Assessment Of Non-Point Source Pollution Using Analytical Model

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Abstract

Assessment of point and non-point source pollution in Mahanadi river system plays an important role for proper water resources management/utilization/protection, reducing environmental/health degradation, suitable waste load allocation and decision-making for pollution monitoring networks. To address the non-linearity, subjectivity, transfer and transformation rule of the pollutants and complexity of the cause-effect relationships between water quality variables and water quality status, development and use of water quality model is of utmost importance. An important variable responsible for increasing pollutant load in the river system is non-point source pollution. For recognizing the importance of influx of nutrients (nitrate) from non point sources and their simulation, an analytical model has been used and non-point source pollution entering the river has been estimated. Different maps are required to be delineated and used as input to estimate non-point source pollution. First topographical maps with drainage pattern are developed to obtain the area contributing over each river reach.

Keywords: Non-point source pollution, Nitrate, Mahanadi River

"1. Introduction"

Water is important to individuals, society and natural ecosystems as life cannot exist without a dependable supply of suitable quality water. With growth and development, the demand for water has increased tremendously and its uses have become much more varied. It has been found that the global freshwater consumption raised by six times at above twice the rate of population growth from the literature during 1900 and 1995 (WMO, 1997). Nonpoint source of pollution are the hydrologic rainfall-runoff transformation processes which is basically attached with water quality components (Notovny, V. and Chesters, G., 1981) and mainly derived from activities on land, from urban runoff, waste disposal, construction, irrigation modification in hydrology, agriculture, and individual sewage disposal (Robinson and Ragan, 1993). Mainly in aquatic environments both nitrates and ortho-phosphate is present in small amount to maintain the growth and metabolism of plants and animals. Intolerable levels of nitrates and phosphates have been depleting the dissolved oxygen levels by causing algae blooms. High amounts of phosphates and nitrates due to eutrophication, is a main source of lake ecosystems destruction around the world

"2. Materials and Methods"

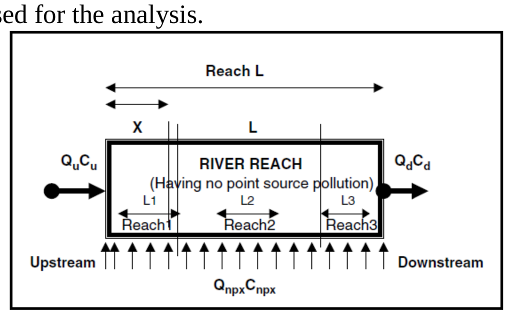
For the pollution survey of the river, various sets of data were collected from various sources during different period. Several approaches have been used to simulate non-point source pollution in River Mahanadi lying in Odisha.

2.1. Delineation of Maps for Assessment of Non-point Source Pollution using Remote Sensing and GIS approach

New tools have been provided successfully for the advanced ecosystem management by the application of remote sensing and GIS. To delineate the basin boundary, drainage pattern, land use, slope, aspect, flow direction, accumulation and digital elevation maps for the Mahanadi river basin, Geographical information systems (GIS) techniques has been used. Arc-GIS software has been extensively used with various tool and 3D analyst and spatial analyst to obtain various maps and overlay maps over each other for estimating non-point source pollution. In principle, a DEM describe the elevation in a digital format of an area and contains information of drainage, crests and breaks of slope. After the DEM map, filtering is executed to arrive at a slope map, aspect map and a flow path map.

"2.2. Non-Point Source Pollution Modeling"

The pollution that enters the receiving surface water diffusely at intermittent intervals is termed as Non-Point Source (NPS) pollution. Infiltration and storage characteristics of the basin, the permeability of soils and other hydrological parameters play an important role as driving forces of diffused contamination (Fig 2). To evaluate the continuous entry of NPS of pollutants into River Mahanadi lying in Odisha state, during the non-monsoon period, an existing modeling approach has been applied. Dataset of important water quality variable nitrate (NO_3) along with discharge observed at different locations of River Mahanadi for one annual cycle were used for the analysis.



