GIS BASED FRAMEWORK FOR INTEGRATED WATERSHED MANAGEMENT WITH LIVELIHOOD LINKAGES

by

PRADEEP KUMAR P. LODHA

Department of Civil Engineering

Submitted

in fulfillment of the requirements of the degree of

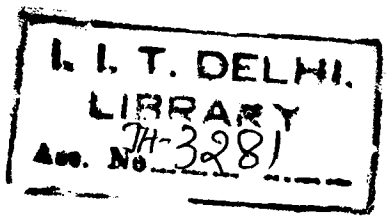
Doctor of Philosophy

to the

Indian Institute of Technology Delhi

Hauz Khas, New Delhi - 110016

January 2006



To my parents,
to Gourav and Garima,
and mostly to my wife Parimita
Pradeep Lodha

CERTIFICATE

This is to certify that the thesis entitled **"GIS based Framework for Integrated Watershed Management with Livelihood Linkages"** being submitted by **Mr. Pradeep kumar P. Lodha** to the ***Indian Institute of Technology Delhi*** for the award of the degree of ***Doctor of Philosophy*** *is* a bonafide record of research work carried out by him under my guidance and supervision. The thesis work in my opinion, has reached the requisite standard, fulfilling the requirements for the said degree. The results contained in this thesis have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.

Prof. A.K. Gosain
Thesis supervisor
Department of Civil Engineering
Indian Institute of Technology Delhi
Hauz Khas, New Delhi- 110016

Acknowledgements

I feel immense pleasure in expressing my profound sense of gratitude to my supervisor, Prof. A. K. Gosain, Department of Civil Engineering, Indian Institute of Technology Delhi for his consistent guidance and constructive criticism during the course of the present investigation, preparation of the manuscript and utmost cooperation at every stage, which culminated in successful completion of my research work.

I wish to extend my sincere thanks to all faculty members of the Water Resources Group, Department of Civil Engineering, Indian Institute of Technology Delhi for their support and encouragement. I also thank Dr. Sandhya Rao of INRM Consultants, New Delhi for her valuable help and guidance through out the study. I thank my friend Acharaz Bhandari and all other staff members of GIS laboratory for their kind help during the present study.

I am thankful to Directorate of Technical Education, Government of Gujarat and All India Council for Technical Education, Government of India for sponsoring me for higher studies at Indian Institute of Technology Delhi. I am also thankful to Prof. J. R. Patel, Prof. M. N. Patel, Prof. K. G. Pandya, and Prof. K. M. Shah, all from my parent institute L. D. College of Engineering, Ahmedabad, Gujarat for their support during the course of study.

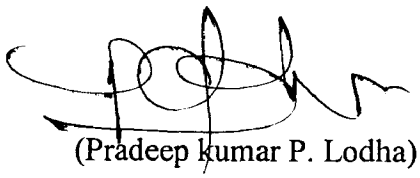
My special thanks are due for Prof. D. J. Bhatt, who has been the source of inspiration and encouragement for my research activities at my parent institute. The

cooperation received from Mr. U. R. Khare, Mr. R. K. Jain and Mr. G. P. Vadodaria is gratefully acknowledged.

I wish to thank Prof. Ian R. Calder of New Castle upon Tyne University, UK and Prof. Tim J. Ward of Mexico University for their valuable suggestions. I am also thankful to Dr. R. N. Yadava, Director, Regional Research Laboratory, Bhopal for providing socio-economic and demographic data of the study area. Help rendered by Dr. R. Ram, Scientist, Regional Research Laboratory, Bhopal in conducting primary survey in the study area and understanding the various maps and reports related to the study area is highly appreciated. I also wish to express my gratefulness to Dr. T. C. Jain, World Bank Consultant for his kind suggestions and material related to watershed projects in India.

I acknowledge all the help I received in getting the data for the watersheds which are pilot areas selected under the ongoing project at Indian Institute of Technology Delhi on "Low Base Flows and Livelihoods in India" (R8171), funded by Forestry Research Programme of Department for International Development (DFID), United Kingdom.

This acknowledgement shall remain incomplete unless I thank my fellow research scholars Mr. Amardeep Singh, Mr. Sumedha Chakma, Mr. Brijesh Yadav, Mr. D. L. Parmar, Mr. R. K. Prasad, Mr. Ravi Kumar, and Mr. Debajit Sathapati for their help and encouragement during this study. The help provided by Mr. Bikram Chand and Mr. Rajveer Agrawal, administrative staff of Civil Engineering Department, I. I. T. Delhi is gratefully acknowledged.



New Delhi, January 2006 (Pradeep kumar P. Lodha)

Abstract

Watershed projects have not only meandered through the degraded landscapes in the country during the past three decades but have grown from being mere technical interventions for restoring degraded lands and vegetations to more specific poverty alleviation initiatives and enhancing livelihood options of the local community. Concerns related to the equity and bringing the stressed households into mainstream are being addressed through watershed programs. In its third phase where amalgamation of the 'top-down' & 'bottom-up' approaches for watershed management has taken place, the rural development programs are also being formulated and launched through watershed programs. In absence of an integrated monitoring and evaluation framework for the health of watershed and its community, measuring levels of success or failure of such watershed programs is not feasible. The existing qualitative techniques for the evaluation of watershed program do not address the objectives of the watershed program properly.

The study presents a watershed based sustainable livelihoods framework which analyses the livelihoods of watershed community, evaluates watershed interventions and establishes linkages between livelihoods and hydrological components. A methodology is proposed for quantification of the socio-economic aspects, which is found effective in measuring the impacts of watershed program on local community. The SWAT hydrological model with ArcView GIS interface has been used to simulate various watershed interventions for water and sediment yields. Statistical analysis like factor and regression modelling is used to establish linkage between livelihoods and hydrological components. The Geographic Information System has played an important role in database creation, data processing and

analysis. The methodology is employed on three watersheds namely Dudhi micro-watershed, Bewas micro-watershed and Dudhi milli-watershed which fall in Raisen district of Madhya Pradesh State in India.

The SWAT model predicts decrease in surface runoff and sediment loading whereas increase in shallow and deep aquifer recharge due to increase in forest cover. Ponds are effective measures in augmenting ground water and reducing soil erosion process. Checkdams serves as water harvesting and recharge structure. Heavy losses in surface runoff may deteriorate the water availability to down stream area stressing water demands especially during the water stressed months.

The proposed methodology was used for livelihood analysis. The treated watershed Dudhi shows a consistent improvement in all developmental indices while the untreated watershed Bewas shows a haphazard development scenario. The values of the standard deviation for various indicators of Dudhi watershed decrease which represents success of the watershed program in providing equitable and sustainable livelihoods to watershed community whereas the values of the standard deviation for various indicators of untreated Bewas watershed increase which represents skewed development of the watershed community.

The potential linkages between the impacts of watershed management on socio-economic development and hydrological components have been established by using factor and regression modelling. The developed regression model for Dudhi treated micro-watershed predicts moderate development in the area. The annual growth rate is about 1.2%, which is lower than the average national rural growth rate. Thus there is a need to mobilise the resources in more effective manner at local level for the sustainability of watershed programs.

Contents