research undertaken at EMPRI feeds into our advocacy, training, and policy development programs.

EMPRI - JUSTIFICATION FOR MANPOWER AND TRAVEL COST UNDER DST PHASE 2 PROJECT

29.1 Budget for Salaries/wages

Designation & number of persons	Monthly Emoluments	BUDGET					(in lakhs)
		1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
Project Scientist -II - 1no.	67,000/-+ (24% HRA)5% hike every 2 years	9,96,960	9,96,960	10,46,808	10,46,808	10,99,148	**51,86,684**
Research Associate – 1no.	47,000+(24% HRA)	6,99,360 (47,000+ (24% HRA)	7,29,120 (49,000+ (24% HRA)	8,03,520 (54,000+ (24% HRA)	8,03,520 (54,000+ (24% HRA)	8,03,520 (54,000+ (24% HRA)	**38,39,040**
Senior Research Fellow-1no.	35,000/-+ (24% HRA)	5,20,800	5,20,800	5,20,800	5,20,800	5,20,800	**26,04,000**
Project Associate II - 2no. (General-1 Lab-1)	28,000/-+ (24% HRA)	8,33,280	8,33,280	8,33,280	8,33,280	8,33,280	**41,66,400**
Total Requirement per Year		30,50,400	30,80,160	32,04,408	32,04,408	32,56,748	**1,57,96,124**

1. Project Scientist : PhD in Science or Masters degree in Engineering or Technology with three years research experience for executing and managing the research components of the projects.
2. Research Associate : PhD in Science for managing the web portal on climate related database and knowledge portal and other research work.
3. SRF : Post graduate in Basic science or graduate/Post graduate in professional course for basic research on phenology related projects.
4. Project Associate : Master's degree in natural or agricultural or life sciences/ Bachelors degree in Engineering or Technology with 2 years' experience for assisting in project activities.

Justification for Manpower

	Personnel	Activities to be undertaken under the project
1	Project Scientist -II -1no.	1) Lead the project team and provide guidance for executing and managing all the research components of the project. 2) Assess district level Vulnerability and Risk mapping for the proposed sectors of the state. 3) Training the staff on methodologies on climate change assessments. 4) To pursue long-term studies on climate change in Permanent preservation plots established in natural forests of Karnataka. Conduct surveys and field visits for recording census/re-census of the plots and manage the tagging system. 5) Organising national and international seminars and conducting workshops for stakeholders on climate change topics. 6) Preparation of progress reports (Quarterly and Annually) and reviewing the utilisation certificates for timely submission to DST. 7) Performing statistical analysis of the compiled result data, and preparing the project report. 8) Preparation of the manuscript for publication in peer-reviewed journals with high impact factor journals. 9) Writing a review/conference proceeding. 10) Participation in conferences and workshops. 11) Perform other duties as assigned by PI.
2	Research Associate – 1no.	1) Updating an interactive database/knowledge portal on climate change. 2) Collection and maintenance of weather data from the automatic weather stations (AWS) round the year. 3) Creation of a database on experts in the field and facilities for networking/video conferencing. 4) Promotion of Butterfly Identification APP (BIA) across all districts of Karnataka through identified nodal agencies (NGC schools, Science clubs, citizen forums and Range Forest Offices). 5) Participation in national and international conferences. 6) Arranging lectures/talks by experts on climate change for the students of local schools/colleges for awareness creation. 7) Perform other duties as assigned by PI and Project Scientist.
3	Senior Research Fellow-1no.	1) Design field activities for phenology based study on forest vegetation response using PhenoCAM in PPPs. 2) Record and analyse the changes in forest phenology and climatic factors over the last two decades for the specific forest type in Karnataka.

		3) Data compilation, report writing, manuscript preparation and publication. 4) Participation in national and international conferences. 5) Perform other duties as assigned by PI.
4	Project Associate II -2no. (General-1; Lab-1)	1) Undertake field and lab analysis by assisting in biometrics and soil/plant sampling in PPPs. 2) Preparation of RFQs for procurement of chemicals and glassware for lab related works. 3) Maintenance of the stock registers and log books. 4) Analyse the soil/plant samples for physio-chemical characteristics. 5) Lab reports generation by compilation and interpretation of the results. 6) Participation in the workshops/training programs. 7) Perform other duties as assigned by PI.

