

**Effect of Climate and Land Use/Cover Change on Spatial and
Temporal Water Availability in Subarnrekha River Basin**

Proposal for Research Grant

Submitted to

Indian National Committee for Climate Change (INCCC)

**Agricultural & Food Engineering Department
Indian Institute of technology
Kharagpur 721 302**

APPLICATION FOR RESEARCH GRANT

1. **Project Title: Effect of Climate and Land Use/Cover Change on Spatial and Temporal Water Availability in Subarnrekha River Basin**

2. **Principal Investigator**

Dr. Ashok Mishra

Associate Professor
Agricultural & Food Engineering Department
Indian Institute of Technology
Kharagpur 721 302
Phone: 03222 283890
Fax: 03222 255303/282244
e-mail: amishra@agfe.iitkgp.ernet.in

3. **Research Institution**

Agricultural & Food Engineering Department
Indian Institute of Technology
Kharagpur 721 302
Phone: 03222 282037
Fax: 03222 277190
e-mail: deansr@hijli.iitkgp.ernet.in
Nearest Railway Junction: Kharagpur
Nearest Airport: Kolkata

4. **Co-Principal Investigators**

Dr. Rajendra Singh

Professor
Agricultural & Food Engineering Department
Indian Institute of Technology
Kharagpur 721 302
Phone: 03222 283148
Fax: 03222 255303/282244
e-mail: rsingh@agfe.iitkgp.ernet.in

Dr. N.S. Raghuvanshi

Professor
Agricultural & Food Engineering Department
Indian Institute of Technology
Kharagpur 721 302
Phone: 03222 283146
Fax: 03222 255303/282244
e-mail: nsr@agfe.iitkgp.ernet.in

Dr. C. Chatterjee

Professor
Agricultural & Food Engineering Department

Indian Institute of Technology
Kharagpur 721 302
Phone: 03222 283158
Fax: 03222 255303/282244
e-mail: cchatterjee@agfe.iitkgp.ernet.in

5. Brief Bio-data of the Investigators

Please refer Appendix I

6. Track Record and Workload Assessment of the PI

(a) Schemes Completed

1. HighNoon: Adaptation to changing water resources availability in northern India with Himalayan glacier retreat and changing monsoon pattern (Co-ordinated Project), European Union, May 2009 to Apr. 2012.
2. Analysis of Climate Change and its Impact on Flood and Drought in a River Basin, IIT Kharagpur, Feb. 2009 to Jan. 2012.

(b) Schemes Foreclosed – none

(c) Schemes Ongoing

1. Climate change adaptations to improve agricultural production in Eastern India. Funded by- MHRD, Department of Higher Education, New Delhi; April 2014 to March 2017.

7. If the scheme is sanctioned, the authority in whose name the payment is to be authorized:

- i) Name of authorized person holding account with complete address:

Dean (SRIC)
Sponsored Research & Industrial Consultancy
Indian Institute of Technology, Kharagpur
Kharagpur, WB 721 302

- ii) Organisation Name as per Bank records :

Sponsored Research & Industrial Consultancy
Indian Institute of Technology, Kharagpur

- iii) Bank Account No.

CA-95563070000023

- iv) IFSC Code:

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- v) MICR Code :

721025103

- vi) Bank Name:

Syndicate Bank

- vii) Bank Branch Address:

Syndicate Bank, SRIC IIT Kharagpur Campus

viii) Unique Agency code of the Organisation and Institute:

ix) Telephone & Mobile No.
Ph: 03222-282037

8. Category of R&D Activity

a.	Basic Research	
b.	Applied Research	X
c.	Action Research	
d.	Education & Training	
e.	Mass Awareness Programme	
f.	Infrastructure Development	
g.	Creation of Centre of Excellence	

9. Description of the Proposal

(a) Background/Origin of the proposal

Water is the most important natural resource to sustain life over the earth surface. The usable water is reducing and becoming scarce day by day. Ever growing population and social development has led to increased demand by different sectors for fresh water which is projected to continue in future. However, the availability is decreasing due to changed pattern of local climate, reduced storage areas and changed land use/land cover (LU/LC) patterns of any region. Generally accepted issues include the likelihood climate change and subsequent changes in hydrological conditions (e.g., runoff and stream flow, root zone soil moisture, soil erosion, groundwater recharge and groundwater levels). The changed regional rainfall pattern, *i.e.* changed frequency and intensity of rainfall, has reduced the temporal availability of regional water when required. This change in regional hydrologic process, though inferred to the changing climate, also have the impact of man made changes in LU/LC pattern in the past. As a result, the natural water storage bodies are reduced in capacity because of high sedimentation and the land which can serve the water storage purpose is lying useless. Development of water resources locally or on unit basis could help in improving water availability on sustainable basis. River basins being the basic unit for natural water resources development and management can be considered to improve the alarming situation and opt for development on sustainable manner.

