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. Raghuwanshi
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:
SYNB0009556

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 4^{th} 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 20^{th} 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 20^{th} century and in the early 21^{st} century. The changes in climate, resulting to change in rainfall pattern, may adversely affect the future water resources availability in a basin (Nearing *et at*. 2005, Burns *et at*. 2007, Ya-ning *et at*. 2007, Gonzalez *et at*. 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 e*t 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 ^{o}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 at*. (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 at*., 2002). Yang *et at.* (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 at*. (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 at*. (2006) studied the Indian perspective of water resources under climate change using GCMs outputs. They elaborated the uncertainity 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 at*. (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 at*., 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 at*. (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 at*, (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

Akhtar, M., N. Ahmad, M.J. Booij, 2008. The impact of climate change on the water resources of Hindukush Karakorum–Himalaya region under different glacier coverage scenarios. J. of Hydrology, 355: 148-163.

Arnell, N.W., 2004. Climate change and global water resources: SRES emissions and socio-economic scenarios. Global Environmental Change, 14(1): 31-52.

Arnell, N.W., 1999. Climate change and global water resources. Global Environmental Change, 9: S31-S49.

Boyer, C.D. Chaumont, I. Chartier, and A.G. Roy, 2010. Impact of climate change on the hydrology of St. Lawrence tributaries. J. of Hydrology, 384: 65-83.

Burns, D.A., J. Klaus, and M.R. McHale, 2007. Recent climate trends and implications for water resources in the Catskill Mountain region, New York, USA. J. of Hydrology, 336: 155-170.

Chattopadhyay, N., and M. Hulme, 1997. Evaporation and potential evapotranspiration in India under conditions of recent and future climate change. Agricultural and Forest Meteorology, 87: 55-73.

Doll, P. and J. Zhang, 2010. Impact of climate change on freshwater ecosystems: a global-scale analysis of ecologically relevant river flow alterations. Hydrol. Earth Syst. Sci., 14: 783-799.

Gonzalez, J.E., E.W. Harmsen, N.L. Miller, and N.J. Schlegel, 2009. Seasonal climate change impacts on evapotranspiration, precipitation deficit and crop yield in Puerto Rico. Agricultural Water Management, 96: 1085-1095.

Gosain, A.K., S. Rao, and D. Basuray, 2006. Climate change impact assessment on hydrology of Indian river basins. Current Science 90(3): 346-353.

Guo, H., Q. Hu, and T. Jiang. (2008). Annual and seasonal streamflow responses to climate and land-cover changes in the Poyang Lake basin, China. J. of Hydrology, 355: 106-122.

Hanson, P.J., S.D. Wullschleger, C.A. Gunderson, K.B. Wilson, and R.J. Norby, 2001. Sensitivity of stomatal and canopy conductance to elevated CO_2 concentration - interacting variables and perspectives of scale. New Phytologist, 153: 485-496.

He, H., J. Zhou, and W. Zhang. (2008). Modelling the impacts of environmental changes on hydrological regimes in the Hei River Watershed, China. Global and Planetary Change, 61: 175-193.

Huntington, T.G., 2003. Climate warming could reduce runoff significantly in New England, USA. Agricultural and Forest Meteorology, 117: 193-201.

IPCC (2007). Special Report on Emission Scenarios. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

Jha, M., J.G. Arnold, P.W. Gassman, P. Giorgi, and R. Gu, 2006. Climate change sensitivity assessment on upper Mississippi river basin stream flows using SWAT. J. American Water Resources Association, 42(4): 997-1016.

Kruijt, B., J.M. Witte, C.M.J. Jacobs, and T. Kroon, 2008. Effects of rising atmospheric CO_2 on evapotranspiration and soil moisture: A practical approach for the Netherlands. J. of Hydrology, 349: 257-267.

Legesse, D., C. Vallet-Coulomb, and F. Gasse. (2003). Hydrological response of a catchment to climate and land use changes in Tropical Africa: case study South Central Ethiopia. J. of Hydrology, 275: 67-85.

Li, Z., W. Liu, X. Zhang, and F. Zheng. (2009). Impacts of land use change and climate variability on hydrology in an agricultural catchment on the Loess Plateau of China. J. of Hydrology, 377: 35-42.

