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Assessing the relationship between water quality parameters and changes in landuse patterns in the Upper Manyame River, Zimbabwe

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ABSTRACT

For the past 30 years, the increases in population pressure and external influences, such as economic growth, have accelerated the demand for land within the Upper Manyame River catchment in Zimbabwe which has caused substantial changes in landuse. The general objective of this research was to assess the impacts of landuse activities on the water quality of the Upper Manyame River which drains the rural and urbanised part of the catchment up to flow gauging station C21. Landcover data for the month of April in years of 1984, 1995, 2003 and 2011 were acquired from available Landsat TM and ETM images and were classified through the maximum likelihood digital image classification using the supervised classification approach. The status of water quality of the Upper Manyame River was also assessed through analyses of historical concentrations and pollution loads for TP, DO, COD, NH_3-N, SS, Pb, NO_3, BOD_5, EC, PO_4-P and TN at the Environmental Management Agency (EMA) gauging station CR21 sampling point for 1996, 2000/1 and 2008/9. Water quality of 15 monitoring sites comprising 25 water quality parameters were monitored monthly from January to June 2012. These locations were selected to reflect a wide array of landuse for both the dry and wet seasons. The results indicated that there was an increase in pollution load from 1995 to 2012; for TP from 130 kg/day to 376 kg/d, and for TN from 290 kg/day to 494 kg/d. This indicates high pollution levels which have severe impacts on downstream users and also severe sewage contamination. Significant deviations occurred in DO (0.1–6.8) mg/L, COD (11–569) mg/L, BOD_5 (5–341) mg/L, PO_4-P (0.01–4.45) mg/L, NH_3-N (0.001–6.800) mg/L and EC (38–642) μS/cm. Hydrologic Response Unit and buffer analysis were used to determine the dominant landuse which contributes to a certain water quality. Results of digital image classification indicate that woodland/forest, grassland and bareland decreased between years 1984 to 2011 by 24.0%, 22.6% and 31.7% respectively. This was mainly due to expansion or increase of agriculture and urban areas by 24.4% and 41.6% respectively over the same time period. It was concluded that settlements and agricultural areas are the ones mainly affecting the water quality in Upper Manyame River with a Pearson's Correlation Coefficient of $r = 0.97$ for COD and $r = 0.78$ for TSS respectively. It was also observed that the water quality status of the Upper Manyame River and its tributaries is very poor and the level of pollution generally increases from upstream to downstream. The results obtained provided baseline information which may be used in the development of appropriate water quality management systems in the catchment. Thus the study recommended a combined programme of point source control and landuse modification.

1. Introduction

Landuse is the primary factor causing habitat degradation and poor water quality (USGS, 1998; Wear et al., 1998; Zampella and Procopio, 2009). Natural processes and both direct and indirect effects of human activities are major drivers of landuse change (Meyer and Turner, 1994; GLP, 2005). Development activities such as agriculture, urbanisation, forestry and industries often lead to more intensive landuse which increases runoff and the consequent transport of pollutants directly into waterways (James et al., 1995; FAO, 1996; Schock, 2000).

The quality of receiving waters is affected by human activities in water bodies through point source pollution, such as wastewater treatment facilities and non-point source pollution, such as runoff from urban areas, mining and farmlands (Lenat and Crawford, 1994; Erle and Robert, 2010). Urban growth and the concentration of people could increase environmental problems related to soil degradation which have important implications on water quality (Young et al., 1989). As human populations continue to expand and increase the use of finite resources, future availability of adequate supplies of freshwater for human and agricultural needs

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could become critical in many regions (Wear et al., 1998; Hogan, 2010).

Hajkowicz (2002) indicated that Australia's surface water resources were deteriorating in quality due to current and historical land management practices with impacts such as changing environmental flows, increase of eutrophication and turbidity to water bodies. A study conducted by Masamba and Mazvimavi (2008) in Botswana determined the effects of human activities within and around an urban village, on the water quality of the Thamalakane-Boteti River which drains from the Okavango Delta. The authors found out that unsustainable landuse is driving land degradation which degrades the water quality.

In Zimbabwe, the quality of water in major rivers, particularly Manyame River upstream of Lake Chivero, shows high degrees of pollution, and this is basically from both point and non-point sources of pollution (Thornton and Nduku, 1982; Moyo, 1997; Muchibwa, 2007). Point source pollution is from sewage effluent, industrial effluent, backyard industry discharges and mining activities, while urban runoff and poor urban agricultural practices could be the non-point pollution sources of this river (JICA, 1996). A closer inspection of all sources of pollution shows the threat and the extent of harm befalling the river courses in Zimbabwe. The inflow of high nutrient levels into the Upper Manyame River have contributed to the hypertrophic status of Lake Chivero which is the major source of water supply for the capital city of Harare and its satellite towns (Phiri, 2000; Gumbo and Savenije, 2001).

The surface water quality of Upper Manyame River has been significantly impaired over recent years, as natural land cover has been urbanised or converted to agricultural uses and industrial activities that affect water quality in the catchments (JICA, 1996; Muchibwa, 2007). The agricultural sector mainly draws untreated water for irrigation and livestock rearing from the rivers and impoundments. Most of the farmland in the catchment is under commercial mixed farming; producing maize, wheat, tobacco, vegetables and horticultural crops, as well as dairy and livestock products (JICA, 1996). Farmers use fertilisers and other agricultural chemicals that are believed to affect the water quality of Upper Manyame River (Magadza, 1997; Gumbo and Savenije, 2001). The general recommendation by the Environmental Management Agency (EMA) in Zimbabwe is that all cultivation activities must be at least 30 m from a stream. However, because of increased pressure for land in recent years, this recommendation is no longer observed and there is no close monitoring of the landuse and other human activities that are taking place within the proximity of the catchment area and this has led to rapid siltation and water quality impairment of the rivers (Bowyer-Bower and Tengeh, 1995; Muchibwa, 2007).

Remote sensing investigations are essential to monitoring the water quality status of larger waterbodies and can provide basic information for inland water management (Dekker, 1993). Point-based assessments of water quality status are not adequate to provide information on the spatial coverage of sources of pollution. Remote sensing therefore offers attentively synoptic, repetitive, consistent, cost effective and comprehensive spatio-temporal views. Remote sensing imaging techniques provide the potential to monitor upstream landuse and landcover changes (LULC) and spread, thus enabling an assessment of areas of severe land

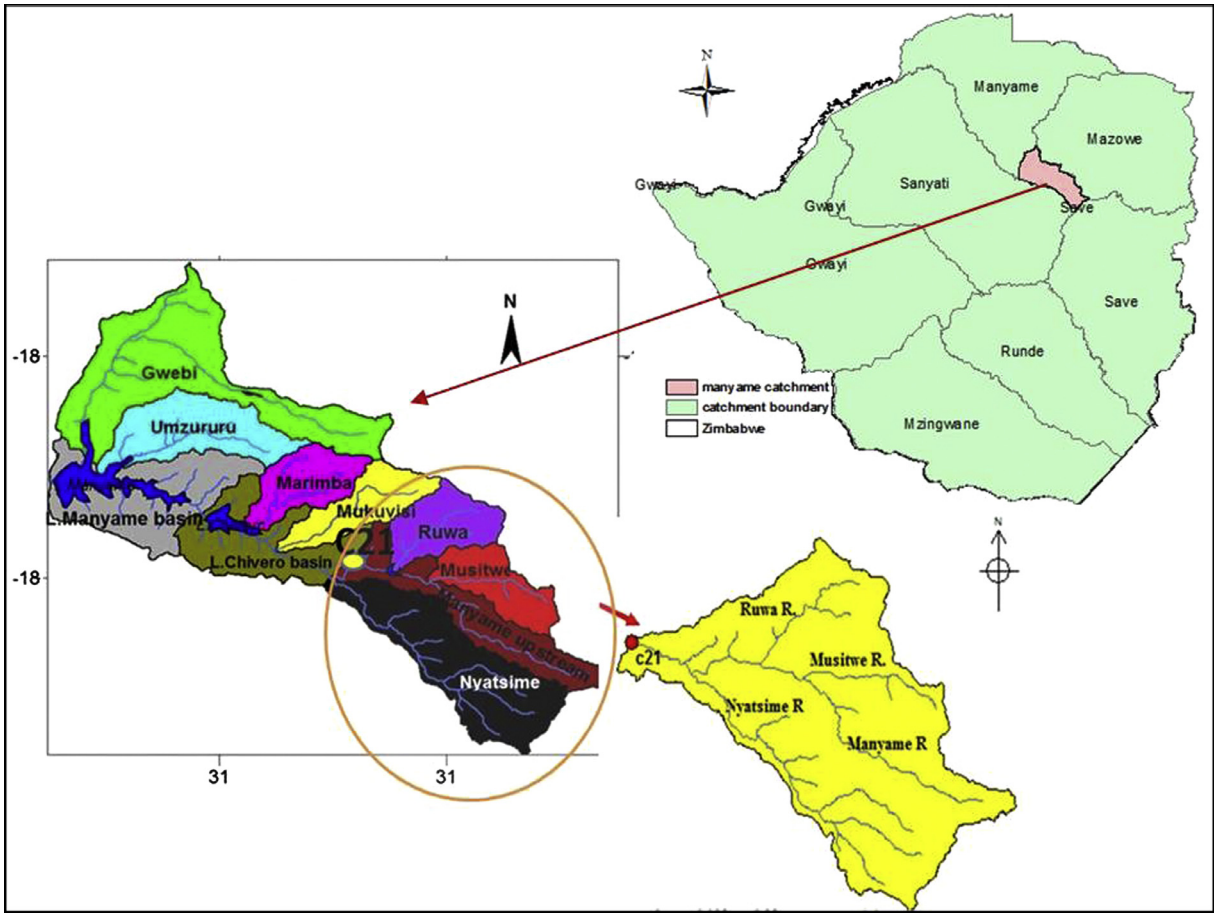

Fig. 1. Location of the drainage area of the Upper Manyame River up to ZINWA flow gauging station C21.

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