Ecological effect of Cedar Forest fire on the watershed: A case study

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Abstract— **In this study the effect that a large scale forest fire has on the watershed had been studied. For our case study we have taken Cedar fire which started on 25 Oct 2003. A large portion of the fire ravaged area fell under the San Diego river watershed as a result of which it caused an extensive damage to the ecology of the watershed. Due to a forest fire there is a loss of vegetal cover which in turn modifies the processes of interception and evapotranspiration affecting the hydrological properties of the watershed. For the current study we have focused on the effect of the Cedar fire on the suspended sediment concentration at the mouth of San Diego River, and the effect on the Lag time between the precipitation and runoff. Our study shows that the forest fire has led to an increase in concentration of suspended solid concentration after the fire event as compared to the same period during last two years. It also revealed that the fire has decreased the lag time between the precipitation and runoff for the San Diego river watershed.**

I. Introduction

In this paper the ecological impacts of the Cedar forest fire which occurred in California during the year 2003 was taken as a case study. In the current study the effect of the fire on the suspended solid concentration at the mouth of the San Diego River and the changes in the stream flow pattern as a direct result of the fire has been studied. The Cedar fire was one of the worst forest fires in California's history. The total area burnt by the Cedar fire is estimated to be 721,791 acres or about 2921 square kilometers. The study region falls under the San Diego county of California.

Forest fires leads to surface erosion which is movement of individual soil particles by removal of material from the soil surface (sheet erosion) or by concentrated removal of material in the down slope direction (rill erosion) or gravity inducted (dry ravel) or by mass movement as landslides and debris flows (Foster 1982). Forested land acts like a sponge, absorbing rainfall and storing the water in the subsurface for a later release. During heavy rainstorms, this slows runoff and reduces flooding. In dry periods, rainfall that entered the groundwater table is released to streams to maintain a steady flow

Sediment yields due to forest fires differ depending on fire frequency, climatic region, vegetation types in the area, and geomorphologic factors such as topography, geology, and soils (Swanson 1981). The maximum amount sediment loss can occur the first year after a wildfire (Agee 1993, DeBano et al. 1996, Robichaud and Brown 1999b) after which the region tends to attain its prior state. Suspended sediment concentrations in stream flow can increase due to the addition of ash and silt-to-clay sized soil particles in stream flow which can adversely affect fish and other aquatic organisms. Disappearance of vegetal cover due to forest fires modifies the processes of interception and evapotranspiration affecting the hydrological cycle. Forest fires can also affect hydrological processes by altering the physical chemical properties of the soil, converting organic ground cover to soluble ash due to burning and giving rise to water repellency (e.g. Chandler et al., 1983). Water repellency is an abnormal condition in soils which results from the coating of soil particles with organic substances which reduce the affinity shown by the soil for water (DeBano et al., 1967). It is an important factor increasing surface runoff, especially in soils affected by large scale fires and thus acts as a barrier to water infiltration so that substantial overland flow may result. Campbell et al., (1977) described a 66% reduction of the infiltration rate in the soil of a pine forest area in Arizona, resulting in an 800% increase in stream flow from the burnt catchment in the first wet season following the fire.

Due to the fire the Total Suspended Solids (TSS) in the river tends to increase, TSS is solids in water that can be trapped by a filter. TSS includes materials such as silt, decaying plant and animal matter, industrial wastes, and sewage. High TSS can block light from reaching submerged vegetation and can cause problems for stream health and aquatic life. If the amount of light passing through the water is reduced photosynthetic activity slows down causing less dissolved oxygen to be released into the water by plants. If light is completely blocked from bottom dwelling plants, the plants stop producing oxygen and eventually die out. As the plants are decomposed, bacteria will use up even more oxygen from the water and thus low dissolved oxygen can lead to fish kills. High values of Suspended Solids can also cause an increase in surface water temperature, because the suspended particles absorb heat from sunlight. This can cause dissolved oxygen levels to fall even

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further. Although forest fires in the US contribute only 2-3 per cent of global emissions, these have been the most widely studied. Forest fires in the tropics are responsible for up to 80 per cent of the total biomass burned on a global scale, and they have been the subject of several recent research studies.

II. Study Area

The study region falls under the San Diego county of California. The Cedar fire was one of the worst forest fires in California's history. The total area burnt by the Cedar fire is estimated to be 721,791 acres or about 2921 square kilometers. A large portion of the fire ravaged area fell under the San Diego river watershed.