Lovelli, S., M. Perniola, T.D. Tommaso, D. Ventrella, M. Moriondo, and M. Amato, 2010. Effects of rising atmospheric CO2 on crop evapotranspiration in a Mediterranean area. Agricultural Water Management, 97: 1287-1292.

Mall, R.K., A. Gupta, R. Singh, R.S. Singh, and L.S. Rathore. 2006. Water resources and climate change: An Indian perspective. Current Science, 90(12): 1610-1626.

Menzel, L., and G. Burger, 2002. Climate change scenarios and runoff response in the Mulde catchment (Southern Elbe, Germany). J. of Hydrology, 267: 53-64.

Ministry of Water Resources, 2008. Comprehensive mission document II. National Water Mission under National Action Plan on Climate Change. Govt of India. New Delhi.

Mujumdar, P.P., 2008. Implications of climate change for sustainable water resources management in India. Phy. and Chem. of the Earth, 33: 354-358.

Nearing, M.A., and X.C. Zhang, 2005. Impact of climate change on soil erosion, runoff, and wheat productivity in central Oklahoma. Catena, 61: 185-195.

Ramesh, R., and M.G. Yadava, 2005. Climate and water resources of India. Current Science, 89(5): 818-824.

Srinivasan, L.S., M. Lal, K.K. Singh, G. Rathore, and S.A. Saseendran, 1997. Vulnerability of rice and wheat yields in NW India to future changes in climate. Agricultural and Forest Meteorology, 89: 101-114.

Yadav, R.K., K.K. Kumar, and M. Rajeevan, 2010. Climate change scenarios for Northwest India winter season. Quaternary International, 213: 12-19.

Yang, T.C., C.K. Wu, and P.S. Yu, 2002. Impact of climate change on water resources in southern Taiwan. J. of Hydrology, 260: 161-175.

Ya-ning, C., L. Wei-hong, X. Chang-chun, and H. Xin-ming, 2007. Effects of climate change on water resources in Tarim River Basin, Northwest China. J. of Environmental Sciences, 19: 488-493.

Zhang, M., L.F. Darren, Y. Luo, E. Luedeling, and E.G. Sarah, 2010. Sensitivity of agricultural runoff loads to rising levels of CO2 and climate change in the San Joaquin Valley watershed of California. Environmental Pollution, 158: 223-234.

Zhang, M., D.L. Ficklin, Y. Luo, and E. Luedeling, 2009. Climate change sensitivity assessment of a highly agricultural watershed using SWAT. J. of Hydrology, 374: 16-29.

