INTRODUCTION
CHAPTER I
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1.1 INTRODUCTION

Watershed is a geographically dynamic unit area that contributes runoff to a common point, has been accepted as a basic unit for planning and implementation of the protective, curative and ameliorative programmes. Its behavior varies both spatially and temporally. The intensive study of individual watersheds is necessary for developing management plan and also for transforming the results of one watershed to another with similar characteristics. Watershed management implies, the judicious use of all the resources i.e. land, vegetations and water of the watershed to achieve maximum production with minimum hazard to the natural resources and for the well being of people. The management should be carried out on the watershed basis. The task of watershed management includes the treatment of land by using most suitable biological and engineering measures in such a manner that, the management work must be economical and socially acceptable.

An accurate understanding of the hydrological behavior of a watershed is important for effective management. Watershed management, in its broader sense, can be considered to be an attempt to reduce soil, water and nutrients losses from nonpoint sources (NPS) within the watershed and to ensure sustainable agricultural production. The nonpoint sources pollutants are the problem of global importance. Agriculture is the single greatest contributor of nonpoint sources pollutants to soil and water resources. Sustainable agriculture requires a delicate balance between crop production, natural resource utilization, environmental impacts and economics. Adopting sustainable agricultural management practices can reduce the nonpoint sources losses from agricultural watersheds.
Many hydrologic and water quality models are in use at present, to evaluate the complex hydrological and environmental processes because the hydrologic and water quality investigations are the basic requirement to any watershed management programme. Surface hydrologic modeling of watershed mainly includes processes like runoff and sediment as well as pollutants from the watershed. The need for accurate measurement of parameters involved in hydrological and environmental processes has grown rapidly due to the acceleration in the watershed management programmes for conservation, development and assessment of nonpoint source pollution pertaining to soil and water resources.

Numerous models such as ANSWERS (Beasley and Huggins, 1982), CREAMS (Knisel, 1980), EPIC (Williams et al., 1985), SHE (Abbott et al., 1986a), AGNPS (Young et al., 1987), SWARB (Williams et al., 1985), and SWAT (Arnold et al., 1996) have been developed to predict runoff, erosion, sediment and nutrient transport to agricultural watersheds under various management regimes. Among these several physically based models, the Soil and Water Assessment Tool (SWAT) is one of the most recent model used successfully for simulating runoff, sediment yield and water quality of small watershed. SWAT is a distributed parameter continuous time model developed by the USDA-ARS (Arnold et al., 1996, 98). SWAT can be applied to a large ungauged rural watershed with hundreds of small sub-watersheds. It is comparatively simple, user friendly and physically based distributed parameter model, which use readily available inputs. It is computationally efficient to operate on large basins in a reasonable time. It is a continuous time scale model, capable of simulating long-term effects of management change. Major components of the model include surface hydrology, weather, sedimentation, soil temperature, crop growth, nutrients, pesticides, ground water and lateral flow.

Several applications of SWAT in various parts of the United States have shown promising results (Srinivasan et al., 1993; Srinivasan and Arnold, 1994; Rosenthal et al.,
In these studies, the model was tested mainly on monthly and annual basis for predicting runoff. However, the model has not been tested widely for prediction of sediment yield. Also, very little work on assessment of the impact of management practices on runoff, sediment yield and nutrient losses has been reported.

The runoff and sediment loss varies from storm to storm and represents the overall hydrologic response of land surface to the given rainfall data. Estimation of runoff and sediment yield especially from an ungauged watershed is one of the major activities in the applied hydrology because in India most of the watersheds are ungauged. An accurate simulation of runoff process is thus useful in assessing the watershed's impact on the environment and the knowledge of sediment yield from a watershed is quite essential, as it is often required to determine the quantity of sediment delivered to a downstream reservoir. Thus, it implies that the basic requirement for any watershed hydrology model is its capability to estimate the surface runoff adequately because it influences the transport of sediments and agro-chemicals.