IPCC (2007), in its 4th assessment report, has projected decrease in winter (December to February) precipitation over the Indian subcontinent implying lesser storage and greater water stress during the lean period. Thereby, India is predicted to be severely impacted by climate change. In changing climate conditions the local weather may have shifted temporally and spatially and needs to be studied for its patterns. By establishing the changing behavior of climate, the projections can be done to assess the future resources to answer the “*what-if-when*” conditions. However, the spatial dimension appears to be a constraint and can be taken care by *hydrologic modeling* equipped with Geographical Information System (GIS) and Remote Sensing (RS) techniques. These tools and techniques have shown their

accurate applicability in gathering required information with less cost and in minimum time. This enables to study the effects of all plausible scenarios of water resources status under changing climate and LU/LC conditions in less time.

Subarnrekha River Basins with a total catchment area of 19,296 sq km is the smallest of the 14 major river basins in the country and is located in the Orissa, Jharkhand and west Bengal states. The total length of the river is about 395 km. It is an important river supporting the agricultural, sanitation and industrial water need of Ranchi and Singhbhum districts of Jharkhand, Midnapore district of West Bengal and Balasore district of Orissa before reaching the Bay of Bengal. It passes through an important industrial belt of Jharkhand (Singbhum and Ranchi districts). The river Subarnarekha is basically a rainfed peninsular river with the wet months being June to September. During the dry period the river goes to motionless condition in the upper and middle reaches and at that condition the river is fully charged with pollutants. In recent years, in the region, it has been experienced that the availability of water (surface as well as groundwater) during different times of the year has been reduced. It has also been observed that the frequency of extreme climate (drought and flood) has increased though the annual total rainfall has not changed much. Another dominant change is guessed in LU/LC over the region. Therefore, it is important to study the expected climate and LU/LC change impact on hydrology of the river basin and to develop some adaptation strategies to minimize their impact.

(b) Definition of the problem

Around the world climate change has been recognized as a major cause behind the change in rainfall pattern resulting in diminishing water resources availability. The Intergovernmental Panel for Climate Change (IPCC) concluded that an increase in the average temperatures in the 20th century was primarily due to heavy industrialization, fossil fuel burning and deforestation which resulted in increased greenhouse concentrations in the atmosphere. This change in the balance of greenhouse gases is thought to be the potential cause behind the changing climate in the later part of the 20th century and in the early 21st century. The changes in climate, resulting to change in rainfall pattern, may adversely affect the future water resources availability in a basin (Nearing *et al.* 2005, Burns *et al.* 2007, Ya-ning *et al.* 2007, Gonzalez *et al.* 2009). Along with the climate change, in the process of socio-economic development, the natural land cover has got disturbed and altered the hydrologic conditions. This has led to reduced availability of water from various surface and sub-surface sources.

Keeping the origin/background and definition of the problem related to climate change effects on water resources in view, the present proposal aims to study the impacts of future projected climate and LU/LC change pattern on spatial and temporal water availability over the Subarnrekha river basin.

10. Objectives: Classify the objectives of proposed research under one or more of the following and explain the objectives briefly

a) Finding answers to as yet un-answered questions (list the question)

- What is the impact of LU/LC change along with climate change on spatial and temporal surface water resources?
- How downscaled climate scenarios (AR5) generated using different General Circulation Models compare for the study area?

b) Development of a new computational procedure (State the purpose of the procedure)

How the hydrology of the study area can be simulated under climate change and LU/LC change conditions using the distributed hydrologic model. The already developed climate scenarios from different GCMs will be used. It will help in understanding how different climate forcings within a GCM and among the GCMs and LU/LC change affect hydrology of study area.

c) Investigation of behavior of a natural process (state how new aspects will be investigated and why)

Efforts will be made to identify the more appropriate GCM and climate change scenario for the study area. This will help in studying the hydrologic behavior of the river basins.

d) Any other: NIL

Specific objectives of the proposed study are given below:

1. To study the historic climate change, morphological properties and land use/land cover change pattern over the Subarnrekha river basin
2. To calibrate and validate the Arc SWAT hydrological model at different spatial scales (Micro-watershed and basin scale) for river basin using current land use and observed climatic conditions
3. To develop future expected land use change and collect downscaled (statistical and dynamical) climate change scenarios (AR5) for base period and compare them with observed period
4. To model spatial and temporal future water availability using downscaled climate and land use change scenarios to quantify the effect of climate and LU/LC change
5. To quantify the uncertainty in modeling analysis arising from model parameters and input conditions
6. To develop management scenarios for minimizing the impact of climate change on spatial and temporal water availability under present and projected land cover changes.

