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Assessment of Enso impacts on rainfall and runoff of Venna River Basin, Maharashtra using spatial approach

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ABSTRACT

El Niño Southern Oscillation (ENSO), the periodic fluctuation of sea surface temperature (SST)-atmospheric pressure over the tropical Pacific ocean, have great influence on the climate all around the world. Many studies reveal that there is direct relationship between Indian monsoon and ENSO. The current study is performed to understand the impact of ENSO on central India. The study focusses on variation in rainfall and runoff within the period 2004-2008 in twenty eight sub watersheds of Venna river basin, Maharashtra during various ENSO events. El Niño (2004, 2006) and La Niña (2007) years were selected based on the Oceanic Niño Index (ONI) available in the National Oceanic and Atmospheric Administration (NOAA) official website. The rain-gauge station rainfall data for each subwatershed was interpolated using Thiessen polygon interpolation method. To assess the impact of variation in runoff, the change in the landuse pattern of the watersheds were estimated for the period 2004-2008. The runoff was calculated using Soil Conservation Service Curve Number (SCS CN) method integrated with remote sensing technique for all subwatersheds. Variation occurring in rainfall and runoff for different subwatersheds were analysed for different years. It was found that all El Nino

/La Nina years are associated with lower/higher rainfall in the watershed. Runoff, which is a factor related to the vegetation and soil permeability characteristics of the area also showing strong relation with the ENSO phenomenon.

Keywords: ENSO, rainfall, runoff, SCS CN method

1. INTRODUCTION

El Niño and the southern Oscillation (ENSO), periodic fluctuation in Sea Surface Temperature (SST) and air pressure of the overlying atmosphere across the equatorial Pacific Ocean, have great influence on global weather and climate. El Niño and La Niña are the two opposite phases of this ENSO cycle. El Niño can be referred as the warm phase of ENSO cycle whereas La Niña is the cold phase. The direct impacts of ENSO on tropics, especially for monsoon affected countries such as Australia, India, Indonesia and Africa are quite severe (Krishna Kumar et al., 1999). Association of ENSO and Indian monsoon was recognized long ago (Walker, 1923, 1924; Normand, 1953). K. Krishna Kumar et al.(2006), by considering India's 132-years rainfall history reveals that severe droughts occurred have always been accompanied with El Niño events. But all the El Niño events have not caused severe droughts; the events occurring in Central Pacific Ocean are more effective in focusing drought over India than events in the eastern equatorial Pacific. Impact of El Niño on Indian monsoon is associated with lower than normal rainfall and opposite for La Niña (Maity and Kumar, 2006). El Niño and La Niña impacts in different parts of the World was studied by Allan et al.,(1996)and as per the figure, the El Niño induces drier conditions in India, where as La Niña induces increased precipitation. Many researchers (Selvaraju, 2003; Bothale & Katpatal, 2014 etc.) also studied the relationship between ENSO on Indian rainfall and crop production.

Various methods such as Southern Oscillation Index (SOI), Oceanic Niño Index (ONI), Multivariate ENSO Index (MEI) are available for monitoring of ENSO. In this study, ONI method was used to identify the phase of ENSO events in the study area. ONI is the mean of three months SST anomaly for the Niño 3.4 region (5ºN-5ºS, 120º-170º W). If the five consecutive overlapping three months value is greater than 0.5 ,then that year can be considered as El Niño and if the value is less than -0.5,then it will be a La Niña year.

