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ASSESSMENT OF NON-POINT SOURCE POLLUTION ON WATERSHED BASIS USING REMOTE SENSING, GIS AND AGNPS MODEL

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ABSTRACT: The Non point Source (NPS) pollutants (eg. Sediment, fertilizers, pesticides, salts, and trace elements) are contaminants of surface and subsurface soil and water resources that are diffuse in nature and cannot be traced to a point location. Agriculture has been identified as the largest contributor of non-point source pollution of surface and ground water systems. Because of diffused sources and vastness of the problem, it is generally estimated by simulation approach using the distributed models. A major limitation in the use of Hydrology and water Quality (H/WQ) models has been their inability to handle the large amounts of input data that describe the heterogeneities of the natural system. A recent and emerging technology represented by geographic information systems (GIS) provide the tools to generate, manipulate, and spatially organize disparate for distributed modelling. The knowledge and information required to address the problem of assessing the impact of NPS pollutants on the environment crosses several sub-discipline lines like remote sensing, GIS ,hydrology, and soil science. The present study demonstrated the application of remote sensing, GIS and distributed parameter model (AGNPS) for assessment of hazardous non-point source pollution in a watershed. The ARC-INFO GIS and Remote sensing provided the input data to support modelling, while the AGNPS model was used to predict several water quality variables within a watershed on cell basis. Thus, flow, soil erosion, and chemical movement at any point in the watershed can be examined. Upland sources contributing to a potential problem are identified and subsequently locations are prioritised for remedial action to improve water quality most effectively. Runoff is predicted using the soil conservation service (SCS) runoff curve method. Sediment yields are predicted using a modified version of the universal soil loss equation (USLE). Nutrient movement components have been adapted from the CREAMS model. The framework was used to evaluate the effectiveness of several alternative management strategies in reducing sediment pollution in the study area. The variation in the cell wise distribution of runoff and sediment yield for different rainfall events was within 20 to 30 percent and 14 to 40% respectively. The simulation technique was also used for reasonably predicting the loading of total pollutants in terms of fertilizer nitrogen and phosphorus.

KEY WORDS*:* Sediment Load, Non point source Pollution, AGNPS model, GIS, Remote Sensing

1.0 INTRODUCTION

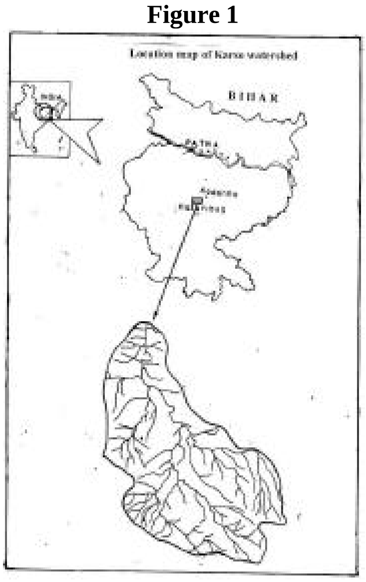
Point source pollutants or rather pollutants that are associated with a point location such as a toxic waste spill site have received the greatest attention in the past because of the obvious severity of their impact at a localized point. Even though point-source pollution is generally highly toxic, it is relatively easily controlled and identifiable. However, over recent years concern has shifted more to pollutants that are low in concentration, but ubiquitous in nature and referred to as non-point source (NPS) pollutants. The NPS pollutants (eg. Sediment, fertilizers, pesticides, salts, and trace elements) are contaminants of surface and subsurface soil and water resources that are diffuse in nature and cannot be traced to a point location. Agriculture has been identified as the largest contributor of non-point source pollution of surface and ground water systems. Siltation of stream beds due to accelerated soil erosion, nutrients (primarily nitrogen and phosphorous) and pesticides in agricultural runoff, and pathogens from feedlots, urban runoff , and sewage were the major causes cited for surface water quality impairments.. During the past several decades, several of researchers attempted to address the problem of non-point source pollution by establishing the relationships between land management practices and environmental and water quality degradation. In recent years, computer modelling has gained wide spread acceptance as a cost-effective tool for developing agricultural management practices that protect water quality. Numerous lumped and distributed parameter H/WQ models, including CREAMS,(knisel,1980),ANSWERS (Beasley and Huggins,1982),AGNPS (Young *et al*.,1989) and., SWRRB-WQ (Arnold *et al*.,1990), have been developed to predict the impacts of agriculture on the quality of surface water.