29.3 Budget for travel: Rs. 21.50 Lakh

		BUDGET					(in lakhs)
		1st Year	**2nd Year**	**3rd Year**	**4th Year**	**5th Year**	**Total**
	Travel (Only inland travel)	4,00,000	4,00,000	4,50,000	4,50,000	4,50,000	21,50,000

Justification

	Travel Details	**Proposed Cost**
1	Visit to field for research related works round the year- Hiring a vehicle to the sites & pay to and fro charges. Travel to different districts of Karnataka for vulnerability related surveys and promotion of Butterfly Identification APP (BIA) through identified nodal agencies (NGC schools, Science clubs, citizen forums and Range Forest Offices). (10 visits @15K per year)	1.5 lakh per year x 5 years = 7.5 lakh
2	Attending meetings and national/international seminars/workshops for presenting the results-Domestic travel to cover airfare (2-ways), registration fee, lodging & boarding and ground transportation for minimum of three staff. (4 seminars/workshops @50K per year)	2.0 lakh per year x 5 years =10.0 lakh
3	Support to the travel of experts working in the same field to EMPRI for scientific handholding, talks and as resource persons for advocacy events. (2 visits @25K each per year)	0.5 Lakh per year x 5 years = 2.5 lakh
4	In the third, fourth and fifth years, there would be more visits for climate change risk advocacy purpose and to attend seminars/conferences. The project staff along with the PI/Co-PI may visit the national capital to attend the DST review meetings, workshops and executive committee meetings. (1 visit @50K per year)	0.5 Lakh per year x 3 years = 1.5 lakh
	Total	**21.50 lakh**

Name of States	Karnataka
Priority highlighted under SAPCC	Vulnerability and Risk Analysis for Water, Agriculture, Forest, Health & Urban Heat Island sectors at District Level in Karnataka
No. of Districts and Blocks	30 districts
Vulnerability Analysis & Risk Assessment done State/District/Blockwise	District level

Selected Indicators for Vulnerability Analysis & Risk Assessment Study

Category		Indicators	Relevance	Dimension	Functional relationship with Vulnerability
Water Sector	1	Average Annual rainfall(mm)	As availability of water increases, there is less vulnerability to climate disasters as it can fulfil the necessary demand	Adaptive Capacity	Inverse
	2	Availability of surface water (BCM)		Adaptive Capacity	Inverse
	3	Availability of ground water (BCM)		Adaptive Capacity	Inverse
	4	Population density	As population increases in a given area, more the vulnerability to climate disasters	Sensitivity	Direct
	5	Domestic Water Demand(BCM)	As the water demand for domestic purposes increases,more the vulnerability to climate disasters	Sensitivity	Direct
	6	Crop Water Demand	As the water demand of crop increases, more the vulnerability to climate disasters	Sensitivity	Direct
	7	Livestock Water Demand (BCM)	As the water demand of livestock increases, more the vulnerability to climate disasters	Sensitivity	Direct
	8	Industrial Water Demand(BCM)	As the water demand for industrial purposes increases,more the vulnerability to climate disasters	Sensitivity	Direct
	9	Average annual temperature (Degree Celsius)	As the ambient temperature increases, it causes more of evaporation of surface waters, this results in greater vulnerability to climate	Sensitivity	Direct
	10	Net irrigated area	Larger the area under	Sensitivity	Direct

Category		Indicators	Relevance	Dimension	Functional relationship with Vulnerability
		(Ha)	irrigated agriculture lesser the vulnerability to climate disasters		
	11	Water Scarcity (m^3)	As water scarcity increases, there is greater vulnerability to climate disasters	Sensitivity	Direct
	12	Total annual ground water extraction (BCM)	As overdraft of water increases greater will be thevulnerability to climate disasters	Sensitivity	Direct
	13	Forest area (ha) per 1000rural population	Availability of large forest areas implies less vulnerability during climatedisasters	Adaptive Capacity	Inverse
	14	Water balance (BCM)	Lesser the water balance more the vulnerability to dependents	Adaptive Capacity	Inverse
	15	Area under Rain-fed agriculture (Ha)	As area under rain fed agriculture increases morewill be the vulnerability to climate disasters	Sensitivity	Direct
	16	Percentage of drip andsprinkler irrigation	As percentage share of drip and sprinkler irrigationincreases, then lesser the vulnerability to climate disasters	Adaptive Capacity	Inverse
	17	Water infrastructure – (Bore wells, open wells,dug wells, lakes/irrigation tanks, rivers, streams)	Better the infrastructure facilities for holding water, lesser the vulnerability to climate disasters	Adaptive Capacity	Inverse
	18	Percentage household with drinking water facility	As number of households with improved drinking water facility increases, thelesser the vulnerability during the climate disasters	Adaptive Capacity	Inverse
	19	Percentage Household	As number of households with	Adaptive Capacity	Inverse

