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Evaluation of stream water quality data generated from MODIS images in modeling total suspended solid emission to a freshwater lake

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HIGHLIGHTS

- MODIS images used to generated total suspended sediment (TSS) time series data for a stream
- The usability of the data to model TSS emission into a lake is evaluated
- Generated data were capable of modestly reproducing monthly variations
- The PBIAS indicated slight underestimation of suspended sediment

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ABSTRACT

Modeling of suspended sediment emission into freshwater lakes is challenging due to data gaps in developing countries. Existing models simulate sediment concentration at a gauging station upstream and none of these studies had modeled total suspended solids (TSS) emissions by inflowing rivers to freshwater lakes as there are no TSS measurements at the river mouth in the upper Blue Nile basin. In this study a 10 year TSS time series data generated from remotely sensed MODIS/Terra images using established empirical relationship is applied to calibrate and validate a hydrology model for Lake Tana in Upper Blue Nile Basin. The result showed that at a monthly time scale TSS at the river mouth can be replicated with Nash–Sutcliffe efficiency (NS) of 0.34 for calibration and 0.21 for validation periods. Percent bias (PBIAS) and ratio of the root-mean-square error to the standard deviation of measured data (RSR) are all within range. Given the inaccessibility and costliness to measure TSS at river mouths to a lake the results found here are considered useful for suspended sediment budget studies in water bodies of the basin.

1. Introduction

Advances in computational power and the understanding of processes at finer scale progressed enormously human ability to numerically model water resource systems (Silberstein, 2006). However, water resources data collection at varying scales is expensive, so that modelers often tend to conceptualize processes based on simplified views of nature (Dozier, 1992) or match the observed data even if the underlying premises are unrealistic (Kirchner, 2006). In addition, collection of water resource data, especially in developing countries, are characterized by inadequate monitoring, gaps in observations, a decline in the number of stations, chronic underfunding and differences in processing and quality control (Harvey and Grabs, 2003; Vörösmarty et al., 2001). Our ability today to monitor extreme events with ground based systems is less than it was 45 years ago (Macauley and Vukovich, 2005).

Space-borne remote sensing has become a potential data source to model land and water resource systems. Various remotely-sensed images based tools are also developed to measure turbidity (Chen et al., 2007, 2009; Shen et al., 2010), suspended sediment concentration (Jiang et al., 2009; Nechad et al., 2010), chlorophyll-a (Fiorani et al., 2006; Wang et al., 2010), phytoplankton (Kwiatkowska and McClain, 2009), cyanobacterial blooms (Kutser, 2009) and other physical water quality parameters (Hu et al., 2004; Liu et al., 2003). Using these data in hydrologic modeling requires an understanding of the potentials and limitations of the data sets.

Modeling of suspended sediment emission into freshwater lakes is challenging due to data gaps in developing countries. There is an existing knowledge base with respect to the stream discharge and

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sediment modeling (Chebud and Melesse, 2009a,b; Conway, 2000; Dile et al., 2013; Kebede et al., 2006, 2011; Setegn et al., 2008, 2010, 2011; Tarekegn and Tadege, 2006; Wale et al., 2009; White et al., 2011; Yasir et al., 2014) using SWAT. Improved hydrologic models have also been more successful in predicting runoff (Easton et al., 2008; Steenhuis et al., 2009; Tilahun et al., 2012). Nevertheless none of these studies had modeled TSS emissions into a lake as TSS measurements over the lake are unavailable. The applicability of total suspended solids (TSS) data generated from remotely sensed images for hydrological model predictions in the Upper Blue Nile basin has not so far been investigated. The present study assesses the usability of TSS data generated from MODIS/Terra version 5 images using a SWAT-VSA model (Easton et al., 2008) set up to model TSS emission from an upstream watershed into a freshwater lake. A ten-year time series data generated from remotely sensed images for Lake Tana at the river mouth (Kaba et al., 2014) is used to calibrate and validate the model. The results in this study will provide scientific basis for using sediment concentration time series generated from MODIS reflectance measurements in lieu of sediment data from rating curves.

2. Materials and method

2.1. Study area

The Gumera catchment drains an area of about 1280 km^2, (Fig. 1). The watershed drains into Lake Tana, a fresh water lake and source of the Blue Nile. Agriculture being a dominant activity in the area represents 96% of the watershed and only 4% is forested.