In general most macro level environmental planning tasks ideally require geographically referenced information. Map information from standard sources is, however, updated only at set intervals, which makes the use of GIS somewhat limited in monitoring environmental phenomena, particularly in areas that are undergoing rapid dynamic change. Satellite remote sensing, on the other hand, is an excellent tool for environmental monitoring, as it allows repeated coverage of areas on a regular basis. Interfacing remote sensing derived digital thematic maps with geographic information systems thus provides a powerful mechanism not only to monitor environmental changes but also to permit the analysis of information derived from remote sensing in conjunction with a number of other environmental variables or thematic layers in the geographic database. Satellite imagery has been widely used in the hydrologic modelling etc. (Ragan and Jackson,1980: Tiwari *et al* ., 1991)..Thus the present study was taken up for quantitative assessment of the non point source pollution within the watershed with the following objectives : (i) to explore capabilities of Remote sensing, ARC-INFO GIS and AGNPS model for estimation of t of runoff and sediment loads on cell basis (ii) to obtain reasonably accurate predictions of Nitrogen and Phosphorus loads in the sediment, and (iii) to compare the impact of alternative land management strategies on surface water quality

2.0 DESCRIPTION OF STUDY AREA

The study area is located in the Damodar river valley in the Hararibagh district of Bihar state, India. The location map of watershed is given as Figure 1. The watershed is approximately 2700 hectares in size. The topography of the watershed consists of uplands and forestland. The predominant soil of the watershed is loamy sand soil. The average annual rainfall of the study area is 1200mm. Of the total annual rainfall, 75% usually falls during monsoon months from June to October. The dominant crop in the study area is paddy.

Figure 1



3.0 DESCRIPTION OF AGNPS MODEL

The AGNPS model was used to analyse Non-point source pollution in the study area. The model is event based. The model uses a distributed parameter approach to quantify a watershed by dividing the area into uniform square cells, allowing analysis at any point within the watershed. The model simulates runoff, sediment, and nutrient transformations from agricultural watersheds. The nutrients considered include nitrogen (N) and phosphorous (P), both essential plant nutrients and major contributors to surface water pollution. Basic model components include hydrology, sediment and chemical transport. Runoff , sediment and nutrient transport processes are simulated for each cell and routed to the outlet. Thus, flow, erosion, and chemical movement at any point in the watershed can be examined. Upland sources contributing to a potential problem can be identified and locations can be prioritized for remedial action to improve water quality most effectively. Runoff was predicted using the soil conservation service (SCS) runoff curve method. Sediment yields were predicted using a modified version of the universal soil loss equation(USLE)(Wischmeier, 1978). Nutrient movement components have been adapted from the CREAMS model . A comprehensive description of the AGNPS model can be found in Young *et al*.(1989).

3.1 Development of model database

The GIS database created for the Karso watershed focused on attributes and data necessary to run the AGNPS model. The major elements of the watershed database include topography, hydrography, soil, land cover, land management, and climate. The 400 by 400m resolution was chosen to facilitate the subdivision of watershed into grid cells, which are basic operational units for AGNPS model. All encoded digital data, coverages, and model variables in the GIS were spatially organized with the same resolution and co-ordinate system. The AGNPS model requires specification of 21 different parameters for each grid cell within the watershed boundary. Many of the parameters were collected either local planning offices or from tables provided in the user's manual. Activities undertaken to acquire data and establish the watershed GIS to assist in AGPNS modelling are described below.

3.1.1 Topography: The topography affects the runoff characteristics and transport processes of sediment and nutrients, which are to be simulated for each cell. AGNPS model has taken care of topography, by considering aspect and slope in percentage for each cell. Land slope coverage, aspect coverage and curvature (slope shape factor) coverage of the study area are generated using ARC-INFO GRID module.

3.1.2 Soils: The soil coverage collected from the soil conservation department was digitized. USLE, K factor and hydrologic soil group are AGNPS parameters which are associated with GIS polygons of the soil coverage. The hydrologic soil group was necessary for calculating SCS runoff curve number . Reclassification of soil coverage with values for these parameters resulted in input parameter layers for the AGNPS model.