Remote Sensing Technology (RST) is suitable to study the most recent pattern of land use/land cover. Geographic Information System (GIS) is a computer-based tool that analyses and manages spatial data. The tediousness and time-consuming nature of extraction of watershed parameters can be eliminated by means of RST and GIS in addition to obtaining high accuracy. The Digital Elevation Models (DEMs) can be used successfully to extract several watershed parameters. These techniques can provide more precise and reproducible measurements than the traditional manual techniques applied to topographic maps. The compilation and input of hydrologic data that are required by the SWAT model are often cumbersome. So that the input data for the SWAT model can be extracted with the use of GIS mainly from the map layers including land use/land cover, DEM, soil, slope, drainage and watershed and sub-watershed boundaries.
Estimation of runoff and sediment yield is necessary for the design of soil conservation structures and for identifying the critical areas of a watershed for implementation of management programmes. Numerous studies indicated that for many watersheds, a few critical areas are responsible for disproportionate amount of soil loss. Effective control of soil and nutrient losses requires implementation of best management practices in critical erosion prone areas of the watershed. It can be enhanced by the use of physically based distributed parameter models, Remote Sensing Technology (RST) and Geographic Information System (GIS) that can assist management agencies in both identifying most vulnerable erosion prone areas and selecting appropriate management practices.

Most of the time the land use pattern and tillage practice changes in agricultural watersheds. Inappropriate cultivation practices accelerate erosion rates and thereby increase the nutrient losses to the streams. Tillage practice plays an important role in agricultural watersheds because tillage influences the infiltration rate, obstruction to surface flow and consequently the rate of soil erosion. Nutrients, that exit the field through runoff or attached to eroded sediment, can be controlled effectively by adapting the improved tillage practices.

Several simulation models are in use to assess the various problems related to watersheds. Adequate procedure to calibrate and validate these models is an important research issue. A Model should be adequately tested before using it for effective watershed management.

1.2 OBJECTIVES OF THE PRESENT STUDY

Chhattisgarh, the newly created state is one among the Indian states have started many watershed development and management projects to tackle soil and water conservation problems in an integrated manner. The Department of Soil and Water Engineering, Faculty of Agricultural Engineering, Indira Gandhi Krishi
Vishwavidyalaya, Raipur is one of the very few organization in the state, which now has established network of stream gauging stations and sediment observation posts for monitoring hydrological parameters on small watershed basis. Since the time series data on rainfall, runoff and sediment yield are available through an established gauging station, therefore it become possible to analyze the cause-effect relationship between the various factors that affect the hydrologic response of a watershed. Information obtained from such analysis can be used to identify critical erosion prone areas and to develop appropriate management plans for soil conservation and water resources development to increase the productivity of the region on sustainable basis.

Keeping the above facts in mind, the present study has been undertaken with the use of a distributed parameter model (SWAT 97.2) and a GIS to estimate the surface runoff, sediment yield and nutrient losses from the small watersheds namely Chhokranala and Arang watersheds in the Chhattisgarh State and to develop the best management plan for the critical erosion prone areas. The specific objectives of the study are narrated in the paragraph to follow:

1. To calibrate and validate the physically based hydrological and water quality simulation model “SWAT” for the selected small watersheds.
2. To test the capability of weather generator module of SWAT model for simulating the monthly rainfall and thereafter runoff and sediment yield.
3. To estimate surface runoff, sediment and nutrient losses from the selected small watersheds using SWAT model, Satellite data and GIS.
4. To identify the critical areas of selected watersheds on the basis of estimated runoff, sediment yield and nutrient losses.
5. To develop and recommend the best management practices for the critical areas of the watersheds under study.
1.3 METHODOLOGY