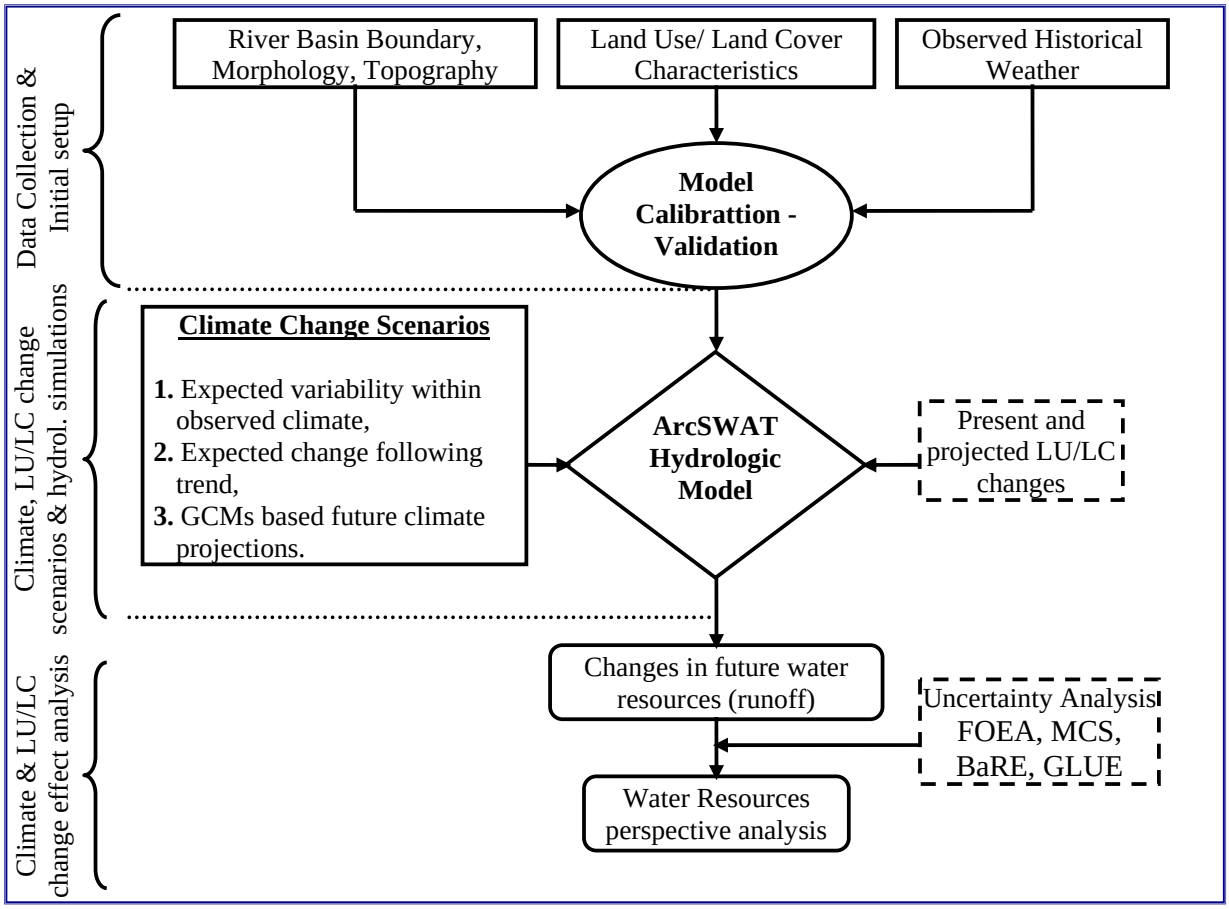
14. Methodology

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 CO_2 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:



15. Cost Estimates

15.1 Total Cost of the Project including Over Head Charges:

Rs. 25,25,600/-

15.2 Subhead wise Abstract

Subhead	Year-Wise Expenditure (₹)			Total (₹)
	First Year	Second Year	Third Year	
Salary - SRF (01 No., M. Tech. qualification) @ Rs. 28000/month.	300000	300000	336000	936000
Travel Expenses (TE) & Contingency	100000	100000	100000	300000
Infrastructure/ Equipment	550000	0	0	550000
Experimental Charges (Field exp./observations assistance, consumables/ supply & material)	170000	170000	170000	510000
Subtotal	1120000	570000	606000	2296000
Institutional Over Head Charges@ 10% (as per guideline)	112000	57000	60600	229600
Grand Total	**1232000**	**627000**	**666600**	**2525600**

15.3 Justification for Budget

Salary: Full time man power (one SRF, M. Tech. qualification) will be recruited in the project for data collection (from various institutions as well as field), processing, compilation, model (Arc-SWAT) setup, and research support, which are necessary for smooth functioning and maintaining the schedule of the proposed research work. SRF will be registered for Ph.D. Degree from the institute. The personnel will be hired on temporary basis.

Travel and Contingency: In the study visits of PI/CO-PI/SRFs are proposed for collection of data from various agencies like state meteorological department, IMD, NBSS, SAUs and river basin(s). Few visits of the research watershed/river basin are also required for ground truth (GT) for geo-referencing and LU/LC information. In addition, travel will be made in connection with the work presentation and progress reporting at the place advised by INCOH/MoWR. Contingency charges are for unforeseen expenditure requirements as well as to purchase supporting material requirement in the project which can not visualize until gone for the work in the field. Also, the contingency grant will be used to support PIs/SRF for attending the conferences (national/international).

Infrastructure (Data): The proposed study is data driven and data on topography, soils, land cover information and hydro-meteorology will be procured from various agencies. Daily hydro-meteorological data involves for at least 30 years of meteorological (rainfall, minimum and maximum temperature, wind velocity, solar radiation etc.) and hydrological (runoff, sediment measurements) data for possibly 5 to 7 number of weather stations and 3 river gauging stations spread over the Subarnrekha river basin. At least 5 passes of remote sensing images (IRS 1C/1D/P6-LISS-III/IV) will be purchased/collected to establish historic LU/LC changes. Apart

from that one dedicated computer and one printer would be required for carrying out the project.