3.1.3 Land Use: Several of the AGNPS model inputs such as SCS curve number, Manning's roughness coefficient, USLE cover (C) factor, USLE support practice (P) factor, surface condition constant, fertilization level, and fertilization availability factor were derived from the grided land cover and land management data. Remote sensing data of IRS IC-LISS III of October 1996 was used for digital classification of land and water resources of the study area. Digital interpretation of the satellite imagery was carried out at the RRSSC, Kharagpur using ERDAS-IMAGINE digital image processing software.

4.0 RESULTS AND DISCUSSION:

4.1 Estimation of Runoff

In the present study, attempt was made to compute runoff, sediment and non point source pollution loading on a spatially distributed basis, using the capability of AGNPS model, GIS and Remote sensing. The simulations were carried out to evaluate watershed response to storm of different sizes for different years 1994,1995 and 1996. The volume of runoff for different rainfall events was computed for each cell using the GIS modelled SCS curve number technique. Composite curve number was generated cell wise for land use delineation definable from IRS – 1C data of 1996 and presented in Figure 2.. For the other years of study, composite curve number was derived from locally available maps. The observed and simulated runoff values were plotted and their distribution along with 1:1 line presented in Figure 3. It was observed that simulated values are distributed about 1:1 line for the observed runoff. It was also observed that the deviation between measured and simulated runoff values for the year 1994 and 1995 varies between 17.6% to 29%. But, for the year 1996, the variation between measured and simulated runoff varied between 9% to 15%. It was seen from the results that model simulations were improved during 1996 as composite curve number was generated using the land use/cover data obtained from satellite image.

4.2 Estimation of Sediment Load

Similarly, sediment estimates were made for different rainfall events of 1994,1995 and 1996. Data sets, which are used for runoff estimation, were adopted here. The cell wise distribution of sediment loads for a particular rainfall event was shown as Figure 4. The observed and simulated sediment values were plotted and their distribution along with 1:1 line presented in Figure 5. It was observed that the deviation between measured and simulated sediment values for the years 1994 and 1995 varied between 24% to 40%. But, for the year 1996, the variation between measured and simulated sediment yield varied between 14 to 22%. Since, The sediment yield depends on surface runoff and peak flow rate, improvements in the runoff predictions for the year 1996, might have led to improvement in the sediment predictions for the year 1996. It was also observed that for all rainfall events, sediment yield was under predicted from 14% to 40%. This may be because the AGNPS model uses many empirical and quasi-physically based algorithms. As the measured values are available for runoff and sediment yield and not for nutrient (pollutant) concentrations, only the runoff and sediment yield were validated. The sensitivity analysis reported by Young et al.,1989 showed that the parameters that most influenced sediment yield were slope, soil, erodability K factor, the runoff curve numbers derived from cover type and hydrologic group. Hence, in the present study, much of the spatial variability in these parameters has been taken care by deriving them either by remote sensing and GIS.

4.3 Estimation of Nitrogen and Phosphorus Load in the Sediment

Further analysis was carried out for estimation of concentration of non-point source pollutants such as Nitrogen and Phosphorous for the study area. The nitrogen loading in sediment yield for different cells of Karso watershed ranges between 0 to 27.0 kg/ha.. The concentration of nitrogen in runoff for different cells ranges between 0 ppm to

2.26 ppm which is realistic with respect to the application rate of fertiliser N. The phosphorus (P) loading in sediment yield in different cells of Karso watershed ranges between 0 kg/ha and 14 kg /ha. The cell wise distribution of N and P loads (kg/ha) in the sediment and concentrations in the runoff for one rainfall event were presented through Figures 6 to 9 . The concentration of Phosphorous in runoff for different cells ranges between 0 ppm and 1.3 ppm . Similar trend of cell distribution of N and P is also obtained for other rainfall events.

4.4 Management Approach:

In the present study, efforts were made to evaluate the effectiveness of different management strategies in reducing sediment loads from the watershed. The simulated sediment loads under three presumed scenarios (Structural controls, Land management practices, Structural + Land Management Practices) were presented in the Figure 10. It was observed that the adoption of land management practices were effective as compared to structural controls. Indeed, the strategies considered in this study were to ascertain whether sediment loads change as a consequence of alternative land management strategies and whether such changes can be evaluated using a GIS based modelling system.