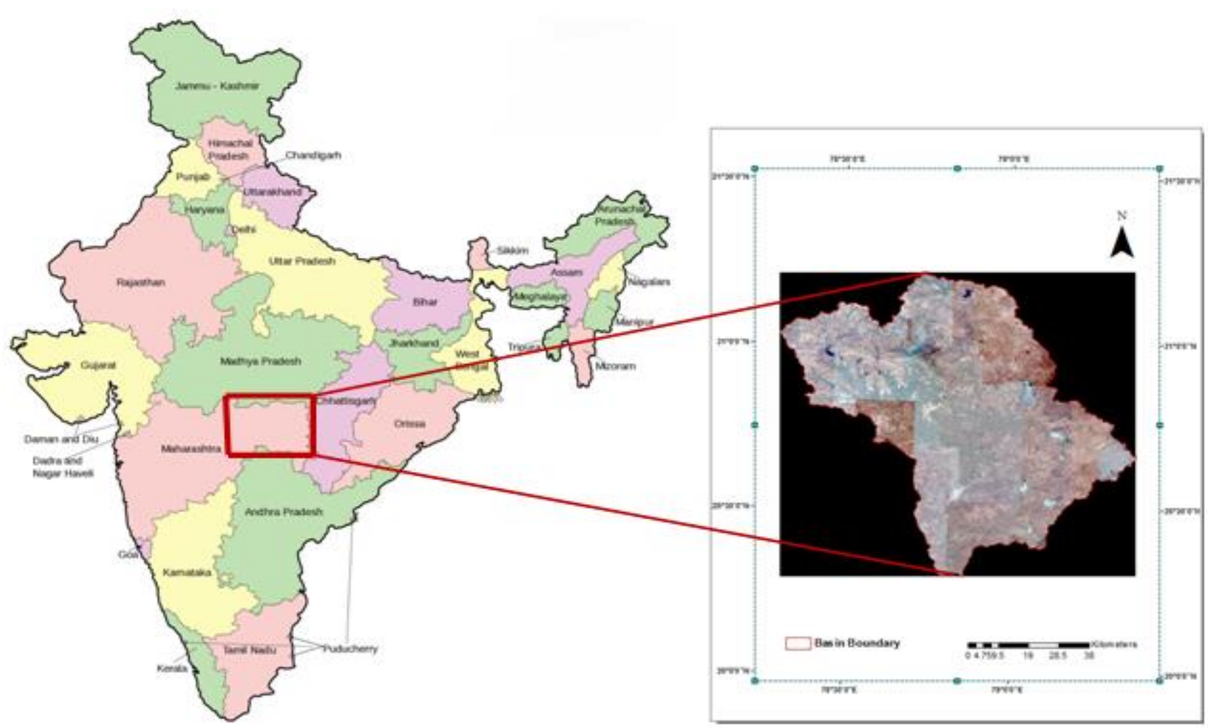

Figure 1
Location map of the study area

In India, most of the watersheds are ungauged and hence accurate information about runoff is unavailable. SCS CN developed by United States Department of Agriculture is one of the widely accepted techniques for calculation of runoff worldwide. Mishra et al., (2003), modified SCS CN model for Indian condition which has been found to be effective for calculation of runoff in Indian ungauged watersheds. The method estimates surface runoff by considering major watershed characteristics such as soil type, landuse, hydrological condition and Antecedent Moisture Condition (AMC)(Ponce and Hawkins 1996; Mishra et al 2004, 2005). Geographic Information System (GIS), in view of its capacity to handle large amount of spatial and attribute data, has become a critical tool in hydrological modelling (Ramakrishnan et al., 2009). Features such as map overlay and analysis help to derive and aggregate hydrologic parameters from different sources such as soil, land cover and rainfall data (Cheng et al., 2006; Winnaar et al., 2007).

2. METHODS

2.1. Study Area

The area selected for the current study is Venna river basin of Maharashtra, India; which is a sub-basin of Wardha catchment comes under Godavari basin. Area of the basin is approximately 5675 sq. km which covers Wardha, Nagpur and Chandrapur districts of Maharashtra. Geographically, the area lies between $21^0$01′42.19′′ and $20^0$23′0.59′′ N latitude and $78^0$18′17.61′′ and $79^0$06′12.23′′E longitude. Average annual rainfall of the area is around 1055 mm with maximum and minimum temperature ranges between 42^0C and 18 ^{0}C. About 95% of the area is covered with Deccan traps and comprise rocks of basaltic composition. The major reservoirs present in the study area are Pothra dam, Wadgaon dam, Bor dam, Vena reservoir, Lower wunna dam and Dham dam. Location map of the study area is depicted in Figure 1.