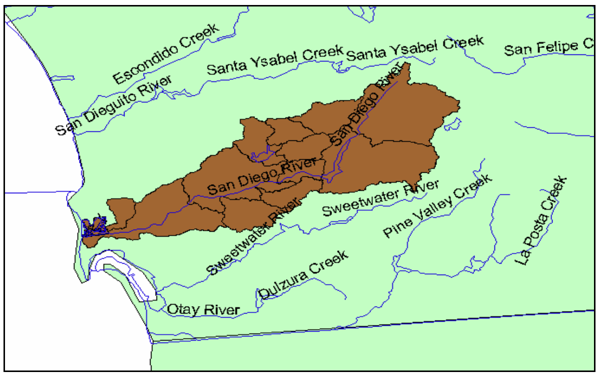

Fig 1 San Diego river watershed shown with fire spread

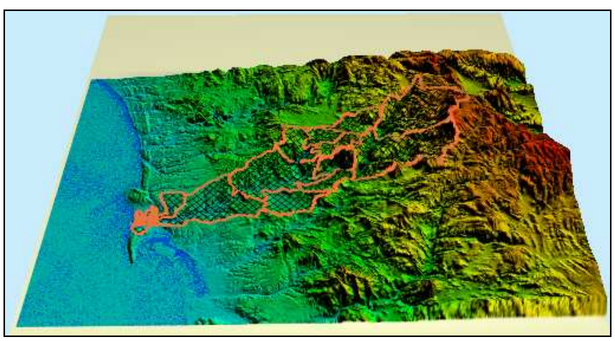
Fig 2 San Diego river watershed and DEM

The purpose of studying the topography of the region was important because in shallow low lying areas the effect of erosion is not pronounced as compared to a hilly terrain. In a hilly terrain because of the erosion the study of suspended solid concentration after a fire event, or the study of the lag between peak precipitation and runoff makes much more sense.

III. Datasets

1. Rainfall

The rainfall data us taken from the TRMM Online Visualization and Analysis System (TOVAS), developed by the GES DAAC. The data used is a daily rainfall product 3B-42 V5. It uses combined rain structure (2B-31) and VIRS calibration (1B-01) to adjust IR estimates from geosynchronous IR observations. Global estimates of rainfall are made by adjusting the GOES Precipitation Index (GPI) to the TRMM estimates. The output data set is a daily rainfall values for 1° by 1° degree resolution data.

TRMM 3B42 V5 Characteristics	
Temporal Coverage	**Start Date: 1998-01-01; Stop Date: Current**
Geographic Coverage	**Latitude: 40°S - 40°N; Longitude:180°W - 180°E**
Temporal Resolution	**Daily**
Horizontal Resolution	**1° x 1°**

Table1

2. Suspended solid

For the suspended solid data was obtained from the measurements by MOIDS TERRA and was downloaded from http://daac.gsfc.nasa.gov/daacbin/MODIS/Data_order.pl?PRINT=1 . The resolution of the data is about 5 kilometers. The data are mapped to a cylindrical equidistant map projection and are stored as a simple rectangular array. The array has 8192 columns, and 4096 rows. This array is stored as a science data set in Hierarchical Data Format (HDF-EOS) files. Pixels containing land and no data are included in this array which is useful for masking. This data collection contains Mean, Number of observation, Standard deviation, Quality Flags. For the current study we have used the monthly mean data sets only.

4. Digital elevation data:

30 Meter Resolution National Elevation Dataset was taken from the USGS site http://seamless.usgs.gov/. This data set is generated by merging the highest-resolution elevation data available across the United States into a seamless raster format has developed the USGS National Elevation Dataset (NED). The data provided is a very high resolution 1:24,000-scale Digital Elevation Model (DEM) data for the conterminous US

5. Stream Flow data:

The runoff (stream flow) data was acquired from the USGS website http://waterdata.usgs.gov/nwis/rt. The data provided is daily stream flow data collected by USGS through a network of stream flow measuring station throughout United States. For the current study the data from station 11023000 was used. The spatial coordinates for the station is 32°45'54" latitude and 117°10'04" longitude, situated in Mission San Diego Grant, San Diego County, (Hydrologic Unit 18070304) on left bank 2.6 mi upstream from mouth of the river.

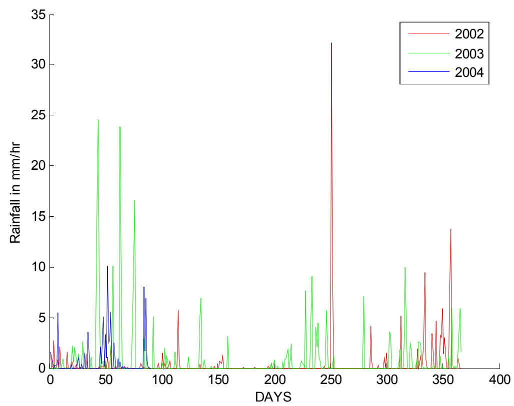

Figure 3 Daily rainfall for USGS station id 11023000

IV. RESULTS AND ANALYSIS

The suspended solid concentration anomalies for two years prior to the Cedar fire and the year of Cedar fire were analyzed. The anomaly images were generated by subtracting the mean of suspended solid concentration for all the three months from the month that we want to compute the anomaly. The December 2003 anomaly maps of the suspended solids shows an increase in the suspended solid concentration in the order of 10 – 15 % greater than the historical mean values near the vicinity of the mouth of San Diego river.