Two watersheds of different locations i.e. Chhokranala and Arang watersheds are gauged watershed and falls under small watershed category are chosen for the study. The topography of the Chhokranala watershed is almost flat and the slope ranges from 1% to 2%. The weighted average slope of the Chhokranala watershed is 1.6% and the predominant soil is sandy clay loam. For Arang watershed, the average slope is 1.5% and the predominant soil of watershed is loam associated with clayey soils. Different types of data like, meteorological data, hydrological data, topographic and soil data, satellite data are collected for the study. The software available such as Arc GIS and Geometica are used for terrain analysis and image processing, respectively. Extracted data are processed in Excel package of Microsoft Office and all the input data files are generated in DOS using UTIL programme, which is built-up with the SWAT model. After that delineation of watershed and sub-watershed boundaries is using DEM (Digital Elevation Model) and generation of various maps (soil texture, drainage and slope) using Geometica. For extracting some of the model inputs such as area, slope, channel length and several others are collected by different types of methodologies. After that the procedure adopted for preparation of land use/land cover using satellite imageries and then the SWAT model calibration, validation, and sensitivity analysis for prediction of runoff, sediment yield and nutrient losses at the outlet of the Chhokranala and Arang watersheds is done and various criteria used for evaluating the model performance. Then the weather generator of SWAT model is used for generating the rainfall. The observed and simulated rainfall, runoff and sediment yields have been compared on daily as well as monthly basis for evaluating the performance of the weather generator. After that critical sub-watersheds are identified on the basis of average annual sediment yield and nutrient losses. The calibrated and validated model is then used for developing the management plan for critical prone areas of Chhokranala and Arang watersheds.
1.4 SCOPE OF THE PRESENT STUDY

The scope of the present study is to develop the effective management plan for erosion prone areas of small agricultural watersheds for sustainable development. Following points described the importance of hydrological modelling for effective management using SWAT model.

1) SWAT is a newly developed model, which can be applied to a large ungauged rural watershed with more than 100 numbers of small sub-watersheds.

2) The SWAT model is a physically based continuous model capable of simulating surface runoff, sediment yield and nutrient losses from small, medium and large watersheds.

3) The SWAT model estimates the runoff and sediment yield for small agricultural watersheds on daily as well as monthly basis.

4) SWAT model also assess the seasonal and long-term effect of agricultural activities on runoff, sediment yield and nutrient losses.

5) The model estimates the nutrient losses, crop yield and the effect of soil and water conservation measures more effectively as compare to other models.

6) The SWAT model simulates the average yield of various crops including rice satisfactorily.

7) The SWAT model assesses the selection of crops, tillage operations, fertilizer and irrigation scheduling to minimize surface runoff, sediment yield and nutrient losses and to maximize the crop productivity in sustainable manner.

8) Develop the best management plan for critical erosion prone areas of small agricultural watersheds with the application of SWAT model.
1.5 ORGANIZATION OF THE REPORT

The thesis has been organized as follows:

(a) Chapter I of the thesis is Introduction, which includes the importance of the study. Justification for developing management plan for effective management of small watersheds and specific objective of the study. Introduction of the study clearly indicating why this study has been done and how the problems can be solved for sustainable development of agricultural watersheds.

(b) A detailed review of the literature on various types of models and their classifications, comparative studies of these models, use of image processing and GIS software in watershed hydrology, coupling of models with GIS and application of SWAT model for effective watershed management is presented in Chapter II.

(c) An overview and brief description of the model operation, features and its limitations along with the description of input files used for evaluating the SWAT model. Description of the study area, data acquisition and theoretical consideration relating to SWAT model discussed in Chapter III.

(d) Application of SWAT model and procedures used for identification of critical sub-watersheds of study watershed are presented in Chapter IV. This chapter includes procedures used for calibration and validation of the model and various criteria used for evaluating the model performance.

(e) The results related to SWAT model calibration, validation, sensitivity analysis and the best management practices for the identified critical sub-watersheds have been presented in the Chapter V.

(f) Chapter VI contains the conclusions and recommendations of the study.

(g) Chapter VII contains the suggestions for the future research.