2.2. Methodology

Long term rainfall trends in the basin were studied by using rainfall data obtained from Indian Meteorological Department (IMD). El Niño and La Niña years were selected based on the Oceanic Niño Index (ONI) available in the National Oceanic and Atmospheric Administration (NOAA) official website. Rainfall analysis was carried out initially for whole Venna basin (2000-2013) and later on for each subwatershed (2004-2008) to understand the rainfall variability during El Niño, La Niña and normal years. Subwatershed wise rainfall values were calculated using theissen polygon interpolation method using rain gauge station rainfall data. Runoff for each sub watershed was calculated using SCS CN technique. To calculate curve number for each subwatershed, watershed map, hydrologic soil group map and landuse map of the area with five land use classes such as agriculture, built-up, forest, water bodies and open spaces were generated and overlaid using union overlay technique. Rainfall-runoff regression analysis was carried out to find the correlation between rainfall and runoff calculated. Variability of calculated runoff during different years were also analysed for each subwatershed to understand the influence of ENSO on runoff.

3. RESULTS AND DISCUSSIONS

To understand the overall trend of rainfall in the basin, rainfall values for period 2000-2013 were potted as presented in Figure 2. From the figure, it is clear that rainfall within the entire basin is showing a negative trend with a R^2 value of 0.2833.

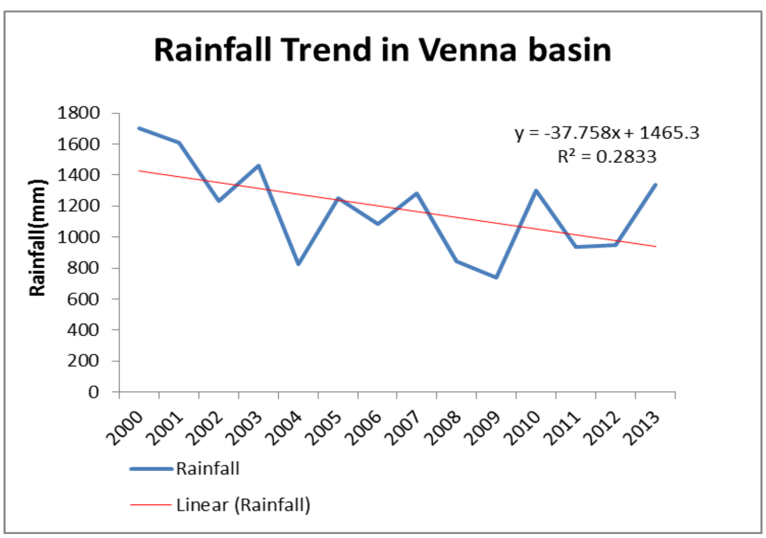

Figure 2

Trend of rainfall within the Venna basin for the period 2000-2013

ENSO years were selected on the basis of ONI values obtained from the NOAA website. El Niño, La Niña and normal years selected based on these ONI values during the study period are shown in Table 1.

Table 1 Years selected as ENSO years based on ONI values

El-Nino Years	La-Nina years	Normal Years
2002	2000	2001
2004	2007	2003
2006	2010	2005
2009	2011	2008
		2012
		2013

Annual rainfall values for the period 2000-2013 were plotted and variability of rainfall during ENSO years and normal years were studied (Figure 3). It is obtained that all El-Niño years are associated with lower rainfall than the preceding normal years and all La Niña years are associated with higher rainfall values.

To understand what will be the impacts of ENSO on rainfall and runoff of a small region instead of considering large area, subwatershed wise studies were also conducted. There are 28 subwatersheds in the Venna basin, which is shown in Figure 4(a).To calculate annual rainfall values for each subwatershed from rain-gauge station rainfall, thiessen polygon interpolation technique were used. Area included under each rain-gauge station is shown in Figure 4(b).Similarly runoff was calculated using SCS CN method. Rainfall and runoff calculated were assigned for each subwatershed and plotted using GIS technique to understand the variability of rainfall and runoff occurring in different ENSO and normal years To clearly understand the rainfall variability, area was divided under six rainfall ranges(<400,401-800,801-1000,1001-1200,1201-1600,>1600)(Figure 5). For the year 2004 which is a El Nino year, eight subwatersheds are showing rainfall less than 400mm and rest of the subwatersheds are also showing less rainfall (<800mm).The year 2006, which is again an El Nino year, also shows less rainfall in all subwatersheds; but the amount of rainfall is better than that of the year 2004.For the two normal years, 2005 and 2008, rainfall is comparatively more; but also for 2008, most of the subwatersheds had received less rainfall. For the year 2007, a La Nina year, shows high rainfall values in all subwatersheds. About 75% of the catchment is receiving rainfall more than 1000mm.