5.0 SUMMARY AND CONCLUSIONS:

The present study described a framework for evaluating non-point sources of pollution at the watershed scale developed on the basis of AGNPS model , ARC-INFO GIS and Remote Sensing. The framework provides an efficient tool to create AGNPS input data from remote sensing and GIS and for manipulating large amounts of disparate data from different sources. Further, the framework was effectively used to prioritize watersheds for the potential severity of water quality problems, to pinpoint critical areas within a watershed contributing to pollution, and to evaluate the effects of alternative management practices. The GIS representation of model input and output also facilitates examination of a wider range of alternatives than would be possible by using standard methods.

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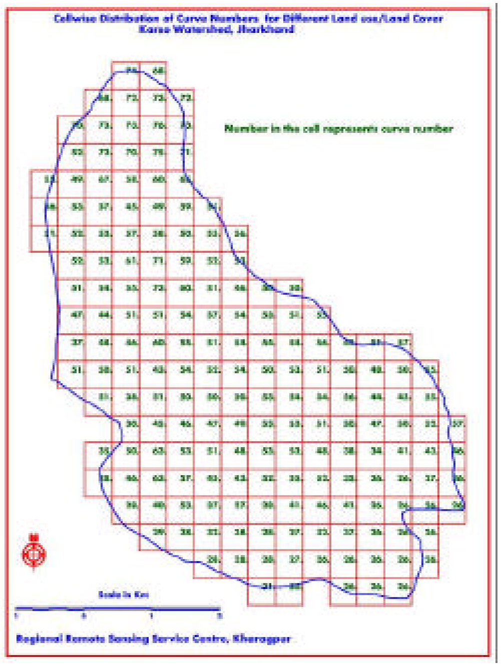