"3. Results and Discussion"

3.1. Delineation of Maps for Assessment of Non-point Source Pollution using Remote Sensing and GIS approach

It is essential to estimate the non-point source pollution at different river reaches. For this, different maps are required to be delineated and used as input to estimate non-point source pollution. In the present work GTOPO30, a global digital elevation model (DEM) with a horizontal grid spacing of 30 arc seconds (approximately 1 kilometer), was derived from the URL:(http://edc.usgs.gov/products/elevation/gtopo30/gtopo30.html) and the Shape file was created for delineated the focused area in Arc-GIS. Figure3 shows the Digital Elevation Model developed for the Mahanadi river basin lying in Odisha.

Figure 2 Sketch showing the inflow of NPS at different reaches of River Mahanadi

To obtain a solution for estimating non-point source pollutant concentration within a river reach receiving non point source pollution, it is assumed that the non-point source pollutants entering the river reach either from the banks or coming from the bed are uniformly distributed over the river reach. Thomman and Muller (1987) made the similar assumption to estimate the respiration, photosynthesis, sediment oxygen demand and biochemical oxygen demand (BOD) for estimating non-point source loads in DO-BOD modeling.

For a river reach of length l receiving diffused sources of pollution from the bed or banks of river at any section of river that is having reach length x from the entry point, the contribution of non-point discharge (Q_{npx}) can be estimated as

$$Q_{npx} = \frac{(Q_d - Q_u)}{l} x \qquad (1)$$

The final equation can be written as:

$$C_{np} = \frac{Q_d C_d - Q_u C_u e^{-kt}}{\left[\frac{l(Q_d - Q_u)}{kt}\left(1 - \frac{1}{kt} + \frac{e^{-kt}}{kt}\right)\right]} \qquad (2)$$

From the equation (2) the concentration of pollutant per unit length of the river reach has been computed for different reaches of Mahanadi river basin.

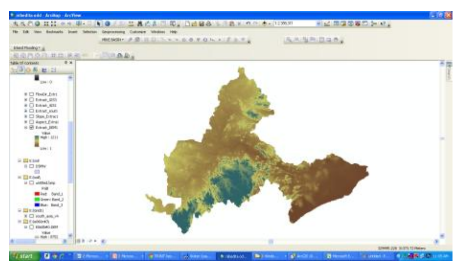
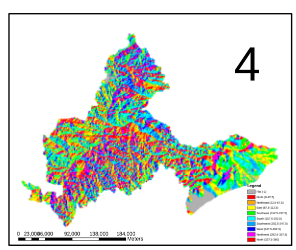
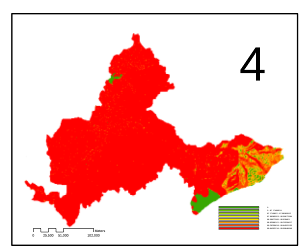


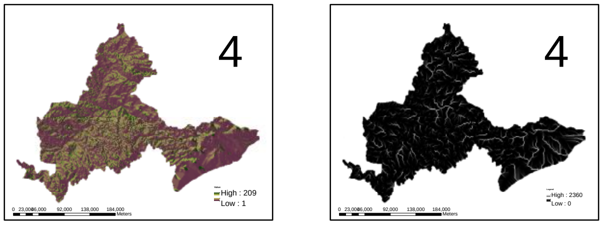
Figure 3: GTOPO 30 Digital Elevation Model of Mahanadi basin lying in Odisha

Figure 3.1 indicates all the maps in sequence. With the use of these maps, non-point source pollution has been estimated.





(a) Aspect map *(b) Slope map*



(c) Flow Direction map *(d) Flow Accumulation map*

Figure 3.1: Development of maps for input to non-point source pollution estimation

Historical and current land cover mapping of the Mahanadi river basin was done to see the changes that have taken place over time. For land cover study, satellite images based on remote sensing being most consistent with synoptic views of large areas. This map is essential to know the agricultural area, urban area, barren land etc. lying in each river each and contributing non-point source pollution. Figure 3.2 shows the land use map of Mahanadi river basin lying in Odisha.