Category		Indicators	Relevance	Dimension	Functional relationship with Vulnerability
		using sanitation facility	improved sanitation facility increases, the lesserthe vulnerability during the climate disasters		
	20	Per capita income	As per capita income increases, the more will be the living standards and lesser will be vulnerability to climate disaster	Adaptive Capacity	Inverse
Agriculture Sector	1	Crop yield variability	Small farmers experience immediate hardship in face of any climate hazard	Sensitivity	Direct
	2	% area under rainfed agriculture	Rainfed agriculture is highly sensitive to the vagaries of weather. Lack of irrigation indicates lack of adaptive capacity to mitigate the impacts of climate risks, leading to increased crop loss and reduced income of household dependent on rainfed agriculture.	Sensitivity	Direct
	3	% of net cultivable area actually under cultivation	More cultivable area can satisfy more food demand	Sensitivity	Direct
	4	% of main workers engaged in agriculture and agriculture labour	Income generating activity	Sensitivity	Direct
	5	Total female agricultural land holdings	Women are known to be more sensitive to climate risks. Females holding agricultural land signify gender equality, enhanced purchasing power and independence. They are likely less vulnerable to climate change.	Sensitivity	Inverse
	6	% area under horticulture tree crops	Horticultural trees are hardy and more resilient to climate variations	Adaptive capacity	Inverse

Category		Indicators	Relevance	Dimension	Functional relationship with Vulnerability
			compared to agricultural crops. They provide alternate income sources to agriculture.		
	7	Sericulture index (% farmers, % area under mulberry, % farmers benefited by different schemes; market density)	Sericulture can be an alternate source of livelihood and additional source of income	Adaptive capacity	Inverse
	8	Livestock index (Livestock units/population; Veterinary institution/livestock unit; indigenous: cross breed ratio)	a) Livestock provide alternate income sources to agriculture. b) Cross-bred cattle are more productive; require more investments in feed, fodder and management and more sensitive to climate change. Higher the number, more is the exposure Indeginous breeds are more tolerant to heat stress	Adaptive capacity	a) Inverse b) Direct
	9	Fisheries index (number of tanks/geographical area; ice plants and cold storage centres/tonne fish catch; %households engaged in fisheries; fish market density)	Fisheries provide alternate income sources to agriculture.	Adaptive capacity	Inverse
	10	Seed distribution/ total number of farmers	Improved agricultural practices. Good quality seeds improves agricultural productivity	Adaptive capacity	Inverse
	11	Market density	Better access to markets helps farmers receive better prices and thus higher incomes. Better market access was also shown to be positively related to technology adoption	Adaptive capacity	Inverse

Category		Indicators	Relevance	Dimension	Functional relationship with Vulnerability
	12	Total agricultural loan/total agricultural population	Farmers have the access to get financial support for agriculture in times of need	Adaptive capacity	Inverse
	13	Members of credit co-operative societies (agricultural marketing and milk)/total agricultural population	Members of co-operative societies will have the access to get financial support in times of need	Adaptive capacity	Inverse
	14	% of area under food grains to total cropped area	Food security	Adaptive capacity	Direct
	15	Fertilizer (NPK) consumption in kg per hectares	High use of fertilizers indicates adoption of improved technologies	Adaptive capacity	Inverse
	16	No. of mechanized farm implements per 1000 hectares	Improved agricultural practices	Adaptive capacity	Inverse
	17	Cropping intensity	Ratio of net area sown to the total cropped area	Adaptive capacity	Direct
Forest Sector	1	% area under forests	Forests are an important source of alternative livelihood and food through extraction of non-timber forest products (NTFPs). Forests also provide essential ecosystem services for the sustainable productivity of rural economies and building of adaptive capacity	Adaptive capacity	Inverse
	2	Non Agricultural land		Adaptive capacity	Inverse
	3	Saplings planted (in lakhs)	% increase in forest cover/afforestation	Adaptive capacity	Inverse
Health Sector	1	Percentage of Child Population to the Total Population	Children are more sensitive to the alterations in climate	Sensitivity	Direct
	2	Population burden on hospitals and other health care facilities index	The availability of doctors and health care specialists at medical institutions represents the functionality of these institutions. Access to	Sensitivity	Inverse