Experimental Charges (Field Assistant, consumables/ supply and material)**:** A lab cum field assistant will be required to arrange and compile the data collected from the field. Also, the daily typing and data entry work will be performed by the field assistant and thus well justified to propose as experimental charges. Consumables like paper, CDs, cartridge etc will be required to prepare the report as well as to prepare and submit the research outcome in the form of Journal paper(s).

Institutional Overhead Charges and Contingency: As Per IIT Kharagpur's rule, all sponsored projects must pay over head charges @ 20 % of the project cost (25% on pre-institutional over heads project cost). This is to compensate for the services of Sponsored Research & Industrial Consultancy, and utilisation of infrastructure facilities like Library, Laboratories, and Technical Services of various institute staff. However, as per the guideline, the overhead charge has been calculated @10% only.

15.4 Amount Sought to be Released at the Start of the Work with Justification: Rs. 10,73,800

The division of the demand is as follows.

Salary for SRF:	Rs. 2,80,800/- (30% of salary budget)
Infrastructure/ equipment:	Rs. 5,50,000/- (100% of infrastructure cost)
TE + Contingency:	Rs. 90,000/- (30% of the budget)
Experimental Charges:	Rs. 1,53,000/- (30% of experimental charges)

15.5 Subhead Wise Details

Salary

Designation	Year 1 to 3		
	Rate/month	Months	Amount
SRF- 01 No.	25000	For 1 to 24 month	6,00,000
	28000	From 25 to 36 month	3,36,000

	I year	II Year	III Year
Total	**3,00,000**	**3,00,000**	**3,36,000**

Grand Total for Salary: Rs. 9,36,000/-

15.6 Man-months Utilization Table

(For each of the project staff, list the activities and the months from start in which he/she will be carrying out each of these activities thus justifying the total man-months)

Designation: Senior Research Fellow (01 No.) Total man months: 36

The project would require the following work to be done as a part of the project:

1. Appointment of the staffs (0-3 months)
2. Understanding the problem (project idea), planning for work schedule and literature review (0-3 months)
3. Identification and selection of hydro-meteorological station, arrangement for hardware and software(s) (0- 3 months)
4. Collection and purchase of data on climate and LU/LC, (0-9 months)
5. Collection of hydrological data from various sources (06-12 months)
6. Scrutiny of data, identifying gap and checking the quality of data (09-15 months)
7. Setting-up the hydrological model (Arc-SWAT) by arranging the input data and its calibration/validation (12-18 months).
8. Analysis to establish climate and land use/land cover change trend, their future projections (16-18)
9. Identification of GCMs, CC Scenarios working well for Indian continent as well as for research region, collection of statistical/dynamical downscaled (GCMs/RCMs) outputs for various scenarios and their comparison with observed base period data for research site (15-21 months)
10. Development of change scenarios and modeling runs to develop relationship between climate, LU/LC change and water resources (22-24 months)
11. Uncertainty analysis for model input parameters, climate change scenario and LU/LC change conditions (25-30)
12. Scenario runs for resources management (28-33 months)
13. Documentation and preparation of report, paper writing and submission to International Journal (30-36 months)

Designation: Field Assistant Total man months: 36

For the duration of project, the field assistant will work with the SRF to collect the field data, sometimes sampling of soil, helps in ground truthing etc. to get information required in modeling study.

At all the levels of work, the project staff will be working according to the needs of the project. Thus, it is evident that all the man months will be utilized for completion of the envisaged project work.