Elevation of the Gumera watershed ranges from 1792 to 3712 m. The watershed climate and vegetation are characteristic of a sub-humid zone with a high diurnal temperature variation between day time extremes of 30 °C to night lows of 6 °C. Rainfall may reach up to 2000 mm per year falling in one rainy season from May to October with July to August as the wettest (Vijverberg et al., 2009). Gumera

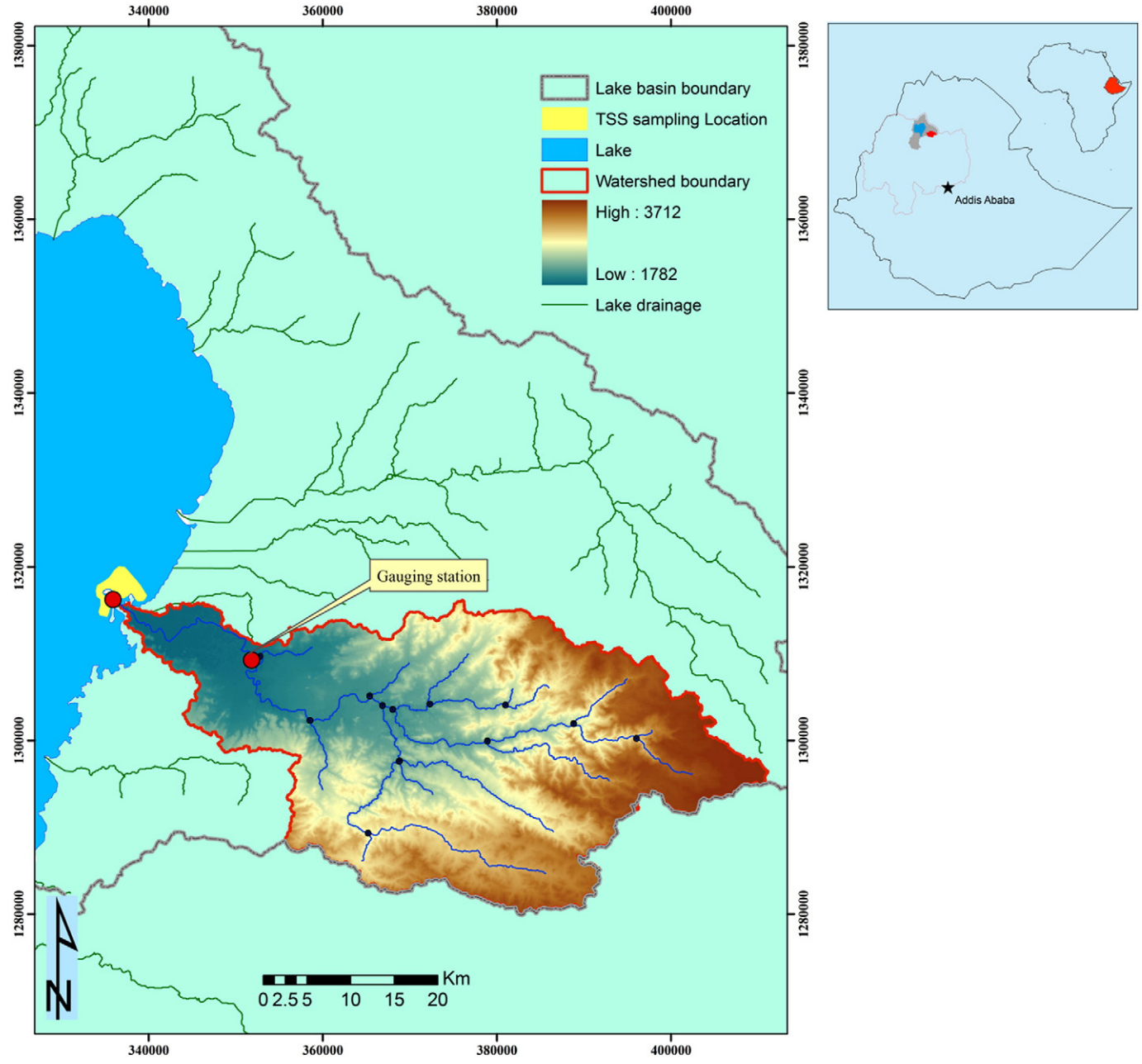

Fig. 1. Gumera watershed, stream network and gauging station up the river mouth.