Category		Indicators	Relevance	Dimension	Functional relationship with Vulnerability
			functional health care infrastructure is essential for the overall health and well-being of a community		
	3	Vector-borne diseases (VBD)	Temperature and rainfall variations can foster higher Vector-borne diseases occurrence.	Sensitivity	Direct
	4	Water-borne diseases	Lack of proper drainage, high incidence of open defecation, and frequent occurrence of floods, lead to an increase in exposure to water-borne pathogens.	Sensitivity	Direct
	5	Maternal Mortality Rate (MMR)	Access to healthcare infrastructure	Sensitivity	Direct
	6	Infant Mortality Rate (IMR)		Sensitivity	Direct
	7	% of schools with toilets for girls	Availability of toilets for girls indicate hygiene practices and infrastructure in the schools	Adaptive capacity	Inverse
	8	% of children immunised	Improved immunity to cope up with diseases	Adaptive capacity	Direct
	9	% of women and children availed benefits under Janani Suraksha Yojana and other schemes	Reduces maternal and neonatal mortality by promoting institutional delivery among poor pregnant women	Adaptive capacity	Direct
Urban Heat Island	1	Children sensitive to heat (< 5 years)	Population factors that may cause people to be more vulnerable to heat risk by reducing their ability to thermoregulate, resulting in illness leading to deaths. Certain populations tend to be more vulnerable due to factors such as age, illness, low income, etc. These factors can be identified as significant	Sensitivity	Direct
	2	Elders sensitive to heat (>65 years)		Sensitivity	Direct
	3	Ill-health/people with disabilities (%)		Sensitivity	Direct
	4	People taking medication (asthma, heart disease, diabetes)		Sensitivity	Direct
	6	Poor social		Sensitivity	Direct

Category		Indicators	Relevance	Dimension	Functional relationship with Vulnerability
		networks (unemployment rate) and homeless people	indicators to map the heat stress and heat vulnerable population in cities.		
	7	Weak economic status (low income)		Sensitivity	Direct
	8	Low level of education		Sensitivity	Direct
	9	Immigration or race		Sensitivity	Direct
	10	Poor social networks (unemployment rate)		Sensitivity	Direct
	11	People living alone (%)		Sensitivity	Direct
	12	Linguistically isolated households (%)		Sensitivity	Direct
	13	Zones with a relatively higher population density		Sensitivity	Direct
	14	Air quality	Hot days per year. Mean temperature increase and several heavy rains.	Sensitivity	Inverse
	15	Air temperature		Sensitivity	Direct
	16	Humidity		Sensitivity	Direct
	17	Precipitation		Adaptive capacity	Inverse
	18	Land surface temperature (LST maps)	Urban hotspots that may cause the city to be at high risk from heat or extreme temperatures; High-resolution traffic-related air pollution estimates.	Sensitivity	Direct
	19	Greenness cover	Green space per person.	Adaptive capacity	Inverse
	20	Impervious surface (%)	Percent cover of roads, high-density areas, and buildings as per land use land cover data that may give information on total impervious surface cover.	Adaptive capacity	Inverse
	21	Mobility/accessibility to thermal comfort Hospitals	Access to medical facilities (emergency services).	Adaptive capacity	Inverse
	22	Ambulance			

Category		Indicators	Relevance	Dimension	Functional relationship with Vulnerability
				Adaptive capacity	Inverse
	23	Medical centres		Adaptive capacity	Direct
	24	Per cent green space or green infrastructure	Various attributes of land use and land cover may play an essential role in thermal comfort or reducing the heat stress of the population nearby	Adaptive capacity	Direct
	25	Impervious surface (%)		Adaptive capacity	Direct
	26	Shopping centres/cinemas		Adaptive capacity	Direct
	27	Community centre/care		Adaptive capacity	Direct
	28	Open spaces		Sensitivity	Direct
	29	Public transport/bus stops/train stops		Adaptive capacity	Direct
	30	Buildings with air conditioning		Adaptive capacity	Direct
	31	Swimming pools		Adaptive capacity	Direct
	32	Quality of the built environment		Adaptive capacity	Direct

These indicators would be subjected to principal component analysis where after the final list of indicators will be evolved. Further, the data availability will be checked for most recent data.