

**EFFECT OF CLIMATE CHANGE ON HYDROLOGICAL
COMPONENTS OF SIND RIVER BASIN AND ITS CONSEQUENCES
ON FODDER PRODUCTION USING SWAT MODEL**

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ON FODDER PRODUCTION USING SWAT MODEL**

by

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Submitted in fulfilment of the requirements of the degree of DOCTOR OF PHILOSOPHY

to the



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May, 2018

**DEDICATED
TO
MY BELOVED WIFE**
(FOR MOTIVATION AND INSPIRATION)



**IN LOVING MEMORY OF
MY PARENTS**

CERTIFICATE

This is to certify that the thesis entitled “**EFFECT OF CLIMATE CHANGE ON HYDROLOGICAL COMPONENTS OF SIND RIVER BASIN AND ITS CONSEQUENCES ON FODDER PRODUCTION USING SWAT MODEL**” being submitted by **Boini Narsimlu** to the Indian Institute of Technology, Delhi for the award of the Degree of Philosophy is a record of bonafide research work carried out by him under our guidance and supervision. The thesis work, in our opinion, has reached the standard, fulfilling the requirements, for the said degree. The research report and the results presented in this thesis have not been submitted, in part or in full, to any other University or Institute, for the award of any degree or diploma.

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SWAT मॉडल का उपयोग कर के सिंधनदी बेसिन के जलीय घटकों पर जलवायु परिवर्तन का प्रभाव एवं चारा उत्पादन पर इस के परिणाम

सारांश

जलवायु परिवर्तन एक वैश्विक समस्या है। भारत में लगभग 700 मिलियन ग्रामीण लोग अपने अस्तित्व और आजीविका के लिए जलवायु संवेदनशील क्षेत्रों (कृषि, जंगल और मत्स्य पालन) और प्राकृतिक संसाधनों (पानी, मिट्टी और चरागाहों) पर सीधे निर्भर करते हैं। जलवायु परिवर्तन के तहत, देश की खाद्य सुरक्षा खतरे में आ सकती है। इसके अलावा, बारानी किसानों, वन और तटीय समुदायों की अनुकूलन क्षमता कम है। जलवायु परिवर्तन से सभी प्राकृतिक पारिस्थितिक तंत्रों पर असर पड़ने की संभावना है। भविष्य में मौसम की चरम सीमाओं में वृद्धि और वर्षा में परिवर्तनशीलता कृषि उत्पादकता को प्रभावित करेगी और विभिन्न कृषि जलवायु क्षेत्रों में उपज में गिरावट का कारण बन जाएगी। जल संसाधनों पर जलवायु परिवर्तन का प्रभाव सतह और भूजल दोनों को प्रभावित करने वाले जलीय चक्र की वृद्धि को इंगित करता है।

प्रेसिस मॉडल (PRECIS Model) के एबी परिदृश्यों का उपयोग मध्य भारत और सिंध नदी बेसिन (एसआरबी) के जलीय घटकों पर भविष्य के जलवायु परिवर्तन प्रभाव का आकलन करने के लिए प्रयास किया गया है और बेसिन में चारा उत्पादन पर जलवायु परिवर्तन के परिणामों का मूल्यांकन करने के लिए भी प्रयास किया गया है।

स्वाट (SWAT) हाइड्रोलॉजिकल मॉडलिंग और मॉडफ्लो (MODFLOW) भूजल मॉडलिंग का उपयोग कुल जल संसाधनों (सतह और भूजल पानी) का आकलन करने के लिए किया गया है। अंशांकन और सत्यापन अवधि में सांख्यिकीय प्रदर्शन संकेतकों के उच्च मूल्य के सहसंबंध गुणांक (R) और एनएसई (NSE) यह दर्शाता है कि एसआरबी के अंशांकन हाइड्रोलॉजिकल मॉडल बेसिन के प्रवाह का वर्णन करने में सक्षम है। इसके अलावा अंशांकित SWAT मॉडल का उपयोग एसआरबी के जलीय घटकों पर जलवायु परिवर्तन के संभावित प्रभावों का मूल्यांकन करने के लिए किया गया था। SWAT मॉडल द्वारा उत्पादित अवयव जैसे पुनर्भरण, रिसाव दर, वाष्पोत्सर्जन, नदी की गहराई, प्रवाह दर और जलीय चालकता के मूल्यों को सिंध नदी बेसिन के भूजल मॉडलिंग में भूजल प्रणाली और सतह, भूजल परस्पर क्रिया को समझने के लिए उपयोग किया गया था। सिंध नदी बेसिन में जल स्तर समोच्च उंचाई इंगित करता है कि भूजल बेसिन के पूर्वोत्तर भाग में उथले गहराई में प्राप्त किया जा सकता है और धीरे-धीरे दक्षिण पश्चिमी क्षेत्र की ओर बढ़ रहा है और पहाड़ी क्षेत्रों के आसपास लगभग गायब हो रहा है।