Figure 2

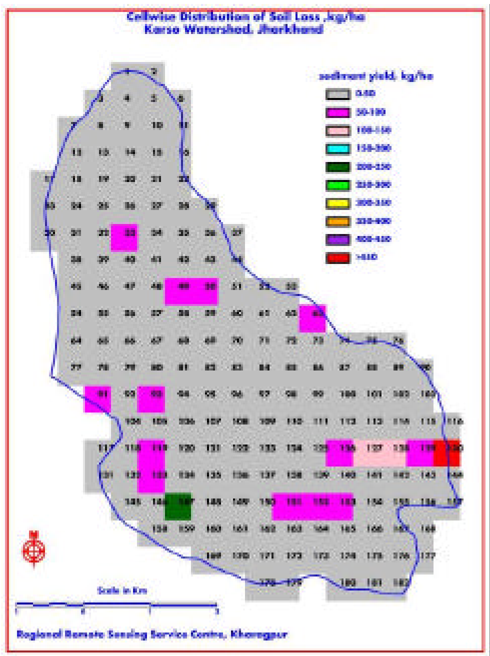


Figure 4

Scatter diagram of Observed and Simulated Runoff for Karso watershed

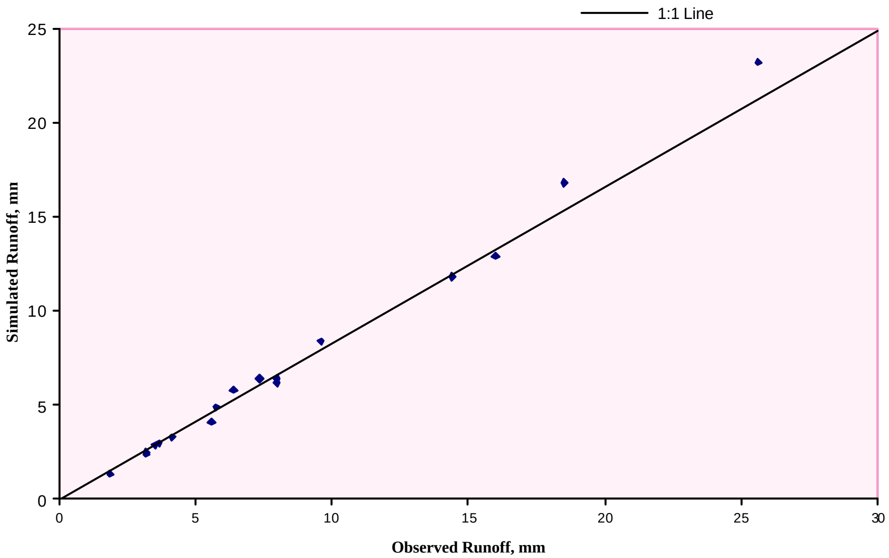


Figure 3

Scatter diagram of Measured Sediment and Simulated Sediment for Karso watershed

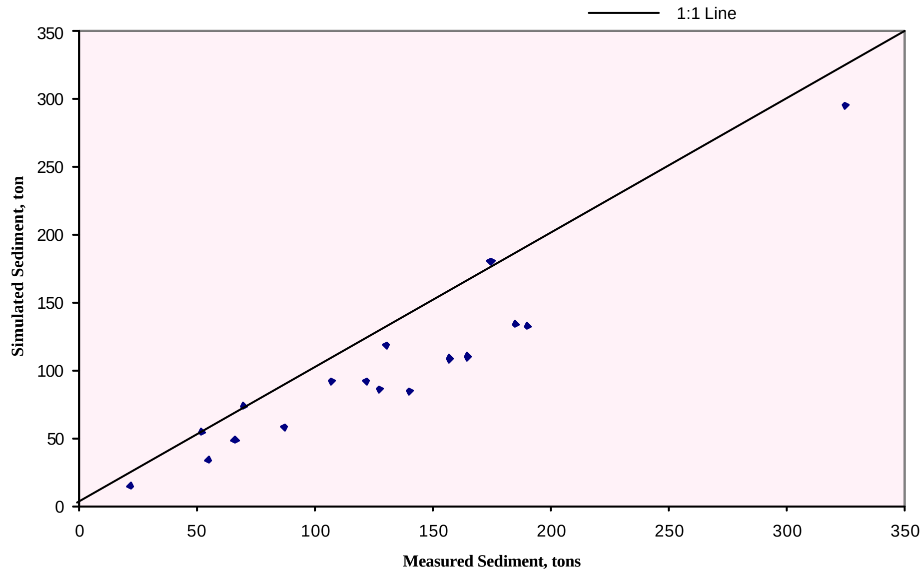


Figure 5