Runoff values were also divided in different ranges such as <100, 101-300, 301-500, 501-800, 801-1000 and >1000. El Nino year 2004 and La Nina year 2007 is showing very low and high runoff respectively in all subwatersheds. Normal year 2005 is showing good runoff but 2008, which is also a normal year is showing less runoff comparatively.

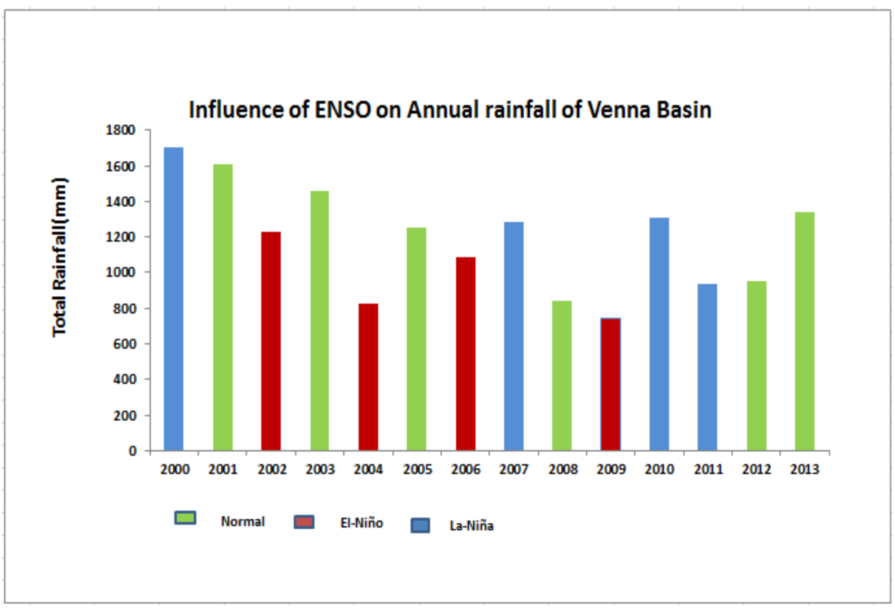

Figure 3

Annual rainfall variability during ENSO and normal years

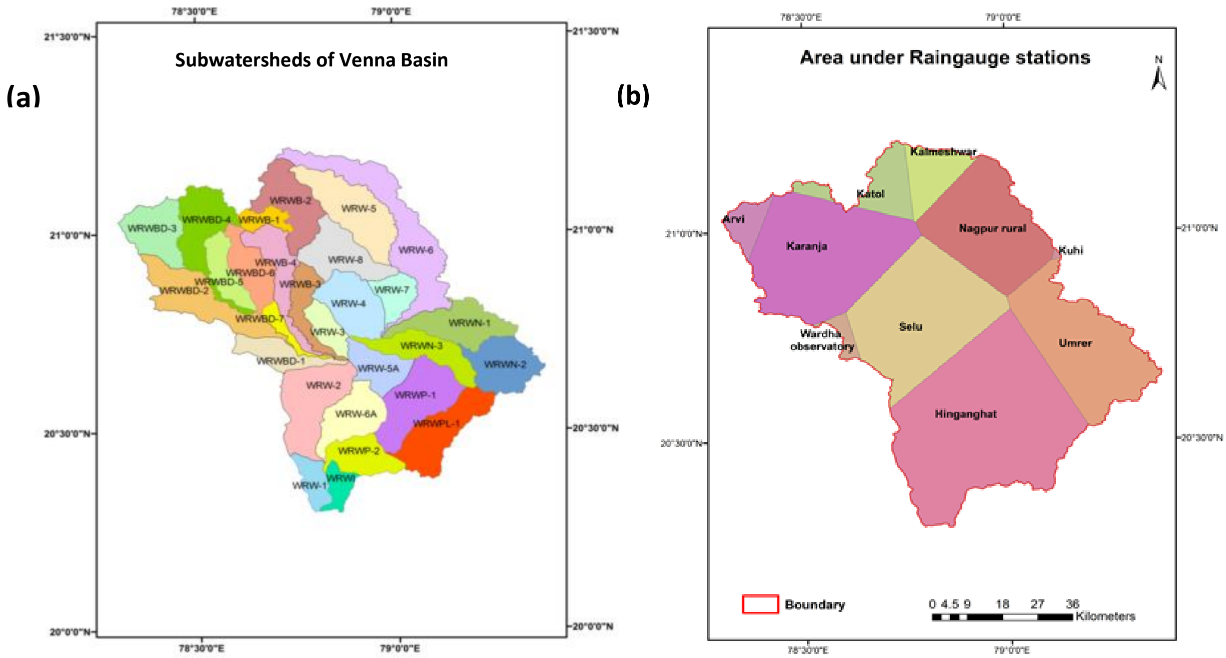

Figure 4

(a) Sub watersheds within the Venna basin and (b) Thiessen polygon showing the area of basin included under each rain-gauge station