15.7 Travel Expenditure (TE)

Place	**Mode**	**No. of Visits**	**Expected Cost/visit**		**Total**
			Travel	**DA**	
IMD Pune	Air	1	15000	10000	25,000
	Rail	1	5000	10000	15,000
CWC + State Meteorology, Bhubaneswar, Kolkata & Basin	Rail/Road	5	30000	20000	50,000
Roorkee	Air + Road	2	40000	20000	60,000
ICAR/SAU/Conferences	Rail	5	25000	25000	50,000
	Air	2	30000	20000	50,000

Total Expenditure: Rs. 2,50,000/-

Long Distance Travel for Presentation:

Mode:	Air
Visits:	02
Cost/Visit:	Rs. 25, 000/-
Total:	**Rs. 50,000/-**

Grand Total for TE: Rs. 3,00,000/-

15.8 Infrastructure/Equipement

Equipment/ Software	**Specification**	**Cost (in Rs.)**
Meteorological data	Hydro-meteorological data from State Meteorology Department + IMD + CWC + ICAR and SAU	1,00,000
Remote sensing images	5 passes of different years- IRS 1B (1 P), 1C/D (3P), P6 (1P)	3,50,000
Computer (01) and Printer (01)		1,00,000
TOTAL		**Rs. 5,50,000**

15.9 Experimental Charges

Designation	**Year 1 to 3**		
	Rate/month	**Months**	**Amount**
Field work/experiments	10000	36	3,60,000
Consumables, Supply & Material	50000/year		1,50,000

Total Expenditure: Rs. 5,10,000/-

16. Work Schedule

(a) Probable Date of Commencement: 2015

(b) Duration of Study: 3 years

(c) Stages of Work and Milestones

Sl. No.	Identifiable Milestones of Progress	Time Schedule (Months from Start)	Amount to be released
1	Start	***0***	***10,73,800***
2	Appointment of Staff, Purchase of computer and arrangement for software(s) to be used	***3***	-
3	Data collection from various sources and arrangement of morphologic and LU/LC information	***9***	-
4	Collection of meteorological and hydrological data	***12***	***8,73,000***
5	ArcSWAT setup, calibration and validation runs	***18***	-
6	Data analysis to establish climate and land use/land cover change trends and scenario generation, collection of downscaled climate change data (GCMs/RCMs)	***18***	-
7	Developing relationship between climate, land use/land cover (anthropogenic changes) and water quantity (Runoff): Arc-SWAT runs using scenarios	***24***	***5,78,800***
8	Analysis of the results and uncertainty analysis for water resources study	***30***	-
9	Scenario runs for resources management	***33***	-
10	Documentation and Report Preparation	***36***	-

17. Declaration

1. I have carefully read the terms and conditions of the research grant and agree to abide by them.
2. This is to certify that I have neither submitted this proposal elsewhere for financial support nor have undertaken it at the request of any commercial agency or as a consultancy.

Ashok Mishra 29/06/2015

Date: 29 June 2015
Place: Kharagpur

(Ashok Mishra)
Associate Professor
AgFE Department, IIT Kharagpur

18. Endorsement from the Head of the Institution

1. The Institute welcomes the participation of Dr. Ashok Mishra as Principal Investigator for above project.
2. The necessary equipment and institutional support as described in item 13.3 will be made available as and when required for the purpose of the project to ensure that the work taken up on priority and completed on schedule.
3. In the event of foreclosure/discontinuation/cancellation of the scheme for any reason, the entire amount released for the scheme will be fully refunded to the MoWR along with the interest prescribed till the date of return by the Institute.
4. The Register of permanent and semi-permanent assets acquired out of the grants from MoWR will be maintained in Form GFR-19.
5. The assets acquired out of this grant shall be transferred to the desired destination in good and working condition as and when required.

M. Bhattacharjee 1/7/15

Date: 29 June 2015
Place: Kharagpur

Dean (SRIC)
IIT, Kharagpur
संकायाध्यक्ष/Dean (Acty.)
अनुदानित शोध एवं औद्योगिक सलाहकारिता
Sponsored Research & Industrial Consultancy
भा.प्रौ.सं खड़गपुर-७२१३०२/I.I.T. Kharagpur-721302

Appendix Ia: Brief Resume of PI

1. **Name** : **Ashok Mishra**

2. **Date of Birth** : 19 April, 1972

3. **Educational Qualification**

Degree	University/Institute	Year	Specialization
B. Tech.	University of Allahabad	1997	Agricultural Engineering
M. Tech.	IIT, Kharagpur	1999	Agril. Systems & Management
Ph.D.	IIT, Kharagpur	2004	Watershed Hydrology & NPS Pollution
Adv. Res.	Columbia Uni., New York	2005-07	Climate Forecast Applications