11. Contribution to Water Resources Development

The review of literature suggests that several studies have been performed to understand the condition of water resources availability under plausible climate change scenarios in India and abroad. However, no study has been performed using climate model projections and LU/LC change conditions in India in general and for Kangsabati river basin in particular. Therefore, the present study may give more

realistic and consequences driven information to be used for resources planning by different stakeholders of the river basin with the possible uncertainty. The propose research will contribute to answer the specific effect of expected future climate and LU/LC change which is still a kind of unanswered question. This will, as well, be useful in learning and understanding the behavior of natural hydrologic processes of river basin under climate change scenarios with their uncertainty rages.

12. Putting the Research to Use

(a) End-Users of the Results

Reviews on climate change and water resources has clearly shown that water resources are declining due to changing pattern of rainfall occurrence and distribution, whereas, the demand is increasing because of increasing population and socio-economic conditions. The expected condition of future water resources as outcome of this study may be helpful in management decision making for several Central and State Government agencies, research and educational institutes who are involved directly or indirectly in managing the regional or area specific water resource for assured water supply in future.

(b) Necessary Actions to Put the Results to Use

For wide fora, the outcomes may be put on use by different users which may be done by communicating the results to some standard journals as well as on internet for easy access by different users.

(c) Difficulties that may be Encountered in Putting the Results to Use

The major difficulty envisaged at this stage is availability of land use/land cover information for sufficient number of years which can be extrapolated to find out the trend in its change. Therefore, every effort will be made to collect the remote sensing images for number of years from NRSC as well as from other international sources to develop land use/land cover information.

(d) Involvement of Possible End Users in Research

The work will be done in coordination with Department of Water Resources, Department of Agriculture and Meteorology of the State of Orissa, Jharkhand and West Bengal where the study area lies. Since, the data regarding the water requirement and availability for the past will be collected and used from these state agencies/departments, they will be involved and get benefited from the research findings. Further the research organizations, institutions, and NGOs which are working for water and agricultural resources will be benefited from the findings of the research project. They will be the end users of the research outcomes as they may use the findings for their planning.

13. Present State of Art

(a) International Status

Around the world climate change has been recognized as a major cause behind the change in rainfall pattern resulting in diminishing water resources availability.

Number of studies has been performed, worldwide to assess the effect of changing climate on regional or area specific water resources. Nearing *et al.* (2005), Burns *et al.* (2007), Ya-ning *et al.* (2007), and Gonzalez *et al.* (2009) studied the effect of changing rainfall pattern on water resources and concluded that the change in rainfall pattern may adversely affect the basin scale future water resources availability. Basins are sensitive to changing climate which can change plant growth rates, runoff and thus affect future water resources (Zhang *et al.*, 2009; Zhang *et al.* 2010).

Doll and Jhang (2010) studied the climate change effect on freshwater ecosystems using the global water model WaterGAP 2.1g to simulate monthly river discharge with a spatial resolution of 0.5 degrees. They considered four climate change scenarios generated from two global climate models (ECHAM4 and HadCM3) considering two greenhouse gas emissions scenarios (A2 and B2). Boyer *et al.* (2010) studied the magnitude of the hydrological alteration associated with climate change at five watersheds on both shores of the St. Lawrence, Canada using hydrological model HSAMI. They used six climate change plausible scenarios generated from three General Circulation Models (HadCM3, CSIRO-Mk2 and ECHAM4) based on two greenhouse gas emissions scenarios (A2 and B2). The projected daily climate series were produced using the historical data of a reference period (1961–1990) with a perturbation factor equivalent to the monthly mean difference (temperature and precipitation) between a GCM in the future for three 30 year horizons (2010–2039, 2040–2069; 2070–2099) and the reference period. Finally they reported that the climate change has effects on monthly and seasonal changes in water availability as well as temporal shift. They also inferred that the regional characteristics are important and should be incorporated in climate studies for more realistic results.