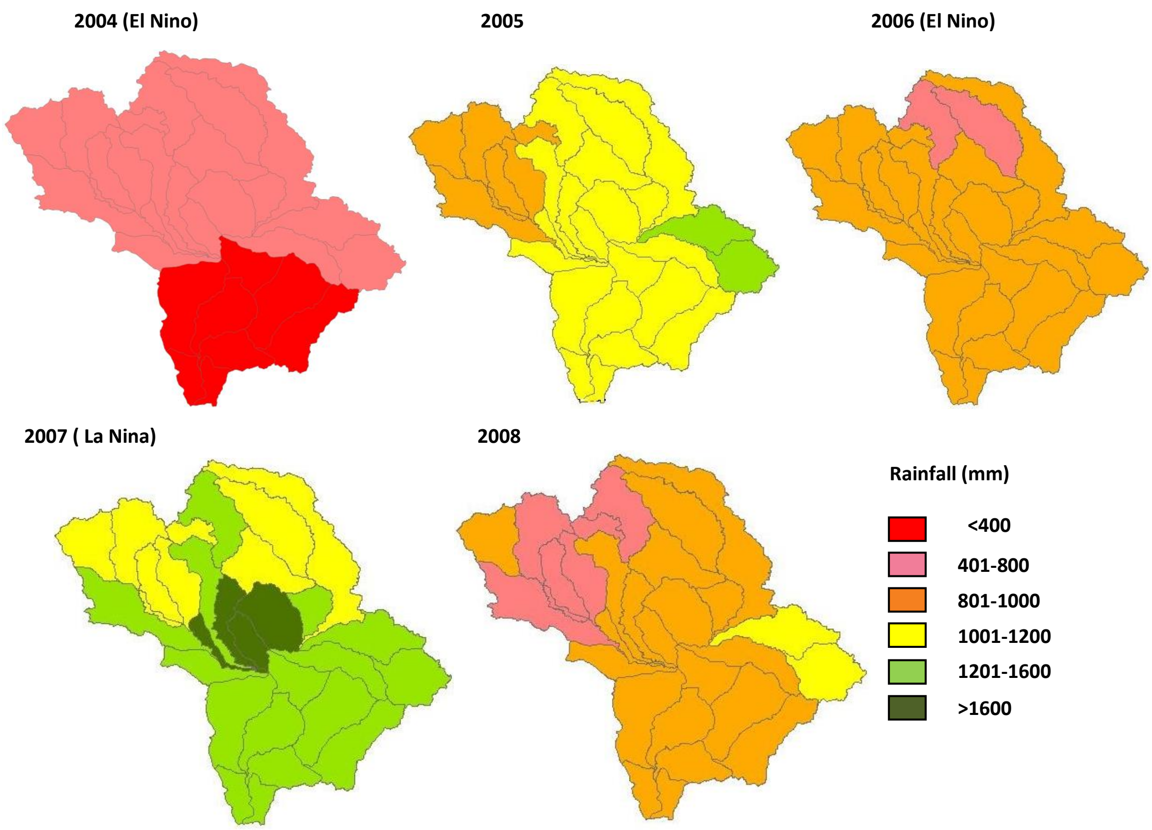

Figure 5

Rainfall variability during ENSO and normal years within different subwatersheds

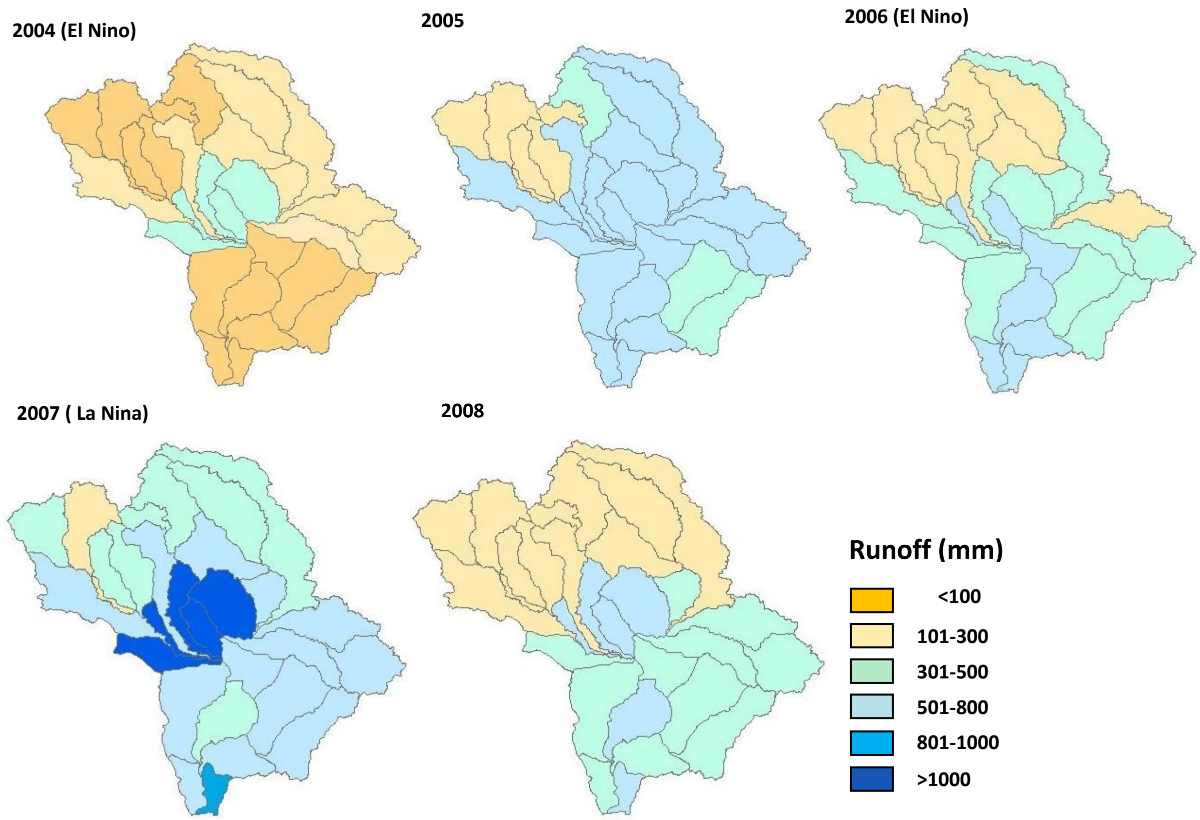

Figure 6

Runoff variability during ENSO and normal years within different subwatersheds

4. CONCLUSION

The impacts of ENSO events on rainfall and runoff of Venna basin have been discussed in the present study. Venna basin is showing an overall decreasing trend in rainfall values for the study period 2000-2013. Study indicates that ENSO events have direct relation with rainfall and runoff in this region. All El Nino/La Nina years within the study period are showing lower/ higher rainfall values than the nearby normal years. Subbasin wise study and GIS representation helps to clearly understand the variability occurring within each area. El Nino year 2004 and La Nina year 2007 is clearly representing deficiency/excess of rainfall and runoff throughout the subbasin.

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