4. **Experience**

Post	Organization	From	To
Associate Professor	IIT, Kharagpur	June 2013	Till date
Assistant Professor	IIT, Kharagpur	April 2007	June 2013
Post-doctoral Research Scientist	Columbia University, New York, USA	Mar. 2005	Feb. 2007

5. **Awards/Honours/Fellowships**

2002	DAAD Fellowship for PhD Research, Hannover University, Germany, 2002-03
2007-till date	Reviewer for J. of Indian Water Resources Society; J. of Water Resources Management, SpringerLink; Hydrol. Process, John Wiley & Sons; J. of Environmental Management, J. Hydrology, Elsevier; American Society of Agricultural.& Biological Engineers (ASABE)

6. **Research Activities**

A. **Research Papers Published/Presented**

		Total
Published	Journals	39
	Proceedings	35

B. **Research Guidance**

	Completed	In Progress
Ph.D.	05	05
M. Tech.	20	02

C. **Sponsored Research**

Completed	In Progress
02 (Sponsoreding Agency: European Commission; SRIC, IIT Kharagpur)	01 (Sponsored by: MHRD, GoI

D. **Consultancy Projects**

Completed	In Progress
03 (Sponsoring Agency: MoRD; IWMI; WORLP)	0

7. **Major Scientific Fields of Interest**

- Hydrological modelling & Watershed management,
- Crop yield modelling,
- Climate forecast analysis & applications in water and crop management.

Appendix Ib: Brief Resume of Co-PI

1. **Name** **: Rajendra Singh**

2. **Date of Birth** : 8 August 1963

3. **Educational Qualification**

Degree	University/Institute	Year	Specialization
B. Sc. Engrg.	University of Allahabad	1985	Agril. Engrg.
M. Tech.	IIT, Kharagpur	1986	Soil & Water Engrg.
Ph.D.	IIT, Kharagpur	1993	Irrigation Water Manage.
Adv. Res.	DHI, Denmark	1995-96	Irrigation Manage.

4. **Experience (All Positions held at IIT, Kharagpur)**

Professor	Associate Professor	Asstt. Professor	Lecturer	Jr. Scientist
Jun 2003 –till date	May 1999 – Jun 2003	Jan 1995 – May 1999	May 1989 – Jan 1995	Mar 1987- May 1989

5. **Awards/Honours/Fellowships**

2007	DAAD Visiting Professor, Potsdam University, Germany (May-July, 2007)
2002	Fellow, National Academy of Agricultural Sciences
2002	International Project (Volkswagen Foundation, Germany) 2002-2005
2002	International Project (DST-DAAD PPP 2002) 2002-2004
2001	DAAD Short-Term Research Fellowship (May – Jul 2001)
1999	Visiting Fellowship, Univ. of Connecticut, USA (May 1999-May 2000)
1998	AICTE Career Award for Young Teachers 1998-2001 (Mar 1998)
1997	ICAR Young Scientist Award 1995-96 (Jul 1997)
1996	Vasantrao Naik Memorial Gold Medal 1996 (Nov 1996)
1995	BOYSCAST Fellowship 1994 (May 1995-May 1996)
1994	Jawaharlal Nehru Award for Best Ph.D. 1994 (Mar 1995)

6. **Research Activities**

A. Research Papers Published/Presented/Communicated

		Total
Published	Journals Proceedings	78 50
Communicated	Journals	3

B. Research Guidance

	Completed	In Progress
Ph.D.	12	02
M. Tech.	43	2
B. Tech.	6	0

C. Sponsored Projects

Completed	In Progress
6 (ICAR, Volkswagen Foundation; DST-DAAD; CGP-NATP, SAC Ahmedabad,)	1 (MoWR), 1 (SAC)

D. Consultancy

Completed
3 (DFID, UK at KRIBP, Ranchi; CMC Ltd, Pune, IGKVV)

Appendix Ic: Brief Resume of Co-PI

1. **Name** : **Narendra Singh Raghuwanshi**

2. **Date of Birth** : 3 July 1962

3. **Educational Qualification**

Degree	University/Institute	Year	Specialization
B. Tech.	J.N.K.V.V., Jabalpur	1984	Agril. Engrg.
M. Tech.	GBPAUT, Pantnagar	1986	Soil & Water Engrg.
Ph.D.	UC, Davis	1994	Irrigation Water Manage.