बेसलाइन अवधि (1961-1990) की तुलना में एसआरबी में जल उपज मध्य शताब्दी (2021-2050) में 12% और अंत शताब्दी (2071-2098) में 13% की वृद्धि होने का अनुमान है। कुल मिलाकर अनुकरण के नतीजे बताते हैं कि सिंध नदी बेसिन में मुख्य रूप से उपजल ग्रहण के मध्य और दक्षिणी हिस्सों में पानी की उपज बेसलाइन से मध्य शताब्दी तक 19.46 - 59.44% की वृद्धि के साथ बदलती है। एसआरबी के दक्षिणी हिस्सों में अंत शताब्दी की अवधि के दौरान ईटी (ET) में 6% की वृद्धि मानव वंशीय परिवर्तनों के कारण हो सकती है, जिससे फसल उत्पादन में वृद्धि के साथ ET की मांग बढ़ी है। अनुमानित ऐतिहासिक आंकड़ों की तुलना में PRECIS; IPCC SRES A1B परिदृश्यों के साथ RCM पूर्वानुमान बेसलाइन अवधि (1960-1999) के दौरान अध्ययन क्षेत्र की वर्षा के लिए कम आंके गए हैं। अंत शताब्दी में वर्षा में वृद्धि से संकेत मिलता है कि निश्चित रूप से अधिक चरम घटनाएं हो सकती हैं, जिससे बाढ़ आ सकती है। जलवायु परिवर्तन के परिणामस्वरूप जून (मध्य शताब्दी) के महीने में वर्षा में कमी मानसून की शुरुआत में

देरी का परिणाम हो सकती है। मॉनसून की शुरुआत में इस देरी से फसल **बुवाई** की अवधि में व्यवधान होगा जिससे कीट और बीमारियों की संवेदनशीलता हो सकती है।

अक्टूबर के महीने के दौरान 5°C तक तापमान में वृद्धि नमीतनाव की स्थिति में वृद्धि कर सकती है और फसल की पैदावार को कम कर सकती है क्योंकि इस अवधि में फसल अपने महत्वपूर्ण चरण जैसे **दाना बनने** और खरीफ मौसम में फसल कटाई के चरण में **होती है**। कृषि और जल उपज पर **इस तापमान में वृद्धि** के परिणामों को दूर करने के लिए **ध्यान देने** की जरूरत है। बेसलाइन अवधि (1960-1999) की तुलना में एसआरबी में चारा का **जैवभार** उत्पादन अंत शताब्दी में 39.26% और मध्य शताब्दी में 26.14% की कमी होने की उम्मीद है। जलवायु परिवर्तन के प्रभाव के कारण बेसलाइन अवधि (1960-1990) की तुलना में चारा उपज मध्य शताब्दी में 18% और अंत शताब्दी में 22.14% घट जाएगी। **Raised bed and furrow system** (आरबीएफएस) और **laser guided land leveling** (लेजर निर्देशित भूमिस्तर प्रणाली) रजलवायु परिवर्तन के प्रतिकूल प्रभावों को दूर करने के लिए इस अध्ययन में मूल्यांकन किए गए संभावित उपाय सुझाये गए हैं। ये जल प्रबंधन तकनीकें, RBFS और LGLS मानदंडों की गुणवत्ता को प्रभावित किए बिना सिंचाई में 50% बचत के साथ प्रभावी पायी जाते हैं।

.

Abstract

Climate change is a global problem. In India about 700 million rural people directly depend on climate sensitive sectors (agriculture, forests and fisheries) and natural resources (water, soil and grasslands) for their subsistence and livelihood. Under changing climate, food security of the country might come under threat. Besides, the adaptive capacity of dryland farmers, forest and coastal communities is low. Climate change is expected to impact all the natural ecosystems. Increase in weather extremes and variability in rainfall in future shall affect agricultural productivity and lead to decline in yield across various agroclimatic zones. Climate change impacts on water resources indicate an escalation of the hydrological cycle affecting both surface and ground water.

Attempt has been made to assess the future climate change impact on hydrological components of the Sind River Basin (SRB), central India using the A1B scenarios of the PRECIS model and also to evaluate the consequences of climate change on fodder production in the basin. SWAT hydrological modeling and MODFLOW groundwater modeling has been used to assess the overall water resources (Surface and Ground water). The high values of statistical performance indicators i.e., Coefficient of correlation and NSE in the calibration and validation periods imply that the calibrated hydrological model of SRB is able to describe stream flow of the basin. Further the calibrated SWAT model was used to evaluate the potential impacts of climate change on hydrological regimes of the SRB. SWAT model generated outputs like recharge, seepage rate, evapotranspiration, river stage, flow rate and hydraulic conductivity values were used in groundwater modeling of the Sind river basin to understand groundwater system and surface, groundwater interaction. Water table contour heads in Sind river basin indicates that groundwater is obtainable at shallow depths in the northeast part of the basin and

gradually increasing towards southwest region and almost vanishing near hilly areas. MODFLOW run results for pre monsoon (Jan-May) and monsoon (Jun-Sep) seasons indicated a rise in water table in the observation wells, but over all there is a gradual decline in the groundwater level in some of the observation wells particularly in midland and hilly areas of the basin.

