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ABSTRACT

This paper presents a methodology for estimating nutrient concentrations of total phosphorus (TP) and total nitrogen (TN) through the use of hydrological modeling, remote sensing datasets, and nutrient export coefficients. The strategy is applied to the Upper Tombigbee watershed, located in the northern region of the states of Mississippi and Alabama, USA. USGS GIRAS (1986), NASA MODIS MOD12Q1 (2001-2004) land use datasets, and USGS-DEM topographical datasets were used to characterize the physiography of the watershed. TN and TP concentration values estimated using the methodology were compared to values reported in the literature.

INTRODUCTION

The absence of water quality monitoring stations that would provide updated data on nutrient concentrations for establishing water quality regulation strategies (such as Total Maximum Daily Loads, TMDLs, or Best Management Practices, BMPs), creates the need for innovative data estimation methods. In areas of the world where the land use coverage is predominantly agricultural lands and forest lands, remote sensing data can provide opportunities for making educated estimations of nutrient concentrations.

For example, the United States of America (USA) has a land area of approximately 900 million hectares, from which about 28 percent is covered by forest land, 26 percent permanent grassland pasture and range land, and 20 percent cropland. The total land used for agricultural purposes in 1997 was about 485 million hectares; that accounts up to over 52 percent of total U.S. land area (Vesterby & Krupa, 1997). Cropland, grassland pasture, and range land accounted for most of the land used for agricultural purposes, but land used...
for agricultural purposes also included forest land used for grazing and land in farmsteads, farm roads, and farm lanes (Vesterby & Krupa, 1997). Land use in the Southeastern United States is predominantly covered by forests and agricultural lands.

Water quality and flow regime (quantity, temporal variation, and spatial distribution) influence the ecological “health” of aquatic biota (Allen, 1995; Karr & Chu, 1999). In watersheds such as the Upper Tombigbee (located in northeastern Alabama and northwestern Mississippi, USA), where agricultural land use can comprise 50% or more of land cover, sediment and nutrient runoff can seriously degrade the ecological quality of aquatic environments (Allen, 1995).

Data on nutrient loads to rivers from non-point sources (characterizing the water quality of a watershed or a river) are particularly difficult to find because setting up field surveys for collecting these data and performing additional laboratory analysis require extensive use of personnel and resources, making it an impractical alternative. A technique for estimating nutrient loads that would combine remotely sensed land use data and export coefficients seems to be particularly attractive given the geographical extent that is covered by land use maps. There are several recent examples of this type of approach for estimating nutrient loads in watersheds located outside the United States (Ierodiaconou, 2004; Liu et al., 2009; Liu, He, & Wang, 2008), but there are no recent studies of this type in the USA.

This paper details a strategy that combines hydrological modeling, geo-processing of physiographic data (land use, topography), and export coefficients for estimating stream flow, runoff, and nutrient concentrations throughout the Upper Tombigbee watershed. The Hydrological Simulation Program Fortran (HSPF) (Bicknell, Imhoff, Kittle, Jobes, & Donigian, 2001) is used for estimating water quantity. Export coefficients and geo-processing of land use datasets are used for calculating nutrient concentrations.

METHODOLOGY

Watershed Under Study

Water bodies in the Southeastern USA are subjected to loads of pollutants resulting from urban development, agriculture, and other human activities. Impairment of rivers in the region is related mainly to sediment and nutrient loads. Monitoring of water quality in the region’s water bodies, however, does not take place in a frequent basis due to costs associated with water quality surveys.

The Upper Tombigbee watershed is located in the states of Alabama and Mississippi in the Southern USA (Figure 1). The watershed drains approximately 13900 square kilometers and it is a main contributor of flow to the Mobile River, with an approximate average stream flow of 169 m³/s.

Physiographic Datasets

Topography and land use datasets were used to characterize the physiography of the Upper Tombigbee watershed. The topographical dataset used in this research was the United States Geological Service (USGS) Digital Elevation Model (DEM), which corresponds to the 3 arc-second (1:250,000-scale, 300 m spatial resolution) USGS topographic map series. A seamless topographical mosaic was produced by using several DEMs that cover the area. ArcInfo (GRID) was used to fill grid cells with no-data values (con, focalmax, and focalmean commands were used). Figure 2 shows a flowchart of the processing steps and the resulting topographical dataset.

From the several digital land use maps that are available in the USA (NLCD, GIRAS, MODIS, etc.), two land use datasets were used in this study (Figure 3): USGS GIRAS, and NASAMODIS MOD12Q1. The USGS GIRAS consists of set of maps of land use and land cover for the conterminous USA, delineated...