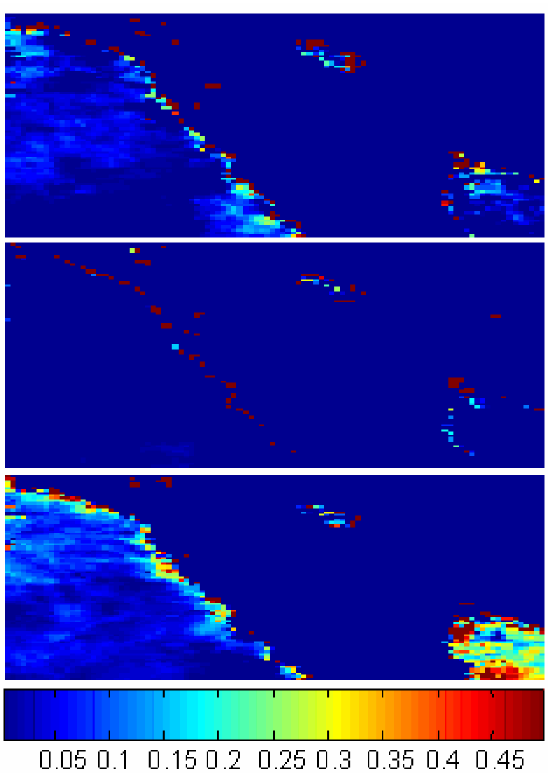

Fig 4 Suspended solid concentration anomaly: Top 2002, Middle 2003, Bottom 2004 (mg/m^3)

The runoff and the precipitation data were used to compute the lag time between the peak precipitations with the peak runoff. For this the precipitation values for February 20-25 of 2003 and 2004 was taken. The precipitation values are taken from a 1° by 1° pixel which contains the north east portion of the cedar watershed within it. The runoff data is acquired from USGS station id 11023000, which lies quite close to the mouth of the river. A correlation coefficient value was computed between the precipitation on February 20 and a 6 days runoff data including February 20 data. The results of this study show us that that the lag time between a rainfall event and peak runoff was about 3 days after the fire event as compared to lag time 6 days between a rainfall event before cedar fire occurred.

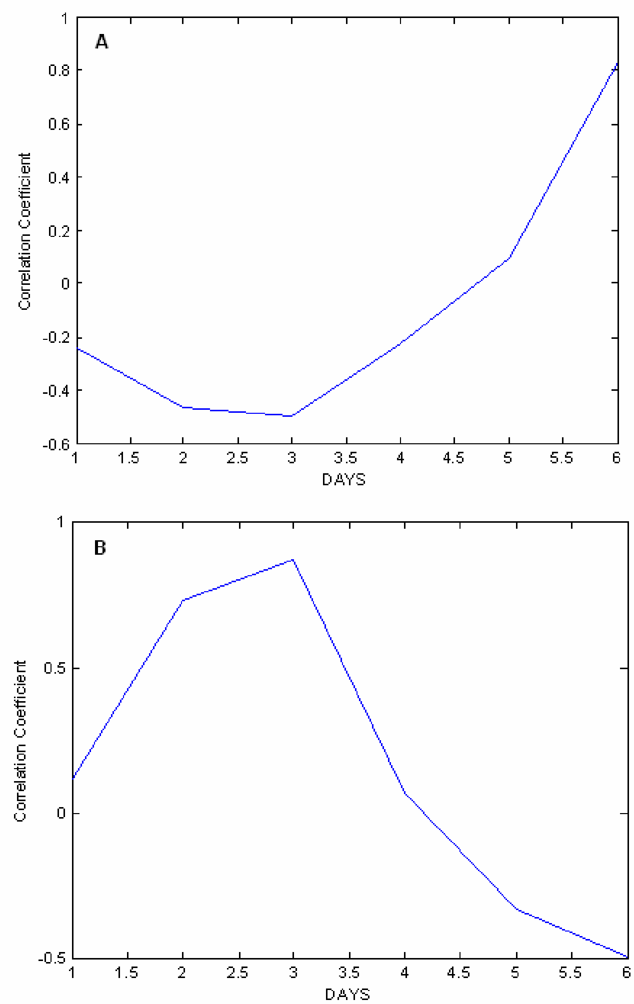

Fig 5 Plot of correlation coefficient between precipitation and runoff (A) February 20-25 2003 (B) February 20-25, 2004

V. Conclusion

In the current project various impacts the Cedar forest fire had on the ecology was studied. The increase in the aerosol anomaly and the suspended solids anomaly was strong enough to be measured. The stream flow data also shows that there is an decrease in the lag time between the precipitation and the runoff for the USGS stream gauge location 11023000. This kind of work is usually done taking hourly stream flow and precipitation data. The future work will involve taking all the rain gauge station located inside the watershed and compute a hourly rainfall data for the whole watershed by interpolating the data points instead of taking a 1 degree by 1 degree 3B42 V5 data. In the current study the limitation was that the pixel taken covered only a small portion of the watershed in the north east region so in essence it did not document what exactly happened for the watershed in a minute detail.

VI. References

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