Climate change scenarios developed from models like Hadley Centre for Climate Simulations (HadCM2 and HadCM3) predicted an increase in the average annual runoff at high latitudes in equatorial Africa, Asia, and South-East Asia, while predicted decrease in the same in mid-latitudes and most subtropical regions (Arnell, 1999). Arnell (2004) again elaborated that in future changing climate will increase the water resource stress in some parts of the world like Mediterranean, southern Africa, central and southern America and in parts of Europe. It was also concluded that by 2025, a significant portion of the world's population will be under severe water stress. General circulation models (GCMs) using current emission scenarios have predicted that the mean annual temperature will increase by 3 °C in the 21st century and thereby an increase in mean global temperatures will alter the potential evapotranspiration (Huntington, 2003).

A study conducted by Hanson *et at.* (2001) has shown that the changes in carbon dioxide concentrations in the atmosphere will change the leaf area and stomatal openings and thus alter the rate of evapotranspiration. Crops have been found to be sensitive towards future water scarcity, changes in temperatures and atmospheric carbon dioxide concentration (Srinivasan *et at.* 1997, Kruijt *et at.* 2008, Lovelli *et at.* 2010). These factors combined together may have severe consequences on the water resource availability of a region and therefore needs to be understood on a basin scale hydrology.

Jha *et al.* (2006) analyzed and concluded that basin scale hydrology is very sensitive to climate change. It has been observed that an increase in the average temperatures is usually accompanied with reduced precipitation in the catchments (Menzel *et al.*, 2002). Yang *et al.* (2002) found that climate change in southern Taiwan influenced precipitation generation thereby increasing runoff in wet seasons and declining during the dry seasons which shows that climate change can also have varying effects according to the seasons.

A few studies (Legesse *et al.*, 2003; Guo *et al.*, 2008; He *et al.*, 2008, Li *et al.*, 2009) have been reviewed which established the individual effect of climate, land use land cover and anthropogenic changes in the watershed. These studies showed that climate change/variability has the maximum impact on water resources availability but at the same time land uses as well as anthropogenic changes too have quite high impact on the hydrologic processes. Researchers mostly suggested putting more attention on these changes when planning for restoration of water resources, hydrological processes, and ecosystems.

(b) National Status

IPCC (2007), in its 4th assessment report, has predicted about India to be severely impacted by climate change. However, a few researchers have analyzed this truth and their findings are discussed here.

Chattopadhyay and Hulme (1997) studied the effect of climate change on hydrologic component-ET and showed that the PET has decreased in the recent years in India. They also showed that future global warming is likely to cause an increase in PET over India. These projected changes in physical processes due to climate change would have significant impact on hydrologic processes and the water resource of the area and necessitates to be studied to manage the resources. Ramesh and Yadav (2005) synthesized the high-resolution palaeorecords of the South Asian summer monsoon from different natural archives and used to reconstruct and compare the monsoon rainfall quantity from its measured records. They also tried to predict the Indian water resources future under the global climate change using the paleomonsoon information.

Gosain *et al.* (2006) used SWAT model in conjunction with the HadRM2 daily data to determine the impact of climate change on 12 major river basins of India. They concluded that in general runoff quantity will decrease.

Mall *et al.* (2006) studied the Indian perspective of water resources under climate change using GCMs outputs. They elaborated the uncertainty involved in GCM predictions and thereby water resources estimations. They clearly indicated that the regional scenario of climate change effect on rainfall may be different than the average country scenario and showed the need of conducting more in-depth studies and analyses to gauge the extent of problems that the country may face. In a specific study they conducted for Ganga basin showed that due to changes in agricultural activities and over-exploitation of water resources to accomplish irrigation demand, the Ganges discharge has reduced by 60% over 25 years and prevailing the condition of about 50% drop in surface water availability, drop in groundwater table and generation of new surface features having different thermal properties. They finally recommended for more studies to be performed in different basins, aquifers and

agro-climatic regions of India to assess the sensitivity of the basin response to climate change.

Akhtar *et al.* (2008) studied the climate change impacts on Himalayan regions and concluded that climate change will result in greater risk of floods in the Himalayan region due to glacier melting.