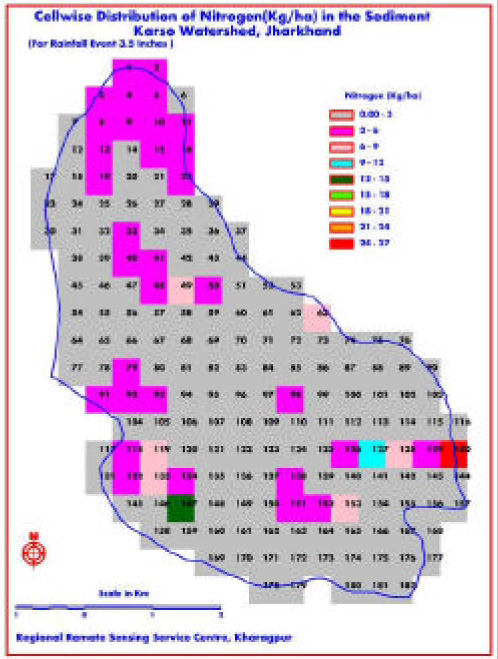


Figure 6

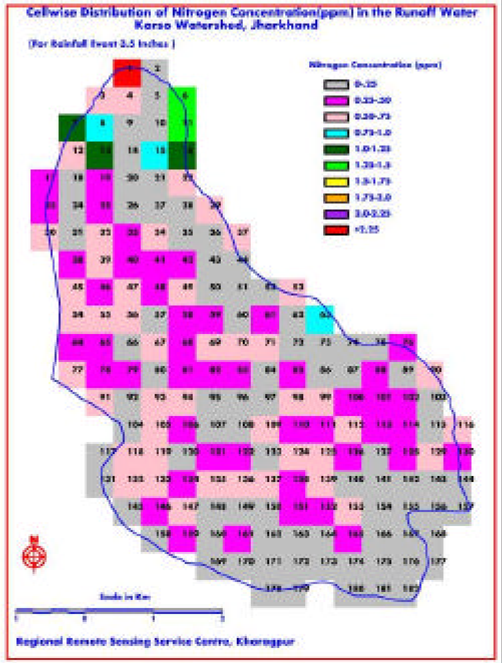


Figure 7

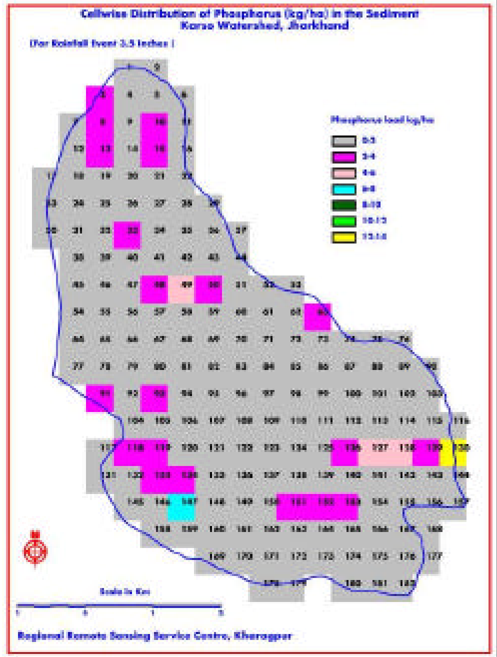
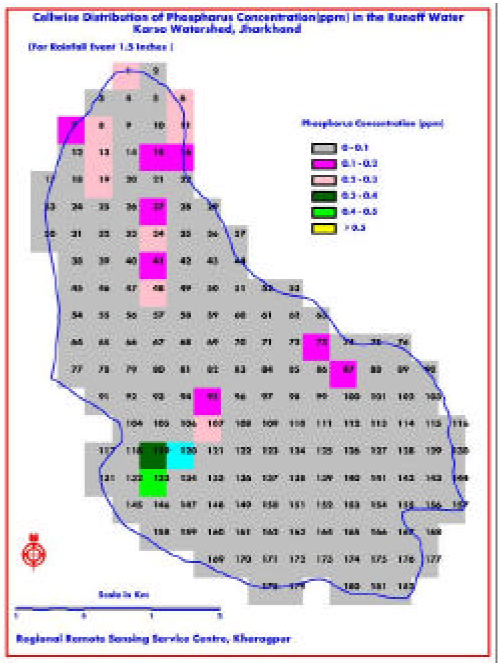


Figure 8



Graph Showing Modelled Sediment load under various management approaches for different rainfall events

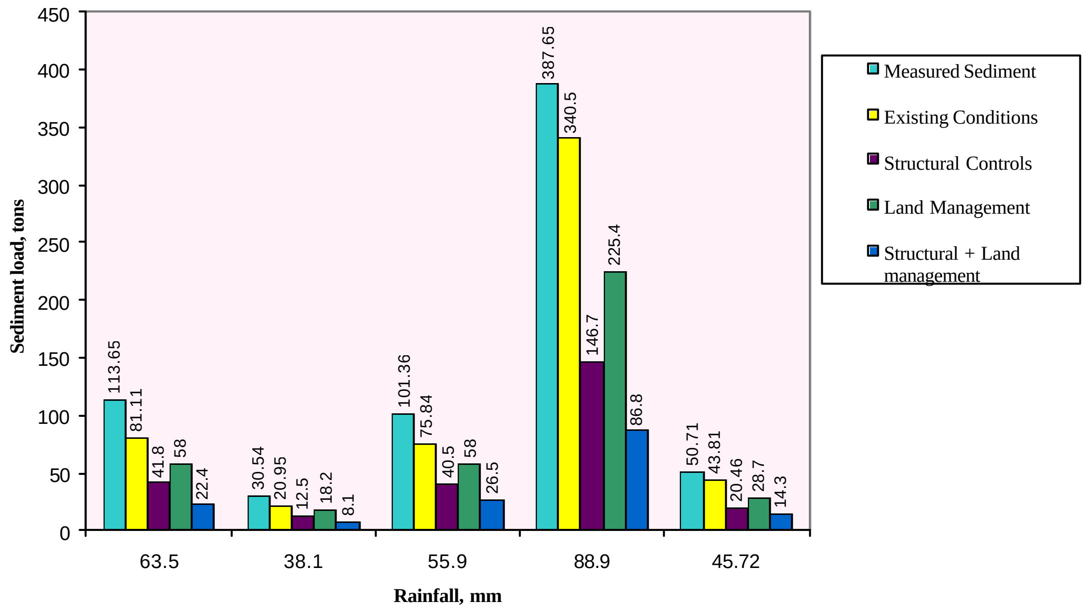


Figure 10