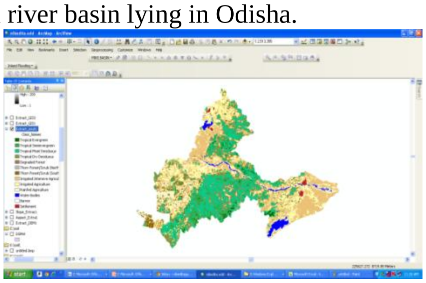


Figure 3.2: Land use/Land cover of Mahanadi basin lying in Odisha (Source: GLC 2000)

3.2 Non-Point Source Modeling

To verify the modeling approach, it is essential to select a river reach, which receives non-point loads from the watershed. For testing the model nitrate is used, which is reactive in nature. The rate of attenuation for nitrate is considered to be 0.10 (Ambrose et al., 1991). Measurements of nitrate at all the sampling points were based on travel time. Figure 3.3 illustrate the nitrate loads along the River Mahanadi during different seasons of different periods and during rainy season, the quantum of nitrate load is more due to intensive rainfall, the chemical applied in the cropland are transported with runoff. However, during non-monsoon period the non-point source pollutants are transported through sub-surface flow and overland flow from areas very close to the banks of the river. Also, the non-point source pollution is calculated using the equation (Eq. 2).

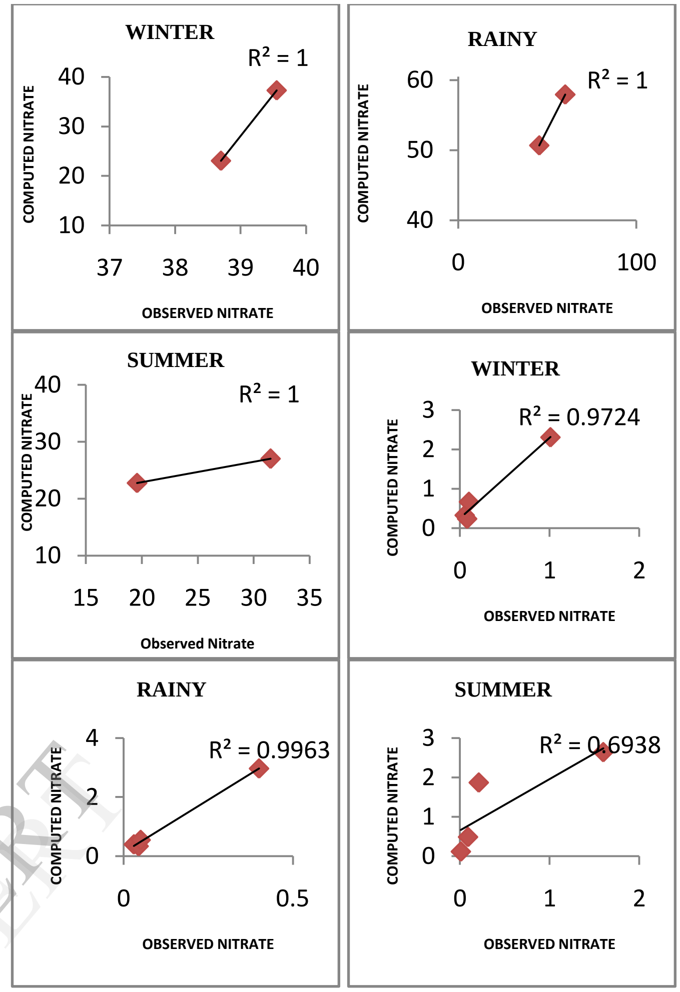


Figure 3.3: Non-point Load (NO_3) in different reaches of Mahanadi basin lying in Odisha (source: Das and Acharya, 2003, CWC)

"4. Conclusions"

The following conclusions are drawn during the course of present investigations: With the help of remote sensing and GIS, a variety of basin characteristics such as land use/land cover, digital elevation model, slope, aspect, map showing flow direction and accumulation have been assessed. Considering that non-point pollutants may also go under a process of attenuation due to a variety of mechanisms including settling, decay due to reaction, modified mass balance equation is used to estimate non-point source pollution. The practice of concentrating the non-point load at the upstream of any reach may not lead to the better description of the distribution of non-point load rather it is assumed that, the uniform distributed load along the reach is found to perform consistently better.

"5. References"

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