4. **Experience**

Post	Organization	From	To
Professor	IIT, Kharagpur	8/04	Till date
Associate Professor	IIT, Kharagpur	8/00	7/04
Assistant Professor	IIT, Kharagpur	7/97	8/00
Post Graduate Researcher	UC, Davis	1/97, 7/95	6/97, 6/96
Senior Project Engineer	IIT, Delhi	6/96	11/96
Consulting Engineer	Davids Engg., Inc., Davis	7/94	6/95
Graduate Student	UC, Davis	9/90	6/94
SRA and Scientist 'B'	NIH, Roorkee	8/86, 5/88	5/88, 7/90

5. **Awards/Honours/Fellowships**

2011	Dr. P. S. Khankhoje Gold Medal 2011
2009	Fulbright-Nehru Senior Research Fellowship, UC, Davis (08/ 09-06/ 10)
2003-till date	Editorial Board, Irrigation Science, Springer Verlag (from 2003)
1997-till date	Reviewer for Jr. of Irrig. & Drainage Engg., ASCE; Irrig. Science, Springer-Verlog; Env. Modeling and Software, Elsevier; Water Resources Research, AGU; Indian Remote Sensing, AIRS; Hydrology IAH; Iranian J. of Sc. & Tech., and Trans. of ASAE. Also reviewed a chapter in Handbook of Water Resources, Edited by Larry Mays and published by McGraw Hill.
1990	Rotary International Fellowship (1990-1993)
1984	*Honours in B. Tech.*

6. **Research Activities**

A. Research Papers Published/Presented

Published	Journals	96
	Proceedings	78
		+15(abstract)

B. Research Guidance

	Completed	In Progress	External examiner
Ph.D.	11	4	3
M. Tech.	50	2	13
B. Tech.	5		

C. Sponsored Research and Consultancy Projects

Completed	In Progress
7 (ICAR, Volkswagen Foundation; DST-DAAD; CGP-NATP, SAC Ahmedabad, DIFD, CMC, IGKVV)	2 (MoWR, MORD)

Appendix Id: Brief Resume of Co-PI

1. **Name** **: Chandranath Chatterjee**

2. **Date of Birth** : 28 November, 1969

3. **Educational Qualification**

Degree	University/Institute	Year	Specialization
B. Tech.	Orissa University of Agriculture & Technology	1992	Agricultural Engineering
M. Tech.	IIT, Kharagpur	1994	Soil & Water Cons.Engg.
Ph. D.	IIT, Kharagpur	1999	Irrigation Water Management
Adv. Res.	Potsdam University, Germany	2005-06 (1 year)	Flood Management

4. **Experience**

Post	Organization	From	To
Professor	IIT, Kharagpur	Oct. 2014	Till date
Associate Professor	IIT, Kharagpur	June 2010	Sep. 2014
Assistant Professor	IIT, Kharagpur	May 2004	June 2010
Scientist 'C'	Centre for Flood Management Studies, NIH, Roorkee	Mar. 2003	Apr. 2004
Scientist 'B'		Feb. 1997	Feb. 2003

5. **Awards/Honours/Fellowships**

2005	Alexander-von-Humboldt Foundn. Res. Fellowship, Germany, 2005-06
2004	Irrign. Award of the Institn. of Engrs. (I) for best research paper, 2004
2002	Certificate of Merit of the Institn. of Engineers (I), 2002
2002	DST Fast Track project for Young Scientists, 2002
1994	Reddy award from ISAE for best M.Tech. thesis, 1994
1994	First position in specialization in M.Tech., IIT Kharagpur, 1994.
1992	University gold medal in B.Tech. (Agril. Engrg.), 1992.

6. **Research Activities**

A. **Research Papers Published/Presented**

		Total
Published	Journals	46
	Proceedings	42

B. **Research Guidance**

	Completed	In Progress
Ph.D.	04	05
M. Tech.	28	02

C. **Sponsored Research**

Completed	In Progress
1 (DST)	3 (IIT Kharagpur, MoWR)

D. **Consultancy Projects**

Completed	1 (Govt. of Orissa)

7. Major Scientific Fields of Interest

- Hydrological modelling
- Remote sensing and GIS applications in hydrology
- Runoff estimation using deterministic & probabilistic approaches.