Climate change impacts study performed by Majumdar (2008) for sustainable water resources management showed that the arid and semi-arid regions of India may be particularly vulnerable to water scarcity due to climate change while flooding may become a large problem in humid and temperate regions of India which will require adaptation to droughts and water scarcity in some regions as well as floods in the other. The effects of global warming may have substantial impact on rainfall pattern resulting in altered monsoon trends in India. This may have adverse consequences for a predominantly agriculture based country. Climate change is predicted to have a varying effect in different parts of India. Future rainfall and temperature have been predicted to increase in the north western part of India by the end of the twentieth century (Yadav *et al.*, 2010).

Ministry of Water Resources (2008) carried out comprehensive review of climate change studies in India under National Water Mission as part of National Action Plan on climate Change and concluded that the findings of each study is different. However, these studies suggest that temperature, evapotranspiration, rainfall variability and glacial melt will increase, whereas there will be decrease in winter precipitation and change in summer monsoon onset.

(c) Importance of the Proposed Project in the Context of Current Status

It is clear from the above studies that climate change is occurring but its magnitude varies in both space and time and thus area specific studies are desired to quantify impact of climate change on hydrologic regimes. In India most of the studies on climate change focused on trend analysis of hydro-meteorological variables such as precipitation and temperature, and evapotranspiration. Gosain *et al.* (2006) studied impact of climate change on runoff of 12 major river basins of India. This study however used very coarse soil and land use data which affect runoff process significantly. Therefore, it is necessary to use basin specific high-resolution data to carry-out climate change studies at spatial scales relevant to decision making for conserving the resources.

The review of literature suggests that several studies have been performed to understand the condition of water resources availability under plausible climate change conditions in India and abroad. However, the water resources availability in a river basin or in a region is also affected by the land use/land cover changes as discussed only for Ganges by Mall *et al.*, (2006). None of the study, in India, has been used the physically based hydrological model along with the downscaled climate and LU/LC change conditions. Therefore, the present study may give more realistic and consequences driven information to be used by the resource planners for better management of resources.

(d) References Examined to Reply to (a)-(c) and additional references

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14. Methodology

Step-wise procedure for carrying out the proposed research is given below:

- *To analyze the historic rainfall, temperature and LU/LC change trend over the Subarnrekha river basin*
 - Historic data pertaining to rainfall, temperature and land use/land cover will be collected from different agencies.
 - Expected change in land use will be developed based on change in the past decades. Remote sensing data (images) will be used to detect change in land use trend.
 - Parametric and non-parametric trends will be established to learn the changes in climatic condition.
 - Plausible scenarios will be developed to learn the changes under continuing condition of these.
- *To calibrate and validate the Arc-SWAT hydrological model for Subarnrekha river basin under present observed climate and LU/LC conditions*
 - Data pertaining to rainfall, temperature, land use, soil, topography, micro-watershed maps, runoff, and sediment loss will be collected from different agencies.
 - GIS will be used to prepare various model input layers.
 - Arc-SWAT model setup will be prepared and will be calibrated and validated for different spatial scales.
 - Calibrated model will be run for a selected base period.
- *To downscale climatic data from different GCMs for base period and compare them with observed climatic data*
 - Downscaled GCMs data (AR5: will be developed by IIT Bombay and IIT Delhi) will be collected for the base period and compared with the observed data of base period.
 - GCMs data will be downscaled for future climate forcing conditions (AR5).
- *To quantify the impact of climate and LU/LC change under different atmospheric forcing and projected LU/LC, respectively, on hydrology*
 - Calibrated and validated model will be used to simulate effect of different climatic forcings (AR5) and projected LU/LC.
 - Similarly model will be run considering different combination of trend based projections of rainfall, temperature, atmospheric CO₂ and LU/LC
 - Effect of climate change and LU/LC will be studied independently and compared
- *To quantify the uncertainty in climate and LU/LC change impacts on water resources*
 - The uncertainty analysis of water resources will be performed considering model parametric uncertainty, and input uncertainties: LU/LC, climate change scenarios (SRES in AR4/ Representative Concentration Pathways (RCPs) in AR5).
 - First order error analysis (FOEA), Monte Carlo Simulation (MCS), Bayesian Recursive Estimation (BaRE), and Generalized Likelihood Uncertainty Estimation (GLUE) methods will be used to estimate the uncertainties.
- *To develop management scenarios to minimize impact of climate and LU/LC change on runoff, sediment yield and water resources availability.*
 - Calibrated and validated model with different climate forcings will be used in conjunction with various management options such as forestation,

conservation tillage, on and off-stream water harvesting structure etc. to develop management plan for minimizing impact of climate and LU/LC change on runoff, sediment yield and water resources availability.

The schematic of the study is given as below:

