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Impact of Land Use/Cover Change on Hydrologic Characteristics: A Study on Upper Narmada Basin (MP), India

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A B S T R A C T

This paper presents an integration approach involving Remote sensing / Geographic information system(RS /GIS) and hydrological models to characterized and quantify the effect of land use/ land cover (LULC) change on basin hydrology parameters. The Arc SWAT model was used daily weather and stream flow data of Upper Narmada basin from 1989 to 2011. Study evaluates change in Surface runoff, Evapo-transpiration, Total water yield, stream flow and Total aquifer recharge. Further analysis present additional evidence that changes in vegetation cover altered the hydrological response to region. As the pressure for changes in LULC in the region continuous to increase, one can expect important further change in the hydrological regime of the basin.

Introduction

Precipitation and land hydrological processes maintain the water balance in a river basin. Land surface performs a role in the hydrological cycle, as water availability is generally a consequence of precipitation redistributed into evaporation, runoff and soil moisture storage (Dolman and Verhagen 2003). The largest part of precipitation passes over the land surface or drain through the soil and bedrock to translate into river flows. The spatial heterogeneity associated with land cover, soil properties and localized precipitation influences soil moisture and surface fluxes. Land cover change and the effects of land management on the hydrological response of a catchment are most likely where the change alters the surface characteristics of a basin. The degree and type of land cover influences surface run-off and the rate of infiltration, and consequently the rate of groundwater recharge (Calder, 2002; Dingman, 2008). Changes in these hydrological variables may have implications for water resources.

The relationship between land cover change and hydrology is complex, with linkages existing at a wide variety of spatial and temporal scales. However, land cover change unquestionably has a strong influence on global water yield (Frenierre2009). Land cover and use directly influence the amount of evaporation, groundwater infiltration and overland runoff that occurs during and after precipitation events (Zhang *et al.*, 2001, Costa 2003). Forests have a higher interceptive potential than grassland, arable land lower than grassland. Conversion to cropland tends to increase water yield compared to native vegetation although this varies with the crop and the season while manmade surfaces such as tarmac have the lowest interceptive potential (Haslam, 1987).

Comprehensive knowledge of Land use /Land Cover (LULC) dynamics is useful for reconstructing past land use and cover changes and for predicting future changes. It may help in elaborating sustainable management practices aimed at preserving essential landscape functions (Hietel *et al.*, 2004). Though many land use models have been developed using GIS (Almeida *et al.*, 2008, Xia and Xiaoping, 2008), a simple approach was taken for scenario analysis of this study due to limited data access.

Materials and Methods

The study area

The Upper Narmada basin is located across the central part of Madhya Pradesh and it is distributed in Dindori, Jabalpur, Mandla, Narsinghpur, Hoshangabadare considered for the study. Total area of the basin is about 45,286km^2.The basin is surrounded by latitude 22^{o}40' N and longitude of 81^o 45' E shown in Figure 1. The climate of the basin is humid and tropical, although at places extremes of heat and cold are often encountered. The average annual (1989-2011) rainfall in the upper Narmada basin varies from 1400 mm at eastern region to 1650 mm to western region.

Data collection and analysis

In the study data required for assessing impacts of Land use/ land cover (LULC) change on hydrology over the Upper Narmada basin, were obtained digital elevation model (DEM) and Satellite Images (Resourcesat-1 LISS-III duration October-November 2011) from *bhuvan.nrsc.gov.in*, MSS and Landsat TM duration October-November 1989) *Landst.org*, these data were processed in ERDAS IMAGINE 2010 performed unsupervised classification for LULC map preparation, soil maps at scale 1:25,00,000 from National Bureau of Soil Science and Land Use Planning (NBSS and LUP, 1996) for Madhya Pradesh. Meteorological data consist of daily precipitation, maximum and minimum temperature, relative humidity, wind speed, and solar radiation were obtained from *globalweather.tamu.edu*. Observed discharge data was used for model calibration were obtained by *indiawris.nrsc.gov.in.*

Hydrological Model

In this study ArcGIS interface of SWAT model version 2009 was used, which is physically-based, semi distributed and continuous time step model and used for predicting the impact of different LULC effect on hydrology (Neitsch *et al.*, 2011). Arc SWAT simulate hydrologic cycle based on water balance. The general eq. is:

$$SW_t = SW_0 + \sum_{i=1}^{t}\left(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}\right)$$

Where, SW_t = final soil water content (mm), SW_o = initial soil water content (mm), t = simulation period (days), R_{day} = amount of precipitation on the ith day (mm), Q_{surf}= amount of surface streamflow on the ith day (mm), E_a = amount of evapotranspiration on the ith day (mm), W_{seep} = amount of water entering the vadose zone from the soil profile on the i^{th}day (mm), and Q_{gw} = amount of base flow on the i^{th}day (mm).

With the help of Arc SWAT model LULC, SLOPE, and SOIL map were used to simulate and create sub-basin and hru for the study. The model uses SCS model (Wieshmeir and smith 1978) to estimate the surface runoff.

Results and Discussion

The SWAT model simulated for the two time periods corresponding to the LULC of 1989 and 2011. A comparison of the selected parameters for LULC 1989 and 2011 effect of changing scenario of LULC for mean annual surface runoff, Aquifer recharge, water yield and Evapotranspiration presented in (Table 1 and Figure 2).

The result indicate that changes in LULC from1989 to 2011 annual surface runoff and total aquifer recharge was decreased 1.62 % and 8.13% respectively. Also analyzed that total water yield was decreased by 6.90 % but evapo-transpiration increases by 2.21% from 1989 to 2011LULC.

Table.1 Parameters from annual simulations for 1989 and 2011 LULC

Item (unit = mm)	LULC_1989	LULC_2011
Surface Runoff	418.73	411.91
Total Aquifer Recharge	168.60	154.89
Total Water Yield	711.54	662.44
Evapotranspiration	499.49	510.54

Fig.1 Map of the study area

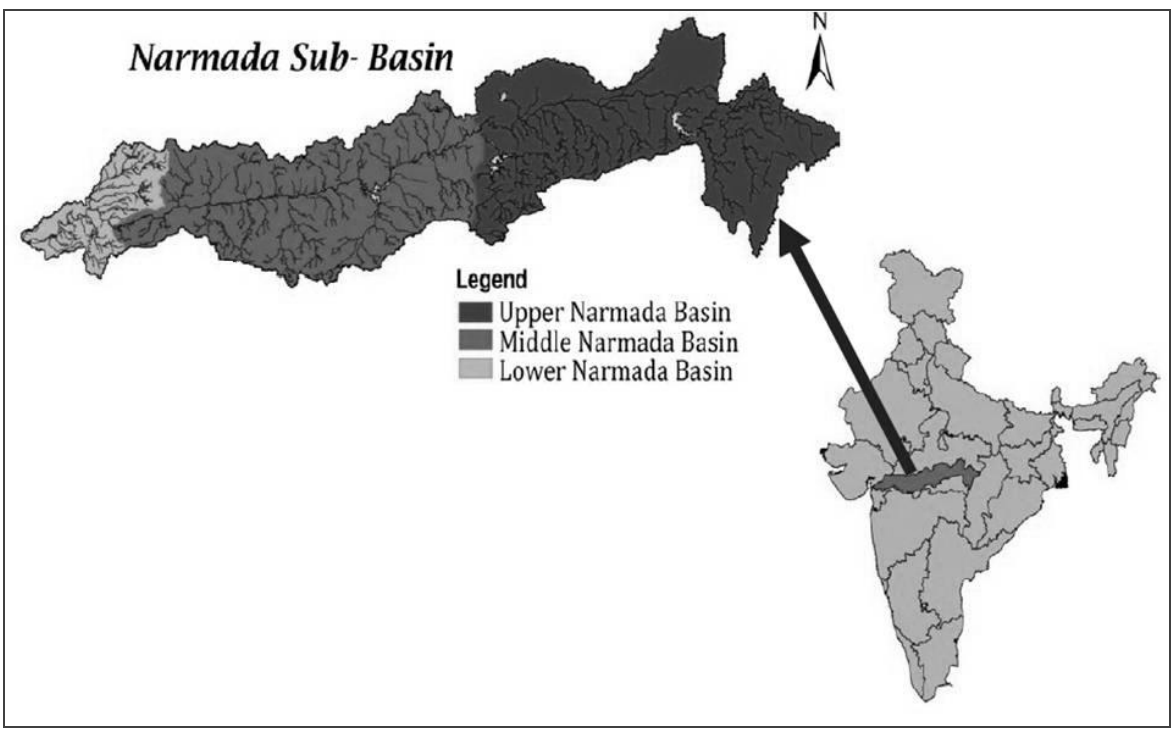
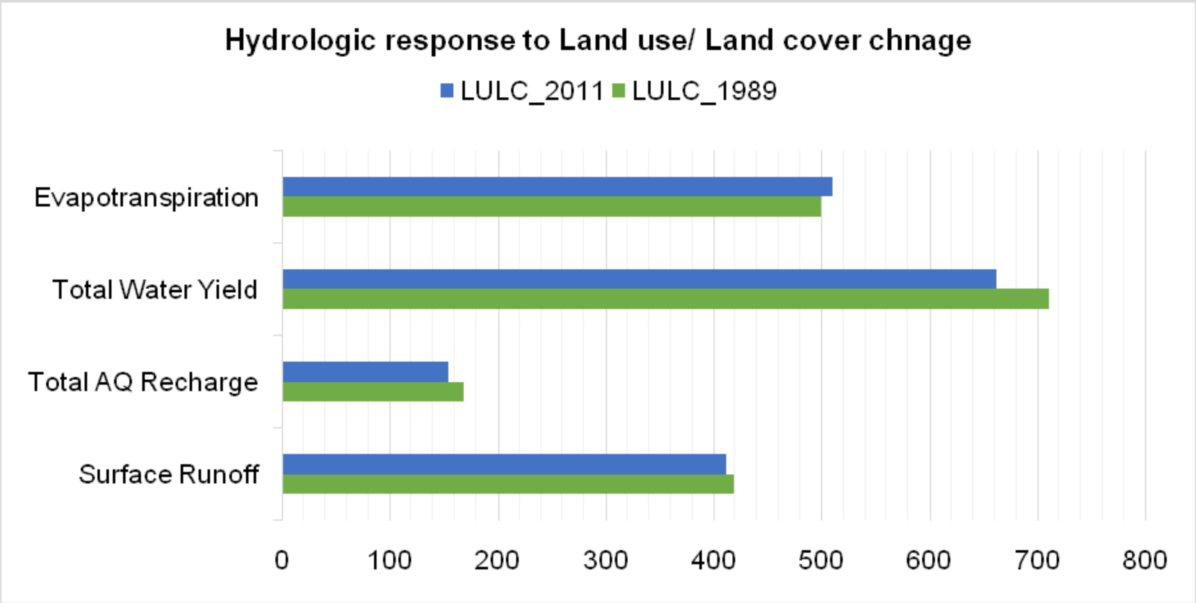


Fig.2 Hydrologic response to land use/land cover change for 1989 and 2011



It can be presumed that the rapid increase in human population has altered the basin. Modifications of land uses are expected in the near future, since farmers in the Upper Narmada basin have already started using ground water and surface water to cultivate market oriented crops. This study also highlighted that detail understanding of historical land use/cover changes and consequent impacts on hydrology will enhance our capability to predict future land use modifications. Therefore, further scenario simulations and optimization strategies that take in to account upstream-downstream water users can provide valuable information to devise more effective management strategies to sustain the livelihoods of the local community.

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