The water yield in SRB is projected to increase by 12% in Mid Century (2021-2050) and 13% in End Century (2071- 2098) when compared to Baseline period (1961-1990). Overall simulation results show that water yield across the Sind River Basin changes from baseline to midcentury with an increase ranging from 19.46 - 59.44% mainly over central and southern parts of sub watersheds. The rise in ET is by 6% during End century period in southern parts of the SRB may be because of anthropogenic changes, which enhanced the demand in ET with respect to increase in crop production.

The PRECIS; RCM predictions with IPCC SRES AIB scenarios under estimated the precipitation for the study area during baseline period (1960-1999) when compared with the observed historical data. The rise in precipitation in end century indicates that more extreme events may occur in due course, which shall lead to floods. The decrease in precipitation in the month of June (midcentury) could be result of delay in onset of monsoon in consequence of climate change. This delay in onset of monsoon shall lead to disturbance in crop sowing window, which may lead to susceptibility to pest and diseases. The rise in temperature up to 5⁰C during the month of October may increase the stress conditions and reduce the crop yields as this period lies in crop critical stages such as grain setting stage and crop harvesting in *kharif* crop season. This rise in temp needs to be addressed to overcome its consequences on agriculture and water yield.

The biomass production of fodder in the SRB is expected to decrease by 39.26% in end century and 26.14% in midcentury when compared to baseline period (1960-1999). Fodder yield shall decrease by 18% in mid century and 22.14% in end century compared to baseline period (1960-1990) due to impact of climate change. The possible adaptation measures evaluated in this study to overcome the climate change adverse impacts on fodder production are Raised bed and furrow system (RBFS), and Laser guided land leveled system (LGLS). These water management techniques, RBFS and LGLS are found effective with 50% saving in irrigation without affecting the quality of parameters.

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List of Acronyms and Abbreviations

Symbol	Definition
ACU	Adult Cattle Unit
AUM	Animal Unit Month
AGCM	Atmospheric General Circulation Model
AGNPS	Agricultural Non Pollution Sources
AOGCM	Coupled Atmosphere Ocean General Circulation
ASCE	American Society of Civil Engineers
BMP	Bio Mass Production
BMPs	Best Management Practices
BSB	Black Sea Basin
CCDC	Critical Continuous Day Calculator
CGCM	Canadian Global Coupled Model
CGWB	Central Ground Water Board
CN	Curve Number
CPE	Cumulative Pan evaporation
CREAMS	Chemicals, Runoff and Erosion from Agricultural Management Systems
CWC	Central Water Commission
DEM	Digital Elevation Model
DFY	Dry Fodder Yield
EPIC	Environmental Policy Integrated Climate
FAR	Fourth Assessment Report

GCMS	General Circulation Models
GDP	Gross Domestic Product
GFDL	Geophysical Fluid Dynamic Laboratory Model
GFY	Green Fodder Yield
GHGES	Green House Gas Emission Scenarios
GHGs	Green House Gases
GIS	Geographic Information System
GISS	Goddard Institute for Space Studies
GOI	Government of India
HadCM3	Hadley Centre Coupled Model (Version 3)
HRU	Hydrological Response Unit
ICAR	Indian Council of Agricultural Research
IGFRI	Indian Grassland and Fodder Research Institute
IITM	Indian Institute of Tropical Meteorology
IPCC	Intergovernmental Panel on Climate Change
ISRO	Indian Space Research Organization
IW	Irrigation Water
KRB	Karkheh River Basin
LU/LC	Land Use/Land Cover
mbgl	meter below ground level
MCM	Million Cubic Meters
mha	Million hectares
MOEF	Ministry of Environment and Forest

MoWR	Ministry of Water Resources
NATCOM	National Communication
NBSSLUP	National Bureau of Soil survey and land Use Planning
NSE	Nash-Sutcliffe Efficiency
PBIAS	Percent Bias
PEST	Parameter Estimation
PET	Potential Evapotranspiration
PRECIS	Providing Regional Climates for Impacts Studies
RCM	Regional Climatic Models
REA	Representative Elementary Area
SCS	Soil Conservation Service
SGWD	State Ground Water Department
SRB	Sind River Basin
SRES	Special Report on Emission Scenarios
SRTM	Shuttle Radar Topography Mission
SUFI-2	Sequential Uncertainty Fitting (SUFI-2) algorithm
SWAT	Soil and Water Assessment Tool
SWAT-CUP	Soil and Water Assessment Tool - Calibration Uncertainty Programme
UKMO	United kingdom Meteorological Office Model
USDA	United State Department of Agriculture
VFS	Vegetative Filter Strips
WEPP	Water Erosion Prediction Project